Centre for Water Systems

COLLEGE OF ENGINEERING, MATHEMATICS AND PHYSICAL SCIENCES

MULTI-SCALE INVESTIGATION OF

WATER-ENERGY-FOOD NEXUS

Submitted by

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ABSTRACT

Water, energy and food (WEF) are among essentials to meet the basic human needs and ensure economic and social development. Globally, the demand for WEF rapidly increases while billions of people are still lacking access to these needs. The main drivers behind increased demand for WEF are population growth, urbanization, economic growth and climate change. It may also be driven by changes in demography, technological developments and diet preferences. To achieve a sustainable supply and effectively manage the demand for WEF, complex interactions between WEF (nexus) need to be understood. Traditionally, WEF have been studied and managed separately with a minimal focus on their interactions.

The primary objective of this study is to investigate WEF nexus at different scales. A bottom-up approach has been employed to develop a system-dynamics based model to capture the interactions between WEF at end-use level at a household scale. Additionally, a city scale model has been developed to quantify WEF implications for agricultural, commercial and industrial sectors. The household level model is then integrated with the city scale model to estimate WEF demand and the generated organic waste and wastewater quantities. The integrated model investigates the impact of several variables on WEF: human bahaviour, diet, household income, family size, seasonal variability, population size, GDP, crop type and land-use for agriculture.

The integrated model is based on a detailed survey of 407 households conducted to investigate WEF over winter and summer season for the city of Duhok, Iraq. The city is chosen as a case study due to the rapid population growth, considerable urbanization, changes in land-use pattern and shifting climate trends toward longer summer duration. These put an additional pressure on WEF demand in the city. The collected data of WEF and household characteristics (demographic and socio-economic) have been intensively analysed to provide a better understanding for the factors influencing WEF consumption. The surveyed data was used to develop statistical regression models for estimating demand as a function of household characteristics using stepwise-multiple-linear and evolutionary polynomial regression techniques.

The integrated WEF model was subjected to sensitivity analysis and uncertainty assessment. A comparison of the model simulation results were made with the historical data. The model results show a good agreement with the historical data.

The WEF model is then applied to assess the risk and resilience of WEF systems under the impact of seasonal climate variability (i.e., increase/decrease in the number of summer days). In order to decrease the risk of not meeting per capita demand for WEF and increase the resilience of system for providing per capita demand for WEF, a number of demand management strategies have been investigated in water and energy systems under the impact of seasonal variability. The results show that using recycled greywater for non-potable application in Duhok water system is the most efficient strategy but it increases the energy demand. Additionally, anaerobic digestion of food waste and wastewater sludge for energy recovery can increase the resilience of Duhok energy system.

Finally, the impact, of *Global Scenario Group* (GSG) scenarios *(Market Forces, Fortress World, Great Transition and Policy Reform)* on the WEF consumption and resulting implications, has been investigated using the WEF model. The results suggest that the Fortress World scenario (an authoritarian response to the threat of breakdown) has the highest impact on WEF consumption. In the Great Transition scenario, WEF consumption would be the lowest. The model results suggest that the food-related water consumption is the highest in the Policy Reform scenario.

LIST OF PUBLICATIONS

The key outputs from the work presented in this dissertation are summarised as below and presented in Appendix F.

<u>Journal papers</u>

- Hussien, W.A., Memon, F.A. and Savic, D.A., 2016. Assessing and modelling the influence of household characteristics on per capita water consumption. *Water Resources Management*, *30*(9), pp.2931-2955.
- Hussien, W.A., Memon, F.A. and Savic, D.A., 2017. An integrated model to evaluate water-energy-food nexus at a household scale. *Environmental Modelling and Software, 93*, pp.366-380.
- Sadr, S.M., Memon, F.A., Jain, A., Gulati, S., Duncan, A.P., Hussien, W.A., Savic, D. and Butler, D., 2016. An Analysis of Domestic Water Consumption in Jaipur, India. *British Journal of Environment and Climate Change, 6(2),* pp.97-115.
- Hussien, W.A., Memon, F.A. and Savic, D.A., 2017. A risk-based assessment of the household water-energy-food nexus under the impact of seasonal variability. *Journal of Cleaner Production.* (**Under review**).
- Hussien, W.A., Memon, F.A. and Savic, D.A., 2017. An integrated model to evaluate water-energy-food nexus at city scale. (**Final draft ready to be submitted**).

<u>Conference papers</u>

- Hussien, W.A., Memon, F.A. and Savic, D.A., 2015, Assessing and modelling the influence of household characteristics on per capita water consumption. *3rd International Conference on Energy Efficient Urban Water Management*, University of Exeter, 5th - 7th Aug 2015.
- Sadr, S.M., Jain, A, Gulati, S., Memon, F.A., Hussein, W.A., Duncan, A.P., Savic, D.A. and Butler, D., 2015. An Investigation into Domestic Water Consumption to Assist Decision Making on Water Efficiency in Urban Areas of India. *3rd International Conference on Energy Efficient Urban Water Management*, University of Exeter, 5th - 7th Aug 2015.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

α = friction of water that appears as wastewater

γ = specific weight of water

Δ = slope of saturation vapour pressure temperature relationship

ΔSD_c = critical supply-demand balance

$\Delta SD_{i,j}$ = supply-demand balance at year *i* under the impact of population growth and an increase in summer season duration by *j* days

ϵ = pump efficiency (%)

λ = latent heat of vaporization

ρ = density of water

σ = standard deviation

ρ_a = mean air density at constant pressure

$\rho_{i,j}$ = system performance in year *i* under the impact of population growth and an increase in summer season duration by *j* days

ω = Psychrometric constant

a_0 = the bias term

a_j = the coefficients of j_{th} polynomial term

A_c = cultivated land for crop c

AF = number of adult females in a household

AM = number of adult males in a household

BaU = business as usual

c = the type of crop

C = number of children in a household

C_{fw} = daily per capita average quantity of food waste

C_m = calorific energy of methane gas

C_p = specific heat of the air

C_{wws} = daily average quantity of wastewater sludge produces doer capita

$d_{s,i}$ = duration of summer season in year *i*

$d_{w,i}$ = duration of winter season in year *i*

Da_k = daily per capita average duration of use of appliance *k*

Dc_r = duration of cooking session of food commodity *r*

De_{ii} = duration of water run during each event of water end-use *ii*

D_s = daily per capita average duration of use of kerosene/LPG heater

$e_s - e_a$ = mean vapor pressure deficit of the air

e_{wt} = energy required for treatment of 1 m^3 of raw water

e_{ww} = energy required for treatment of 1 m^3 of wastewater

$E =$ number of elders in a household

Ea_k = daily per capita average energy consumption of appliance *k*

E_{cit} = annual total energy consumption for the city

$E_{com,i}$ = annual total energy requirements for commercial sector in year *i*

E_{dom} = annual total energy consumption for domestic sector

Ee_s = daily per capita average energy consumption by each end-use during summer season

Ee_w = daily per capita average energy consumption by each end-use during winter season

E_{fw} = energy generated from anaerobic digestion of food waste

E_h = daily per capita energy consumption for water heating

$E_{ind,i}$ = annual total energy requirements for industrial sector in year *i*

EM = energy management

E_p = energy required for pumping water

EPR = evolutionary polynomial regression

$E_{p,u}$ = the present demand for energy in subsector *u*

ER_m = effective rainfall during month *m* in the investigated region

E_s = daily per capita average kerosene/LPG consumption for space heating

ES = the matrix of unknown exponents

ET_o = monthly reference evapotranspiration for the region under investigation

$ET_{c,m}$ = water use for crop *c* during month *m* (crop evapotranspiration)

E_{wws} = energy generated from anaerobic digestion of wastewater sludge

f(X) = the polynomial function constructed by EPR

$F =$ number of floors in a household

Fc_r = average quantity of per capita consumption of food commodity *r* per cooking session

Fe_{ii}= daily per capita average frequency of water end-use *ii*

F_r = daily per capita consumption of food commodity *r*

FS= average family size

FS_g= average family size of the income group *g* (i.e., low, medium and high)

FW = Fortress World

FW_r = quantity of waste from food commodity *r*

$G =$ total garden area

GDP = gross domestic product

GDP_i = gross domestic product in year *i* of the investigated period

GDP_p = current gross domestic product

GHG Greenhouse gas

GSG = Global Scenario Group

GT = Great transition

$h =$ high income households

hf = soil heat flux

H = the depth/height of water to be pumped

$HH =$ total household built-up area

$I =$ per capita monthly income

IWR = annual total water requirements for irrigation purposes

k = number of subsectors

K_c = the crop type coefficient

$l =$ low income households

LPG = Liquefied petroleum gas

$LPG_{cs,r}$ = LPG consumption per cooking session of food commodity *r*

LPG_d = daily LPG consumption for cooking purposes

LPG_h = LPG consumption per hour of using hob ring for cooking purposes

LPG_r = daily average LPG consumption to prepare the food commodity *r*

$m =$ medium income households

M_{fw} = methane gas produced per 1 ton of food waste

MF = Market Force

M_{wws} = methane gas produced per 1 ton of wastewater sludge

n = total number of impacts (increase in the duration of summer season by 1, 2, 3,..., n days)

np = the total number of polynomial terms

Na_k = average ownership level of appliance *k* per household

Nc_r = average number of cooking sessions of food commodity *r* per week

N_d = number of days each gas cylinder lasts

N_s = average number of kerosene/LPG heaters in use in a household

PFW_r = percentage of waste from food commodity *r*

P_g = percentage of households in income group *g (g=low, medium and high*)

Pop = population size for the city under investigation

PR = Policy Reform

Q = pumping flow rate

Q_h = daily quantity of hot water consumption per capita

Q_s = quantity of kerosene/LPG consumption by each heater per hour

r_a = aerodynamic resistance

$r_{i,j}$ = system resilience in year *i* under the impact of increase in summer season duration by *j* days

r_s = the canopy surface resistance

R = correlation coefficient

R^2 = coefficient of determination

Re_{ii} = average flow rate of water end-use *ii*

R_i = risk of exceeding acceptable level of shortage in per capita demand during year *i*

R_n = net radiation

RO = number of rooms in a household,

Rs_i = integral resilience in year *i* of the time horizon under investigation

S = specific heat capacity of water

S_l = acceptable level of shortage in per capita demand

Td = total duration of use of hob ring for food preparation per day

SDM = system dynamics modelling

TE_i = annual per capita total energy consumption during year i

T_{in} = water temperature at the heater inlet

T_{out} = water temperature at the heater outlet

TW = daily per capita water consumption

TW_i = annual per capita total water consumption during year *i*

V_c = LPG cylinder size

Ve_{ii} = quantity of water consumption during each event of water end-use *ii*

w = whole sample of surveyed households

Wa_i = daily per capita total quantity of available water in year *i*

Wa_k = average wattage of appliance *k*

W_{cit} = annual total water consumption for the city

$W_{com,i}$ = annual total water requirements for commercial sector in year *i*

Wc_r = per capita average water consumption in each session of washing and cooking food commodity *r*

Wd_i = daily average per capita water demand during year *i*

WDM = water demand management

W_{dom} = total water consumption for domestic sector

WEF = water-energy-food

We_{ii} = daily per capita average consumption for water end-use *ii*

We_s = daily per capita average water consumption by each end-use during summer season

We_w = daily per capita average water consumption by each end-use during winter season

$W_{ind,i}$ = annual total water requirements for industrial sector in year *i*

$W_{p,u}$ = the present demand for water in subsector *u*

W_r = daily per capita average water consumption to prepare food commodity *r*

WW_b = bathing wastewater

WW_c = cooking wastewater

WW_{cw} = clothes washing wastewater

WW_{dom} = annual total wastewater generated in domestic sector

WW_{dw} = dishwashing wastewater

WW_{fw} = wastewater from house floor washing

WW_{hw} = wastewater from hand wash basin tap use

WW_{sh} = showering wastewater

WW_{tf} = toilet flushing wastewater

WW_{vw} = vehicle washing

$\bar{X}$ = mean

X_k = the k_{th} independent variable (household characteristics)

Y = the EPR estimated water/energy consumption

Z = total number of food commodities consumed at a household

UNITS

bt/p/d	number of baths per person per day
ºC	Celsius (centigrade)
cm	centimetre
cs/d	cooking sessions per day
cs/w	cooking sessions per week
d	day
fl/p/d	number of toilet flushes per person per day
g	gram
gal	gallon
g/hh/d	gram per household per day
g/p/cs	gram per person per cooking session
g/p/d	gram per person per day
GJ/hh/y	giga Joule per household per year
GJ/mon	giga Joule per month
GJ/y	giga Joule per year
GW/y	gigawatt per year
ha	hectare
ha/p	hectare per person
ha/y	hectare per year
hh	household
hr	hour
hr/d	hours per day
hr/hh/d	hours per household per day
hr/htr/d	hours per heater per day
hr/p/d	hours per person per day
hr/p/w	hours per person per week
hr/wtr	hours per watering session
ID	Iraqi Dinar
ID/mon	Iraqi Dinar per month
J	Joule
kcal/p/d	kilocalorie per person per day
kg	kilogram
kg/ha	kilogram per hectare

kg/hh/d	kilogram per household per day
kg/hh/y	kilogram per household per year
kg/p/d	kilogram per person per day
kg/p/y	kilogram per person per year
kJ/kg	kilojoule per kilogram
km	kilometre
km^2	kilometre square
km/hr	kilometre per hour
km^2/y	kilometre square per year
kN/m^3	kilo newton per cubic meter
kPa	kilopascal
kPa/ ^oC	kilopascal per centigrade
kPa/m^3	kilopascal per cubic meter
kW	kilowatt
kW/MJ	kilowatt per mega joule
kWh	kilowatt hour
kWh/hh/d	kilowatt hour per household per day
kWh/m^2	kilowatt hour per square meter
kWh/m^3	kilowatt hour per cubic meter
kWh/p/d	kilowatt hour per person per day
kWh/p/w	kilowatt hour per person per week
kWh/p/y	kilowatt hour per person per year
kWh/wsl	kilowatt hour per washing cycle
l	litre
l/bt	litre per bath
l/cs	litre per cooking session
l/d	litre per day
l/event	litre per tap use event
l/fl	litre per toilet flush
l/hh/d	litre per household per day
l/hh/w	litre per household per week
l/hr	litre per hour
l/htr/d	litre per heater per day
l/htr/hr	litre per heater per hour
l/kg	litre per kilogram

l/min	litre per minute
l/p/cs	litre per person per cooking session
l/p/d	litre per capita per day
l/p/y	litre per person per year
l/wsl	litres per clothes washing load
m	meter
m^2	square meter
m^3	cubic meter`
m^2/hh	square meter per household
m^3/d	cubic meter per day
m^3/hr	cubic meter per hour
m^3/hh/y	cubic meter per household per year
m^3/p/y	cubic meter per person per year
m^3/sec	cubic meter per second
m^3/y	cubic meter per year
min	minutes
min/cs	minute per cooking session
min/event	minute per event of using tap
min/p/d	minutes per person per day
min/p/w	minute per person per week
min/p/wsh	minutes per person per wash
min/p/shw	minutes per person per shower
min/shw	minutes per shower
min/wsh	minutes per wash
min/wtr	minutes per watering
ml/p/cs	millilitre per person per cooking session
ml/p/d	millilitre per person per day
mm/mon	millimetre per month
mm/y	millimetre per year
MJ	Mega joule
MJ/d	Mega joule per day
MJ/kg	Mega joule per kilogram
MJ/m^3	Mega joule per cubic meter
MJ/m^2d	Mega joule per square meter per day
MW	Megawatt

MW/hh/y	Megawatt per household per year
MW/hr	Megawatt per hour
MW/y	Megawatt per year
MWh	Megawatt hour
MWh/y	Megawatt hour per year
no.	number
ppm	parts per million
sec	second
sec/tpu	seconds per tap use
shw/d	number of showers per day
shw/p/d	number of showers per person per day
ton	tonne
ton/hh/y	tonne per household per year
ton/km^2	tonne per square meter
ton/y	tonne per year
tpu/p/d	number of tap uses per person per day
USD	United States dollar
W	Watt
Wh	Watt hour
wsh/d	number of washes per day
wsh/w	number of washes per week
wtr/d	frequency of garden watering per day

CHAPTER ONE: INTRODUCTION

1.1 Background and justification

Water, energy and food (WEF) are fundamental for human life and essential for economic and social development of the society. Water sources are generally available as surface water or groundwater. The major sources of energy can be coal, oil, natural gas, biomass, potential energy from hydropower, kinetic energy from wind, solar radiation and heat from nuclear fission and geothermal wells (McElroy, 2010). Generally, food sources are all types of agricultural crops and animal meat.

By 2050, the increase in water and food demand is expected to be approximately 55% and 70%, respectively (WWAP, 2012). This can lead to increase in the cultivation of additional land (5.5 x10^6 ha/year) to meet the food demand (Deininger and Byerlee, 2011). Energy demand also increases annually at an average rate of 1.6%, causing increase in greenhouse gas emissions (WEO, 2013). The stresses on WEF resources increase due to the high influence of population growth, urbanization, economic development as well as changes in technologies and land-use (Hoff, 2011; FAO, 2014; Lawford et al., 2013; Bonn Nexus Conference, 2011; WWAP, 2012). These drivers can be the greatest challenges for sustainable development (UNESCO, 2012). Therefore, without efficient and synergistic management of WEF, the risk of shortages will increase. Investigating the water-energy-food nexus may provide opportunities to improve the sustainability of the available WEF resources (Biggs et al., 2015).

The nexus idea started as a new term to define sustainable development (Gies, 2012). Bonn Nexus Conference (2011) highlighted that the nexus approach can improve WEF security. According to Hoff (2011), the nexus is “an approach that integrates management and governance across sectors and scales”. The water-energy-food nexus approach aims to understand the complex interactions (inherent interdependent relationship) between resources in the system in order to manage it as a whole and achieve different social, economic and environmental goals (FAO, 2014).

Nexus emphasizes the interrelationships between WEF resources (Figure 1.1). This means that utilizing any of water, energy or food has a simultaneous impact on the remaining two. For example, substantial amount of energy is required for water treatment processes, pumping, distribution and water heating for human use. Water is heavily used across the supply chain of most types of energy (e.g., extraction, processing, converting and delivery to user) and to grow agricultural crops and livestock. Additionally, both water and energy are used across each stage of food supply chain (production, processing, storage, transportation and consumption).

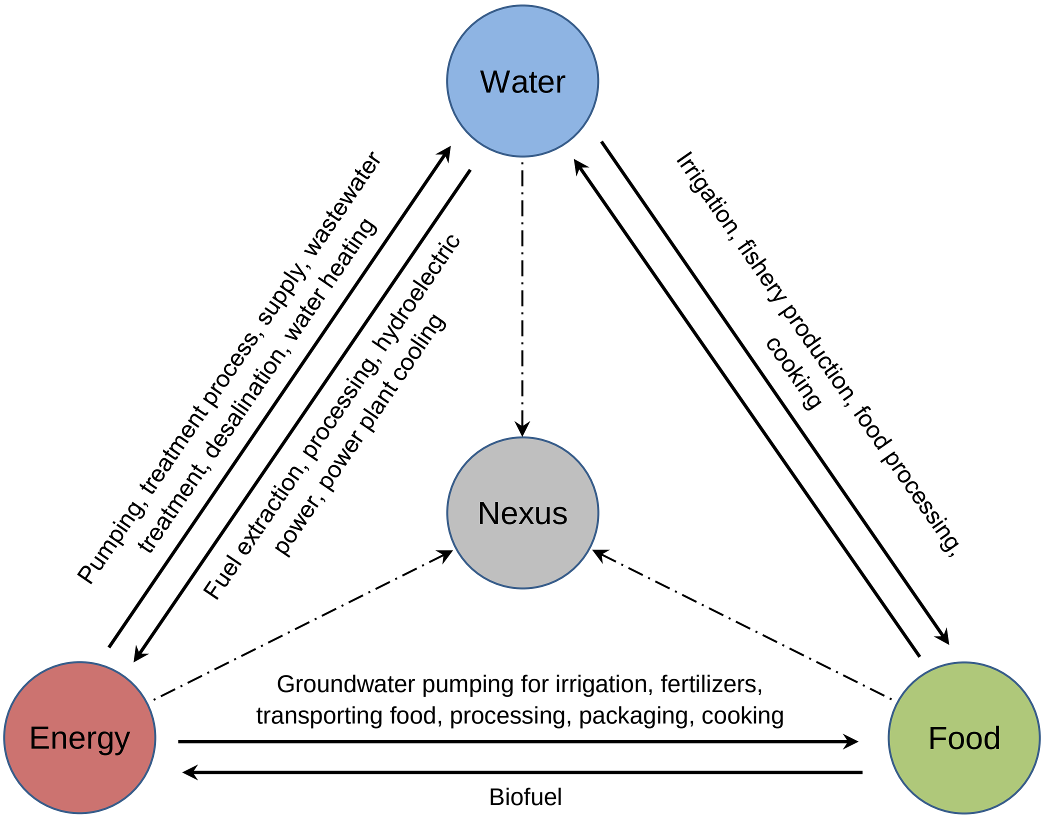


Figure 1.1 Interactions between water-energy-food

Although the attention on the nexus approach has increased over the past decade (Chen and Lu, 2015), there is a lack of studies investigating the water-energy-food nexus at a household level (Djanibekov et al., 2016; Endo et al., 2015; Loring et al., 2016; Wakeel et al., 2016). Even when there were attempts to study the nexus at the level of households, the focus was often on water-energy nexus without taking food consumption into the account (Arpke and Hutzler, 2006; Flower, 2009; Kenway et al., 2013; Wang and Chen, 2016). The water-energy-food nexus emphasizes that anyone of the resource should not be considered in isolation. Dalziell and McManus (2004) stated that understanding the properties of a system cannot be achieved by analysing its components in isolation.

The influence of variability in household characteristics (demographic and socio-economic) and appliance efficiency on the end-uses of each of WEF is widely addressed in the literature (Blokker et al., 2009; Pakula and Stamminger, 2010; Richter, 2011; March et al., 2013; Romano et al., 2014; Navajas, 2009; Bartusch et al., 2012). However, the impact of seasonal variability has not been addressed fully. The main driver for estimating the future household demand for water and energy is the impact of hot and dry weather conditions (Proust et al., 2007). Energy consumption for space heating and cooling varies with the temperature and humidity. Water consumption can be much higher during summer season than that in winter (Jacobs and Haarhoff, 2004a). Additionally, food consumption might be seasonally varied, particularly in developing countries where the price of the most food commodities varies seasonally (Leonard and Thomas, 1989). Therefore, the seasonal variability of resources consumption should be taken into account while estimating the annual demand.

WEF nexus at city scale remains broadly under-investigated. According to the UN (2015), more than 50% of the world's population are living in cities. Therefore, the majority of WEF consumption and the generated CO_2 emissions take place in the cities (Rees and Wackernagel, 1996; Beatley, 2012; Brugmann et al., 2014; Bulkeley et al., 2011). Cities do not only heavily consume natural resources but can also provide opportunities for the recycling and reuse of waste resources. Although modelling nexus at a city scale is necessary, the majority of previous studies addressed nexus and related governance issues at global and national level (Al-Zu'bi, 2017). Even when there were attempts to study the nexus at a city scale, the focus was often on water-energy nexus without taking food consumption into the account (Al-Ansari, 2016).

An assessment tool is required for considering the interconnections between WEF systems simultaneously and the surrounding environment at different scales (household and city). This tool should be able to quantify the impact of other factors, such as seasonal variability and household characteristics on WEF consumption.

1.2 Aim and objectives

The overall aim of this research is to investigate water-energy-food nexus at a household and city scale. The aim will be achieved through the completion of the following objectives:

1) Identify the interactions between end-uses of WEF at a household level.
2) Investigate the relationship between household characteristics (socio-economic and demographic) and the consumption for WEF at a household level.
3) Develop a system dynamics based simulation model capable of capturing the interactions between food, energy and water end-uses at a household level.
4) Identify the interactions between WEF for other sectors: agricultural, commercial and industrial.
5) Develop a city scale tool to capture WEF interactions for different sectors (agricultural, commercial and industrial)
6) Integrate the household scale WEF model with the city scale WEF model.
7) Apply the integrated WEF model using a case study from Iraq.
8) Apply the WEF model to:
   a) Assess the risk of exceeding acceptable level of shortage in per capita WEF demand under the impact of seasonal variability.
   b) Quantify resilience of water and energy systems for providing per capita demand under the impact of seasonal variability.
   c) Investigate the impact of future scenarios on WEF and their interactions and the generated waste at a household and city scale.

1.3 Scope of work

The work done in this research can be grouped into five main components:

- literature review
- water-energy-food consumption data collection
- household scale WEF model development
- city scale WEF model development
- models application for risk assessment and resilience quantification under the impact of seasonal variability

The interactions between these components are shown in Figure 2.1.

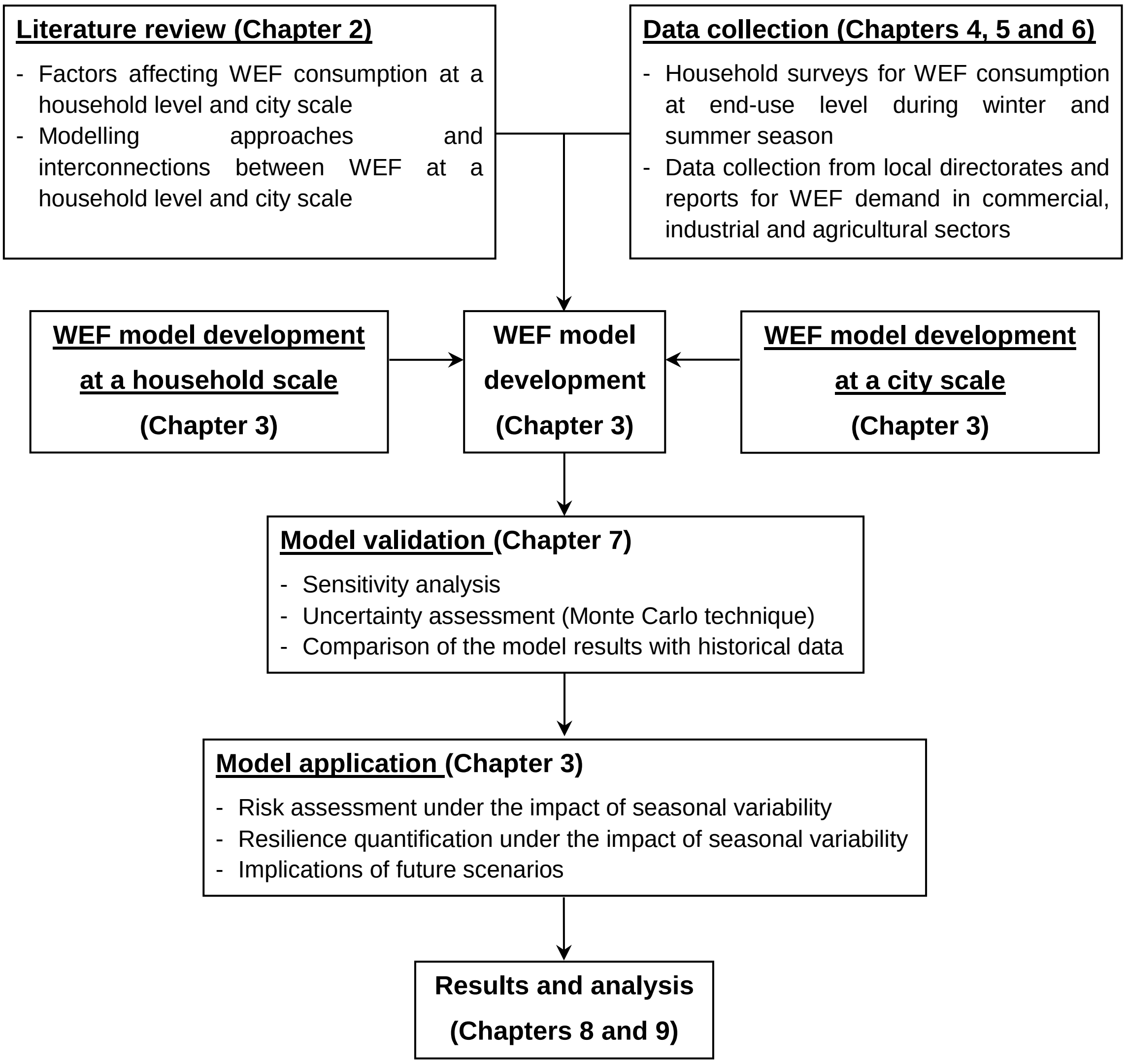


Figure 1.2 Interaction between various components of the thesis

1.4 Contribution to knowledge and originality of the research work

The work carried out in this research can be considered as original and makes a contribution to knowledge in the following ways:

- The research produces a number of datasets on WEF consumption at a household level and city scale. These can be used to understand the influence of household characteristics (i.e., number of children, elders, adult males and adult females, total household built-up area, garden area, number of rooms, number of floors and income) and seasonal variability on WEF consumption at end-use level in developing countries.
- The collected data has been used to develop models based on multiple linear regression (STEPWISE) and evolutionary polynomial regression (EPR). These statistical regression models can be used to estimate the future demand for water and energy as a function of household characteristics.
- The research develops systems dynamics-based household and city scale models which can be used to quantify WEF demand for user defined scenarios and calculate the impact of WEF management strategies.
- A methodology has been developed to assess the risk and quantify the resilience of WEF under the impact of seasonal variability. This can be used to assess the impact of WEF management and reuse strategies.

1.5 Outline of the thesis

The thesis consists of ten chapters. Chapter one provides background and justifications for the conducted research, describes the aim and objectives and identifies specific contributions to the knowledge.

Chapter 2 provides a detailed literature review on the factors affecting WEF nexus. The chapter also explores WEF modelling approaches developed so far.

Chapter 3 presents the methodology for:

- WEF consumption data collection and analysis
- Development of WEF models

- WEF model validation
- Risk and resilience assessment under the impact of seasonal variability

Chapter 4, 5 and 6 present the detailed statistical analysis for WEF consumption surveys results, respectively. The relationship between household characteristics (socio-economic and demographic) and the consumption for WEF is investigated in Chapter 4, 5 and 6, respectively. These chapters focus on analysing the impact of income and seasonal variability on household consumption for WEF. Furthermore, Chapter 4 presents statistical regression models developed to estimate per capita water consumption as a function of household characteristics. Similarly, regression models have been developed for estimating per capita energy consumption and presented in Chapter 5.

Chapter 7 presents the sensitivity analysis of the household WEF model developed in this study. The chapter tests the validity of the WEF model results using Monte Carlo simulation technique for uncertainty assessment and provides a comparison between the model results and historical data.

In Chapter 8, the applications of the WEF model are presented. The chapter assesses the risk of exceeding acceptable level of shortage in per capita demand for WEF under the impact of seasonal variability. Additionally, the resilience of water and energy systems for providing per capita demand under the impact of seasonal variability is quantified. Furthermore, various demand management strategies for water and energy are investigated using the WEF model to decrease the risk or increase the resilience.

Chapter 9 investigates the implications of global scenario group (GSG) scenarios on the future demand for WEF, the generated waste and land-use for the chosen case study. The investigated GSG scenarios are: *Market Force (MF), Fortress World (FW), Great Transition (GT) and Policy Reform (PR)* (Kemp-Benedict et al., 2002).

Finally, Chapter 10 summarises the key findings of this research and makes recommendations for future research studies.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Increasing demands for WEF to meet basic human needs and unsustainable management is putting pressure on the natural resources in many regions (Hoff, 2011). The stresses on WEF resources increase due to population growth, urbanisation and economic development (FAO, 2014; Lawford et al., 2013). For example, global energy demand is expected to increase by 40% by 2030 (IEA, 2009), and food demand will grow by 60% by 2050 (WBCSD, 2014). Hence, agricultural water requirements will increase in order to meet food demand for a larger population (Khan and Hanjra, 2009). Greater understanding and consideration of the linkages between WEF (nexus) can help towards improved management of resources and future planning (Leck et al., 2015). Accounting for synergies and trade-offs between WEF at spatial and temporal scales is a significant challenge faces decision-makers (Howells and Rogner, 2014).

This chapter presents background information and review of literature relevant to WEF at a household and city scale. The impact of household characteristics on each element of nexus has been investigated in Section 2.2 to 2.4. The available techniques for modelling each element of nexus have been investigated in these sections. Section 2.5 covers the available literature on modelling nexus at a household scale. Additionally, the impact of seasonal variability on water-energy-food estimation at a household level is reviewed in Section 2.6.

The chapter also reviews literature on nexus at a city scale. This includes water-related energy (Section 2.7), water and organic use within energy production (Section 2.8) and resources use (water, energy and land) within food supply chain (Section 2.9). The extant literature on modelling water-energy-food nexus at a city scale has been critically analysed in Section 2.10. The chapter finally concludes by outlining current gaps in the body of knowledge.

2.2 Water demand at a household level

Water is used in a household for several purposes, such as drinking, food preparation, showering, clothes washing, toilet flushing, car washing and garden watering. The U.S Agency for International Development, the World Bank and the World Health Organization recommend that the range of basic water requirement is 20 - 40 l/p/d (Zhang, 1999). However, in some regions can be much higher, such as New Zealand (180-300 l/p/d), Australia (up to 340 l/p/d), England and Wales (150 l/p/d), China (up to 230 l/p/d) (Parliamentary Commissioner for the Environment, 2000) as well as the city of Duhok in Iraq (277 l/p/d) (Duhok Directorate of Water and Sewerage, 2014).

Household water consumption is a function of climate condition, hydrological, technical and socio-economic factors (Slavíková et al., 2013). It varies with weather, season, lifestyle, people’s habits, technology, income level and culture (White et al., 1972). Therefore, household water use varies from region to another region. Numerous studies have investigated and assessed the impact of various factors on residential water consumption. Some of these studies with their key findings are listed in Table 2.1.

2.2.1 Indoor water requirements

Water requirements for indoor water use activities comprise the following end-uses.

Showering and bathing

Several studies investigated the relationship between showering and household characteristics. Household water demand for showering increases with increasing family size and the household total income (Mayer et al., 1999). Foekema and Engelsma (2001) investigated the relationship between age and shower duration. They showed that teenagers tend to take the longest showers. Household water use for showering and bathing may be influenced by climate conditions. Human tends to have more showers in hot regions than that in the cold regions (Rathnayaka et al., 2015).

Table 2.1 Summary of the factors affecting household water consumption

Factors	Reference	Key findings
Income	Agthe and Billings (1997)	Water consumption in high income households in Tucson is higher 56% and 37% than that in low and medium income households, respectively.
	Romano et al. (2014)	Per capita income has a positive effect on water consumption.
Human behaviour	March et al. (2013)	Human behaviour is important factor affect household water consumption.
Area of a household	Hewitt and Hanemann (1995); Mayer et al. (1999)	They used area of a household as a measurement of personal wealth to investigate water demand.
Number of bathrooms	Cavanagh et al. (2002)	They used number of bathrooms in a household to investigate water demand.
House ownership	Billings and Day (1989)	They used house ownership to investigate water demand.
Family size	Piper (2003)	Household water demand increases with the increase in family size (number of members).
Age of family members	Hanke and de Mare (1982)	Per capita water consumption for age under 20 is higher than that for adults.
	Nauges and Thomas (2000)	Families with children consume more water while elders tend to use less.
Education level	Whitehead (2006)	The correlation is strong between household water quality and each of household income and education level.
Resident's religious	The Sphere Project (2004)	The quantity of water demand for domestic use depends on the available sanitation facilities, religious obligations, diet and the clothes style they wear.
Water price	Romano et al. (2014)	Per capita water consumption decreases with increase in water price.
	Nauges and Thomas (2003)	In high income countries, per capita water demand is not sensitive to the change in water price.
	Hansen (1996)	In Denmark, household water consumption is more sensitive to the energy price than to water price due to the wide utilization of heated water.
Weather condition	Martins and Fortunato (2007)	High temperature leads to increase the quantity of water consumption for household activities. However, rainfall barely affects water demand for indoor activities.
	Domene and Saurí (2006)	Household water consumption is higher during summer season.
Climatic zone	Gleick and Iwra (1996)	Per capita water use in a dry area varies between 60-80 l/p/d while in a humid region is only 20-40 l/p/d. In the average climatic zone, it is 40-60 l/p/d.

In terms of water saving, Inman and Jeffrey (2006) found that using low flow showerhead can save 35 – 50% of indoor water consumption. This is because a conventional showerhead uses 11 to 27 l/min while a water saving showerhead uses only 3.8 to 9.5 l/min (Wilson, 2001). Kalbermatten et al. (1982) estimated water demand for bathing and showering in developed (45–100 l/p/d) and developing countries with areas of poor water distribution systems (15–25 l/p/d). On the other hand, Gleick and Iwra (1996) recommended that the water demand for bathing is ranged between 5 and 70 l/p/d and the minimum is 15 l/p/d.

Toilet flushing

The impact of various factors on water use for toilet flushing is investigated. Household water use for toilet flushing correlates positively with number of family members (Mayer et al., 1999; Foekema and Engelsma, 2001). However, it decreases with increasing the number of family members that employ full-time outside the house (Blokker et al., 2009). Additionally, water requirements for toilet flushing vary with the time of year and the age of family members. Moreover, water availability and culture factors influence the choice of sanitation technology (White et al., 1972).

A considerable quantity of water can be used for toilet flushing. One flush of a Western toilet uses as much water as the average person in some developing countries uses for the activities of a single day of washing, cleaning, drinking and cooking (UN, 2003). The required water for toilet flushing depends on the type of sanitation technology, for example, pour flush and pit latrine toilets require 6-10 l/p/d and 1-2 l/p/d, respectively (The Sphere Project, 2004). Table 2.2 shows the estimated daily per capita water requirement for toilet flushing depending on the type of technology and the source of water (Inocencio et al., 1999).

Table 2.2 Water requirements for sanitation (Inocencio et al., 1999)

Sanitation type	Water source	Water requirement (l/p/d)
Hand flush	Private wells	8
	Piped connection	17.5
	Standpipe	2.5
Cistern flush	Private wells	15
	Piped connection	45

Cooking and drinking

Water use for food preparation and drinking is a function of various factors. The frequency of use of kitchen tap for cooking and dishwashing is strongly related to family size (Blokker et al., 2009). The quantity of water demand for cooking increases with the increase in household income (Blokker et al., 2009). Globally, per capita minimum water demand is 10 l/p/d for food preparation while it increases to up to 50 l/p/d in the rich regions (Gleick and Iwra, 1996). Water requirement for food preparation is also affected by the type of water source, such as standpipe (10.5 l/p/d), piped connection (7-15 l/p/d) and private well (15 l/p/d) (Inocencio et al., 1999).

Per capita average quantity of drinking water for survival is one l/p/d (Clarke, 1993). This amount varies depending on the climate conditions and human physiological characteristics but the variation is very slight (Inocencio et al., 1999; Gleick and Iwra, 1996). Daily per capita water demand for drinking is small compared to water use for teeth brushing. Inocencio et al. (1999) estimated that each person use less than 2 l/p/d of water for teeth brushing but up to 10 times of this amount when the tap left open during brushing.

Dishwashing

Water use for dishwashing correlates positively with family size (number of family members) but decreases with increasing the number of family members that employ full-time outside the house (Mayer et al., 1999). Human habit related to dishwasher use (e.g., dishwasher load capacity, programme temperature) also affects water and energy consumption. Additionally, households with a dishwasher tend to combine manual and automatic dishwashing to a certain extent (Richter, 2011).

Using a dishwasher, the amount of water and energy consumption is 50-80% and 6-40% less than that when the process is done manually, respectively (Richter, 2011). For instance, in the UK, daily per capita average consumption for manual dishwashing is 49 l of water and 1.7 kWh of energy (Berkholz et al., 2010). However, using a dishwasher for washing the same amount of dishes, the consumption decreases to 13 l of water and 1.3 kWh of energy. Although, using a dishwasher can save a considerable amount of water, energy, time and money (Berkholz and Stamminger, 2010), it does not commonly use in some regions due to lack of continuous electricity supply.

Clothes washing

Family size, income, number of teens in the family and number of family members that employ full time outside the house are some of the factors that are influencing and directly related to water use for clothes washing (Mayer et al., 1999). The quantity of water required for clothes washing varies depending on whether it is manual washing or using washing machine and also the type of clothes washer (i.e., horizontal and vertical axis machine) (Pakula and Stamminger, 2010). Horizontal axis clothes washer uses much less water than vertical axis machine.

Water source type can be another factor affecting the quantity of water required for clothes washing. In the developing countries, it is approximately 8–10 l/p/d for private well water source, 5–38 l/p/d for piped connection and 5 l/p/d for standpipes (Inocencio et al., 1999). However, the required water for laundry can be much higher in some countries such as the United States (29–71 l/p/d) (Gleick and Iwra, 1996).

2.2.2 Outdoor water requirements

Outdoor water requirements for a household comprise water use for garden watering, vehicle washing and filling swimming pools. Thomas and Syme (1988) showed that the outdoor water use is more sensitive to the changes in water price than indoor use. Garden watering is usually the main reason for increasing the quantity of household water consumption (Fan et al., 2013). Daily average water consumption for outdoor uses (almost all outdoor water is used for garden watering) accounts approximately 56% of the total household consumption in Perth, Western Australia (Loh and Coghlan, 2003).

However, water demand for outdoor uses differs depending on the climate of the region and also the garden watering system. It might be higher in the dry and hot climate regions and also when using an inefficient watering method in the garden. For example, in North Coast and San Francisco, 26% of household water demand is consumed for outdoor purposes but it is over 55% in South Lahontan and San Joaquin River (Mini et al., 2014). Household swimming pool can also be an intensive outdoor water consumer. The quantity of water required for filling an average swimming pool is approximately 19000 gal (Mini et al., 2014). In addition, a significant amount of water may evaporate from swimming pool, especially in an arid region.

A range of approaches have been developed to calculate outdoor water demand for a household. One of the methods is summer-winter approach (Skeel and Lucas, 1998). This method assumes that the difference between daily per capita water use in summer and winter is equal to the outdoor water usage. Minimum month method is another approach. This method considers indoor water usage is constant during the year and is represented by the month that records the lowest water usage during the year (Mayer et al., 1999). The monthly water demand for outdoor is the difference between household water usage in each month of the year and the lowest household water usage. Costello et al. (2000) developed landscape method which requires more specific data about type, density and climate conditions of the field to calculate landscape coefficient and estimate irrigation requirements.

2.2.3 Estimation of household water demand

One of the challenges that face water demand model designers is data availability, for example, water price, cost of water collection, quality of water service and socio-economic characteristics of a household (Nauges and Whittington, 2010). Some factors can be ignored in the analysis of household water demand, such as water price when the price schedule is similar for all households (Larson et al., 2006). Usually water utilities have no information on household socio-economic and demographic characteristics, such as income, household composition, age, gender, education level and household size.

Therefore, water demand surveys in a household can be conducted to provide these data.

There are two common approaches to estimate or forecast the future water demand for a household. In the simplest approach, per capita water consumption for daily activities is estimated and used with the predicted size of population. The main disadvantage of this approach is that it is difficult to consider the changes in per capita water consumption as a result of seasonal weather variation, income/economic growth, change in water price, lifestyle and technological development (Nieswiadomy, 1992; Altunkaynak and Nigussie, 2017). The second is economics approach which aims to develop a water demand estimation model as a function of various factors (e.g., income, weather, water price and other factors) (Bauman et al., 1998).

One of the efficient techniques for understanding and estimating household water demand is to disaggregate water consumption to end-uses (Marinoski et al., 2014). The definition of end-use depends on the scale of the investigation. At a household level, it comprises cooking, showering, clothes washing, dishwashing, tap uses, toilet flushing, vehicle washing and garden watering. End-use technique can assist water utilities to design effective demand management programs and develop an efficient water saving strategies to reduce water consumption, such as using low flow toilets and showerheads and adoption of water efficient irrigation technologies (White et al., 2004).

In the developing countries, less effort has been made for modelling household and domestic water demand, compared to that in the developed countries (Nauges and Whittington, 2010). This may be due to the household’s access to more than one type of water sources in the developing countries. Abu Rizaiza (1991) developed water demand models for households supplied by water distribution network and tankers, separately, to estimate water demand in four cities in Saudi Arabia. Cheesman et al. (2008) separated water demand for households with a private connection only and households combining private connection and well water. Different household characteristics are used for water demand modelling and estimation in the developing countries, such as, walking time to water source (Persson, 2002), number of women in the household (Mu et al., 1990), family size (Larson et al., 2006), education level

(Madanat and Humplick, 1993), income (Nauges and Strand, 2007) and reliability of water from other sources (Nauges and van den Berg, 2009). However, household physical characteristics (e.g., built-up area, garden area, number of rooms and number of floors), grey water recycling and rainwater harvesting should also be taken into account to develop effective models for domestic/household water demand estimation as.

2.3 Energy demand at a household level

In addition to the appliances used in a household for various purposes, daily water consumption for indoor uses (i.e., showering, bathing, dishwashing, clothes washing and cooking) usually requires energy in the form of electricity or natural gas (Pelli and Hitz, 2000; Mayer et al., 1999). Greenhouse gas (GHG) emissions produces from energy use of these appliances is the main cause of climate change (Norman et al., 2006). To reduce energy use and the associated GHG emissions in a domestic sector, it is necessary to understand the factors that influence household energy consumption (Jones et al., 2015).

Previous researches addressed the relationship between household characteristics (demographic and socio-economic) and household energy consumption (Muller and Yan, 2016). However, this area of research still requires more attention (Brounen et al., 2012; Longhi, 2015). Understanding the impact of social, economic and demographic characteristics on household energy consumption can help to identify alternative ways to permanently reduce households' energy consumption (Longhi, 2015). Table 2.3 summarises the impact of various factors on household energy consumption. Per capita income can be one of the most important factors affecting household energy consumption (Kriström, 2008; Alkon et al., 2016, Druckman and Jackson, 2008).

Table 2.3 Summary of the factors affecting household energy consumption

Factors	Reference	Key findings
Family size	Navajas (2009)	Household energy consumption is positively related to the family size.
Age of family members	Labandeira et al. (2006)	The age distribution of family members affects household energy consumption.
	Mileham and Brandt (1990)	Elders require higher energy for space heating than young members of a family.
	Bartusch et al. (2012)	Electricity consumption increases in a household with higher number of children and teenagers due to their less consciousness of the consumption.
Human behaviour	Shimoda et al. (2010)	Energy consumption at a domestic sector is affected by human behaviour.
Lifestyle	Anker-Nilssen (2003)	Changing lifestyle has a dramatic impact on energy consumption.
Time spending at home	Lucas et al. (2001)	Energy consumption is directly correlated with the duration of staying at home (e.g., working from home).
Education level	Roberts (1996)	Household members with a higher education level tend to consume less energy (i.e., conserve energy).
Culture	Reinders et al. (2003)	Culture-related energy consumption varies depending on the diet, dressing style and recreation.
Income	Anker-Nilssen (2003)	High income households tend to use more energy for different daily household tasks rather than doing them manually. However, energy saving is negatively correlated with household income.
Number of appliances	Kelly (2011)	The number of appliances in use in a household is positively associated with the building size, resulting in more energy consumption.
Area of a household	Mileham and Brandt (1990)	Household energy requirement for space heating, cooling and lighting is higher in the large household size.
Type of the building	Arpke and Hutzler (2006)	Energy use varies depending on the type of the building.
Age of the household	Yamasaki and Tominaga (1997)	Household energy consumption depends on the age and type of building and also the residential area (i.e., rural or urban).
Energy prices	Ljones et al. (1992)	With increasing energy prices, low income households tend to save energy while high income households seem not to react.
Weather condition	Beccali et al. (2008)	Weather variables (i.e., temperature, humidity, wind and number of sunny days) influence heating and cooling energy consumption.
Number of rooms	Bedir et al. (2013)	Household electricity consumption increases with increase in the number of rooms.

2.3.1 Energy end-uses

A number of key energy functions (i.e., end-uses) have the main role in household energy consumption, such as space heating and cooling, water heating, lighting and appliances. Modelling these energy end-uses can help to understand the dynamics and possible future trends of household energy consumption (Daioglou et al., 2012). One of the effective ways to reduce energy consumption and the associated GHG emissions in residential buildings is to improve the efficiency of energy end-uses (Aydinalp et al., 2002). The energy end-uses at a household level are explained as below.

<u>Water heating</u>

Factors influencing household energy consumption for water heating are family composition, inflow temperature and fuel type (Aguilar et al., 2005). Type and efficiency of water heater can be another factor (BRANZ, 2004). Energy consumption for water heating may change with seasons and climate (cold region consumes more hot water) (Daioglou et al., 2012). It may also be higher during the weekend than the consumption during weekdays (Goldner, 1994).

<u>Space heating and cooling</u>

Energy consumption for household space heating and cooling is influenced by climate and house insulation factors (Swan et al., 2011). It is modelled as a function of dwelling area, family size and air temperature (Daioglou et al., 2012). The energy consumption for interior heating increases with human age (Liao and Chang, 2002). Owned residential buildings tend to be fitted with more efficient heaters, compared to the rented properties (Rehdanz, 2007). Also, detached house unit consumes more energy for heating and cooling than attached unit (Ewing and Rong, 2008).

<u>Lighting</u>

Energy consumption for artificial lighting depends on the daylight hours and season (Yao and Steemers, 2005). It increases in winter due to the short lighting hours. Household electricity consumption for lighting is linearly related to the floor space (Daioglou et al., 2012). Yao and Steemers (2005) and Ren et al. (2013) formulated lighting energy consumption as a function of house floor area, number of rooms and occupants in the household.

Washing appliances

Dishwashing is one of the household activities that heavily consumes water and energy. Energy and water consumption for manual dishwashing is influenced by occupant's behaviour (Berkholz et al., 2010). Globally, the average resource consumption in manual dishwashing is 113 l of water, 2.9 kWh of electricity and 36.9 g of detergent for washing 12 standard place settings of tableware (Berkholz and Stamminger, 2009). Using automatic dishwasher, the average consumption of each cycle is 13.2 l of water, 1.3 kWh of energy and 152 min of time in the UK (Berkholz et al., 2010). Globally, the average energy use per a single wash of automatic dishwasher is 4.8 kWh (Berkholz et al., 2010).

Water and energy consumption for clothes washing is a function of technology of the washing machine, number of washes, washing temperature and the load size even in one single washing machine model (Pakula and Stamminger, 2010). Resident's behaviour is another factor. In some regions like China, Turkey and Eastern Europe, they often wash their clothes manually in spite of owning an automatic clothes washer (Pakula and Stamminger, 2010). The annual number of washing cycles was 520 per household in Japan whilst just 100 cycles per household in China. Therefore, the annual water and energy consumption for clothes washing varies widely from region to region. The variation in the consumption may also be related to the efficiency and operating temperature of washing machines.

The type of clothes washing machine (horizontal and vertical axis) is another important factor. Plappally and Lienhard (2012) stated that the water consumption is higher in a cold wash vertical type washing machine; however, the electricity consumption is lower than that in the hot wash horizontal type washing machine.

Cooking and food preservation

Cooking is one of the main daily energy consumption activities. The energy use for food preparation depends on the available technology and type of energy. For example, energy source for cooking purposes in rural areas in developing countries is biomass for approximately 2.5 billion individual (IEA, 2007). Energy consumption for food preparation and preservation can be high. In Sweden, it accounts for 25% of the total energy used within food supply chain (Wallgren and Hojer, 2009).

User's behaviour can be the main factor affects energy consumption for cooking. For example, using a bigger cooker ring than the cooking utensils causes energy waste (DeMerchant, 1997). Additionally, 50% of energy uses for cooking can be saved with using an electric kettle for boiling water rather than the electric stove, and coffee machines for brewing coffee rather than manual preparation with boiling water in a pot (Oberascher et al., 2011). Boiling eggs in an egg cooker instead of a pot without a lid will save 60% of energy use for cooking. Moreover, electric rice cooker uses 23–57% less energy than other rice cooking methods (Das et al., 2006).

2.3.2 Estimation of household energy demand

Residential energy demand has been modelled as a function of various parameters, such as physical characteristics of a household, appliances in use and number of occupants in a household and climatic condition. Depending on the level of input data or information, modelling techniques for household energy demand can be categorised into top-down and bottom-up approach (Swan and Ugursal, 2009).

Top-down models for energy demand estimation use data collected at an aggregate level to derive causal relationships between determinants and energy consumption (Swan and Ugursal, 2009). Top-down model can be developed as a function of macro-economic indicators (e.g., GDP, unemployment and inflation), energy price and climate conditions (Swan and Ugursal, 2009). Examples of top-down models are residential and commercial sector of Asian mega-cities (Tooru et al., 2002), the National Energy Modelling System of the U.S. Department of Energy (DOE, 2005) and the residential energy demand system for Spain (Labandeira et al., 2006).

In contrast, bottom-up models use data collected at an individual dwelling level (e.g., energy end-uses) to determine the relationship between household characteristics and energy use (McLoughlin et al., 2012). The variables used with bottom-up models are for example family size, household area, properties of appliances in use and indoor temperature. Examples of bottom-up models are the application of survey data sources to the residential sector of Delhi (Kadian et al., 2007), the adaptive neural network technique that applied to a residential building in Montreal (Yang et al., 2005) and a model of Norway's household developed based on 2013 dwellings by Larsen and Nesbakken (2004).

Bottom-up models can be further classified into statistical and engineering model. Engineering models can estimate the consumption of energy end-uses through involving equipment usage and energy rating. However, the consumption of energy end-uses in statistical model can be estimated as a function of household characteristics (Min et al., 2010).

2.4 Food demand at a household level

Population growth and changing individual's food consumption habit are the main reasons for increasing food demand (Canning et al., 2010). Globally, it has increased to more than double since 1950 (Khan and Hanjra, 2009). It is likely that individual income and household budget are also playing a role in this growth. For example, high income families rely on a large quantity of meat in their diet, putting more pressure on water consumption because the production of one kg of meat requires 4000–15000 l of water, while cereal grains require 1000-2000 l/kg (Mekonnen and Hoekstra, 2010). Additionally, 2.5-10 times more energy is required to produce the same amount of calorie energy from meat than grains (Khan and Hanjra, 2009).

It is indicated that daily per capita calories intake for survival is ranged between 2000 and 3000 kcal/p/d (NRC, 1989). Based on the regional diet, the daily per capita average calories intake from various types of food is estimated by Gleick and Iwra (1996). They found that the highest calorie intake is attributed to Western and Eastern Europe (i.e., >3300 kcal/p/d) while Africa and South of Sahara has the lowest (i.e., <2200 kcal/p/d).

Food availability, access and consumption are complex issues that include a wide range of interconnected economic, social and political factors (Codjoe and Owusu, 2011). Therefore, the impact of household characteristics (e.g., family size, gender of household-head, education level, income, culture and geographic location) on food consumption has been investigated by authors. The outcomes of some studies are presented in Table 2.4. Within the investigated factors, per capita income is one of the most important determinants of food consumption (Kostakis, 2014; Abdel-Ghany et al., 2002; Kirkpatrick and Tarasuk, 2003; Ricciuto et al., 2006).

Seasonal viability of food consumption has also received a considerable attention in the literature (Doyle et al., 1999; Shahar et al., 1999). However, the results were inconsistent. Some studies found that the daily total calorie intake remains broadly unchanged throughout the year (Subar et al., 1994; Shahar et al., 1999). The intake of some nutrients does not change throughout the year, such as proteins (De Castro, 1991) and carbohydrates (Hackett et al., 1985). Other studies stated that the intake of fat (Doyle et al., 1999) and carbohydrates (De Castro, 1991) varies seasonally.

Table 2.4 Summary of the factors affecting household food consumption

Factors	Reference	Outcome
Family size	Nguyen and Mergenthaler (2013)	Per capita meat consumption tends to decrease with the increase in a family size.
	Sinha (2005)	The increase in family members has a positive and significant impact on per capita calorie intake.
Age	Van Phuong et al. (2015)	Young and old family members consume larger amount of dairy products.
Gender	Nishi et al. (2017)	The total calories intake for men is higher than that for women.
	Sinha (2005)	In a family headed by female, per capita calorie intake tends to be higher than those families headed by male.
Education level	Han et al. (1996)	Education level has a significant and positive impact on per capita consumption for vegetables.
	Kostakis (2014)	Both education level and age of the head of a family have no impact on the household food consumption.
Income	Okutu (2012)	Income is the most important factor affecting the food expenditure.
	Tiffin and Dawson (2002)	The relationship is strong between calorie intake and per capita income.
	Nguyen and Mergenthaler (2013)	The consumption for meat and dairy products is positively influenced by per capita income.
Technology	Musaiger (1982)	Food consumption pattern is influenced by change in technology, such as improve electrical cooking appliances, new food products and food shops.
Geographical location	Han et al. (1996)	The geographical location has a significant impact on per capita diet and food consumption.
Food prices	Maxwell et al. (2000)	Per capita diet is strongly influenced by food prices and availability of packaged and processed foods, advertising and the media.
Lifestyle	Atkinson (1995)	Per capita diet is strongly influenced by lifestyle and a family structure.
Religious affiliation and ethnic	Codjoe and Owusu (2011)	Per capita food consumption may be related to ethnic composition of some communities and religious affiliation.
Changes in weather	Clover (2003)	Increase the quantity of precipitations cause food rot (moulds) leading to more waste or contaminations.
Farm size	Babatunde et al. (2010)	In rural areas, the size of field own by a family contributes positively and significantly into their calorie intake.

2.5 Modelling water-energy-food nexus at a household level

Households consume considerable quantities of resources (water, food and energy) to meet everyday demand of inhabitants. The household is a unit of demand and it can also be the most appropriate unit for influencing consumption practices. A high portion of WEF consumption in the cities can be attributed to household uses. For instance, energy consumption at a household level accounts approximately 72.5, 75, 80, 80.6 and 81% of the total energy consumption in Tanzania, Burkina Faso, Duhok in Iraq, Kenya and Nigeria, respectively (Hermann et al., 2012; General Directorate of Duhok Electricity, 2014; Mohamed and Yashiro, 2013).

Although, the attention on the nexus approach has increased over the past decade (Chen and Lu, 2015), there is a lack of studies investigating the water-energy-food nexus at a household level (Djanibekov et al., 2016; Endo et al., 2015; Loring et al., 2016; Wakeel et al., 2016). A single element of the nexus has been addressed in some studies. For example, Cominola et al. (2016) and Daioglou et al. (2012) modelled domestic water demand at end-use level. Sarker and Gato-Trinidad (2015) developed a model for household water demand estimation in Yarra Valley Water, Australia at end-use level. However, their model did not include garden watering end-use. A residential end-use model was developed to estimate cold (indoor and outdoor) and hot water demand as well as wastewater generated for each month of the year (Jacobs and Haarhoff, 2004a; Jacobs and Haarhoff, 2004b). This model highlights the impact of seasonal variability on water consumption.

Energy consumption and associated emissions from a household in Delhi is modelled by Kadian et al. (2007). They considered the impact of income and family size on energy consumption. Aydinalp et al. (2002) modelled domestic energy consumption at end-use level. Ren et al. (2013) developed a tool to predict the energy consumption at end-use level and related greenhouse gas emissions of Australian households, considering the impact of household occupancy patterns. However, their model does not address the seasonal variation of energy consumption.

Even when there were attempts to study the nexus at the level of households, the focus was often on water-energy nexus without taking food consumption into the account. The interactions between water and energy at a household level have not been addressed very intensively (Kenway et al., 2013). Cheng (2002) analysed water-related energy in residential buildings in Taiwan. They found that 88% of water-related energy use is attributed to water heating and household water pumping, while the rest is used for water treatment, water supply and wastewater treatment. Water-energy nexus at a household level has been investigated in Beijing–Tianjin–Hebei region by Wang and Chen (2016). Arpke and Hutzler (2006) modelled four household types and showed that 97% of water-related energy is attributed to water heating. Based on this model, Flower (2009) simulated water heating-related energy in Victoria, Australia using electricity and gas heater. Kenway et al. (2013) developed a model to investigate the energy use for household water heating in Brisbane, Australia, without considering the impact of household characteristics. They found that the household is the key driver for energy consumption and associated greenhouse gas emissions in the city.

Additionally, Abdallah and Rosenberg (2014) developed an approach to model household indoor water and energy use and their interactions. Their approach considers the impact of behavioural and technological water and energy use factors that affect the indoor use. Apart from energy consumption for household water uses, they did not account other energy end-uses (e.g., lighting, cooking, and space heating and cooling). They found that dishwasher consumes more energy per gallon of water than clothes washer and toilet flushing. However, using dishwasher saves more water and energy than manual dishwashing (Abdallah and Rosenberg, 2014). Enhancing the efficiency of household water-consuming fixtures (e.g., toilets, showerheads, taps and water heaters) contributes to reduce wastewater and the treatment-related energy (Chang et al., 2016). Although, toilet flushing has a significant role in reducing water consumption, it has a limited impact on reducing water-related energy use and the associated carbon emissions at a household level (Fidar et al., 2010).

Food consumption at a household scale has been addressed in some other studies. Demerchant (1997) investigated the user's influence on the energy consumption of the cooking system using electricity. The possibility to reduce the electricity use for food preparation is investigated by Wallgren and Höjer (2009). They suggested that using a microwave oven is more energy-efficient than a conventional oven for cooking some types of food. Additionally, an electric kettle consumes less energy for boiling water than a hotplate. Singh and Gundimeda (2014) found that in Indian households the highest energy efficient fuel for cooking purposes is liquefied petroleum gas (LPG). The impact of bioenergy use on rural households, environment and natural resource use has been partly addressed for the developing countries by Djanibekov et al. (2016). Wenhold et al. (2007) provided an overview of the interactions between agriculture using residential land, irrigation water and household food security for South African countries.

2.6 Seasonal variability of water-energy-food

The influence of variability in household characteristics (demographic and socio-economic) and appliance efficiency on the end-uses of each of WEF is widely addressed in the literature (Blokker et al., 2009; Pakula and Stamminger, 2010; Richter, 2011; March et al., 2013; Romano et al., 2014; Navajas, 2009; Bartusch et al., 2012). However, the main driver for estimating the future household demand for water and energy is the impact of hot and dry weather conditions (Proust et al., 2007). Weather plays an important role in the fluctuation of energy consumption throughout the year (Sailor, 2001). For example, the energy demand for space heating and cooling varies with the temperature and humidity. Therefore, the seasonal variability of energy consumption should be taken into account while estimating the annual demand.

Additionally, the variability of household water end-uses between winter and summer has not been investigated thoroughly (Rathnayaka et al., 2015). Jacobs and Haarhoff (2004a and 2004b) developed a model for residential end-uses to estimate monthly consumption for cold and hot water and the generated wastewater. However, their model captures the impact of seasonal variability only on water consumption. They found that the daily water consumption during summer season is higher 1.2–1.6 times than the average annual daily consumption.

Although per capita food consumption may not remain constant throughout the year (Rossato et al., 2015), most studies addressed only the consumption during a particular period of the year (Costa, et al., 2013). This may influence the correct estimation of demand for different foods. The seasonal variability in food consumption might be more pronounced in developing countries where the price of the most food commodities varies seasonally (Leonard and Thomas, 1989).

2.7 Energy use within water supply chain at a city scale

Energy is required along every stage of a water use cycle (Figure 2.1) (Cohen et al., 2004). For example, pumping water from source to the treatment plant, treatment process and pumping through water supply network to the user. The quantity of energy required in each stage can vary significantly from region to region depending on the geographical, physical and technological factors as well as depth of water to be pumped and pipe diameter (Siddiqi and Anadon, 2011). The stages of water use cycle are explained in the following Sections (2.7.1 to 2.7.4).

2.7.1 Water abstraction

The quantity of energy required for pumping groundwater linearly increases with the depth from which it is pumped, at a specific pressure (Reardon et al., 2012). The depth of water table may change depending on groundwater recharges (Martin et al., 2011). The energy required for pumping can also be a function of the pump efficiency, length and diameter of pipe, roughness coefficient of the pipe and the quantity of pumped water (Ahlfeld and Laverty, 2011). To lift 1 m^3 of groundwater from 1 m depth, the required energy is about 0.004 kWh (Cohen et al., 2004). The amount of energy consumption for pumping surface water varies with the elevation and distance to the area of supply (Cheng, 2002). It is estimated to be 0.002 - 0.007 kWh when 1 m^3 of surface water is pumped to 1 km distance from water source (Plappally and Lienhard, 2012).

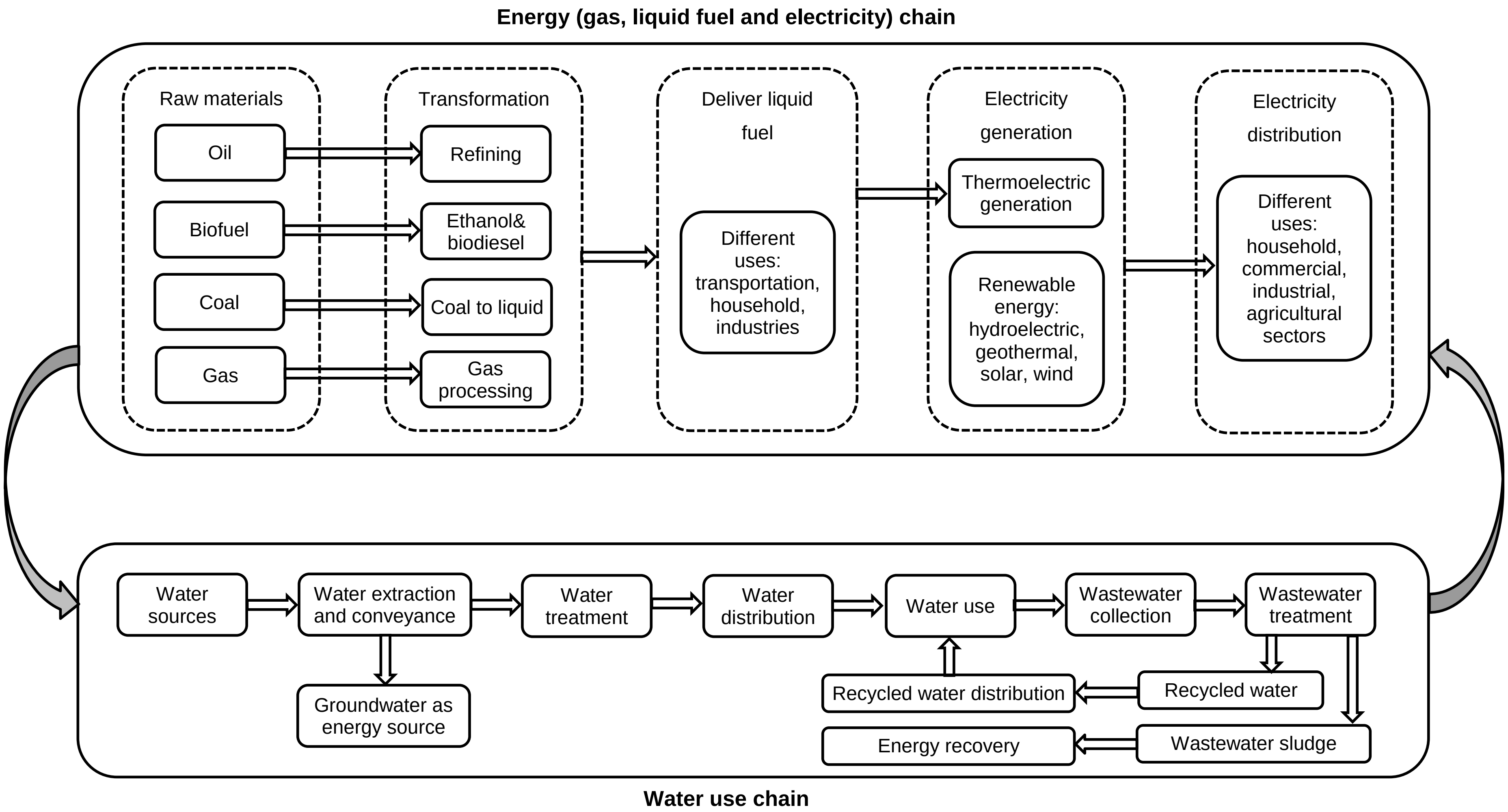


Figure 2.1 Summary of water-energy nexus

2.7.2 Water treatment

Water treatment is a process of improving the quality of water by removing contaminates to obtain acceptable clean water. Water treatment comprises physical, chemical and biological processes (Goldstein and Smith, 2002). The treatment process and related energy consumption vary according to the water source due to the variation in contaminant rate (Elliot et al., 2003). Groundwater treatment process is much less complicated than that for surface water (Goldstein and Smith, 2002). Groundwater is usually less polluted than surface water but it still may contain dissolved mineral, inorganic and organic chemicals (Plappally and Lienhard, 2012). Basic disinfection might be carried out for pumped groundwater including chlorination or ozonation while typical treatment process is required for surface water which includes mechanical screen, sedimentation/flocculation, rapid mixing, filtration and disinfection (Plappally and Lienhard, 2012).

The amount of energy consumption for water treatment can range between 0.01 kWh/m^3 in Australia (Cammerman, 2009) and 1.5 kWh/m^3 in Spain (Muñoz et al., 2010). According to Siddiqi and Anadon (2011), the total electricity consumption through a treatment process for surface water is approximately 0.4 kWh/m^3. However, the World Economic Forum (2009) stated that this value varies depending on raw water quality. The size of water treatment plant can also affect energy consumption for water treatment: 1483 and 1407 kW/MG for 1.0 and 100 MG/d plant size, respectively (Klein et al., 2005).

In terms of desalination process (remove salts and minerals), the required energy can be high, depending on the salinity of raw water (Plappally and Lienhard, 2012). The salinity of seawater (15000-50000 ppm of total dissolved solids) is much higher than that for brackish water (1500-15000 ppm of total dissolved solids) (Fritzmann et al., 2007). Energy consumption for desalination process is approximately 1.5-15.0 kWh/m^3 of saline water (Siddiqi and Anadon, 2011). This variation in energy consumption depends on the treatment technology.

2.7.3 Water distribution

Water would meet the required standards after the treatment process where it is then distributed to residential, commercial, industrial and agricultural sectors. Pumping water through a water supply network to these sectors consumes energy as mentioned in Section 2.7.1. Leakage from water distribution network can be one of the important factors that affect the energy requirement for pumping. The quantity of leakage depends on the pressure in the water distribution network, time period of leaking and area of leak (UN Habitat, 2012). The rate of leakage resulting from 1 drop/sec is 10 m^3/y and also a 2.5 cm diameter hole with a pressure of 2.8 bars may cause a leak of more than 570 l/min (UN Habitat, 2012).

2.7.4 Wastewater treatment

Once treated water is used in domestic, commercial and industrial sectors, wastewater is collected in sewer networks and then transported to the wastewater treatment plants. The energy required for wastewater treatment process depends on the plant size and age, impurity rate, type of the treatment process and quality of reused water (Twort et al., 2000). In some countries, wastewater is partially treated in septic tanks and cesspools at a household. Not all of the wastewater generated by municipal and industrial sectors is reusable. In Saudi Arabia only 18% of treated wastewater is reused in the industrial sector and the rest is discharged as unused wastewater (Al-Musallam, 2006).

In a typical wastewater treatment plant, wastewater passes through primary, secondary and advanced treatment stages (USGAO, 2011). Large debris and small particulate matter are removed from wastewater in the primary stage via screening, grit removal and sedimentation process. Primary sludge pumping at this stage of wastewater treatment consumes high energy, ranged between 0.04 and 0.19 kWh/m^3 in New Zealand and between 0.02 and 0.1 kWh/m^3 in Canada (Plappally and Lienhard, 2012). The sedimentation process has lower energy consumption (0.008-0.01 kWh/m^3) (Tassou, 1988). The total energy consumption within the primary stage of wastewater treatment is about 0.01-0.37 kWh/m^3 in Australia (Kenway et al., 2008).

In the secondary stage, wastewater goes through a biological treatment process which is based on cultivating micro-organisms in wastewater to break down organic matter into water, carbon dioxide and other inorganic compounds. Carbon dioxide is reduced through injecting oxygen to create air bubbles in the wastewater using blower or diffused aeration process. Aeration blower needs half the energy consumed by diffused aeration treatment system (Water Environment Federation, 2010). In a typical plant in China, aeration process consumes more than half (51.58%) the total energy required for wastewater treatment (Tao and Chengwen, 2012).

Consequently, the micro-organisms should be able to digest the organic matter and then the digested materials are settled in the second sedimentation tank. The total average energy consumption within the secondary stage of wastewater treatment is ranged between 0.2 kWh/m^3 in USA (Water Environment Federation, 2010) and 0.42 kWh/m^3 in Sweden (Yang et al., 2010). It is roughly the same (i.e., 0.305 kWh/m^3) in Japan (Mizuta and Shimada, 2010) and Australia (Kenway et al., 2008).

The removal of additional contaminates (e.g., nutrients) is done in the advanced treatment stage. In Japan, the energy consumption of this stage of wastewater treatment is high (0.39-3.74 kWh/m^3) (Mizuta and Shimada, 2010). Overall, the average energy consumption to treat 1 m^3 of wastewater is 0.254 kWh/m^3 in China (Tao and Chengwen, 2012), 0.32-0.88 kWh/m^3 in New Zealand (Kneppers et al., 2009).

2.8 Water and organics consumption for energy production at city scale

Water is central at various stages of production of most types of energy (DOE, 2006). Understanding the linkage and the quantity of water used within the stages of production of each form of energy can help policy-makers to choose the appropriate type of energy for the local water. The quantity of water requirement varies depending on the energy producing technology and the stage of energy production chain: extraction of raw materials (e.g., coal, oil, biomass and gas), transformation (refining and processing) of raw materials to usable energy (e.g., ethanol and biodiesel) and delivery to the user (Hardy et al., 2012). The quantity of water consumption is minimal in the process of delivery of natural gas and liquid fuels to the user (Yergin and Frei, 2009).

Increase the energy demand and concern about GHG emissions stimulate action towards renewable energy sources as an alternative of traditional fossil energy sources (Mann, 2011). This may reduce the quantity of water consumption for energy production in the future and CO_2 emissions (Meah et al., 2008). However, some renewable types of energy (e.g., biomass and ethanol) are more water intensive (King et al., 2008) and require additional land for agricultural uses (Hardy et al., 2012). Water consumption within the stages of production of all types of energy (i.e., gas, liquid fuels and electricity) is explained as below.

2.8.1 Gas and liquid fuels

Energy sources extraction

The quantity of water consumption to extract conventional natural gas as a raw material can be minimal (Mielke et al., 2010). Water use for oil extraction varies depending on the geography, geology, recovery technique and reservoir depletion (Mielke et al., 2010). In terms of water requirements for mining each of uranium and coal, it depends on whether the mine is an underground or a surface mine as well as the geology of the region (DOE, 2006). Table 2.5 presents the estimated quantity of water requirements to extract and processing different types of energy fuels.

Table 2.5 Water requirements for extraction and processing energy fuels

Energy source		Extraction raw materials (l/GJ)	Transformation (l/GJ)	Total (l/GJ)	Reference
Oil	Traditional	3-7	Refining: 25-65	28-72	Yergin and Frei (2009)
		0.5			Carrillo and Frei (2009)
				40-400	Mielke et al. (2010)
	Oil sands	70-1800			Yergin and Frei (2009)
		40-130			Mielke et al. (2010)
Biofuel	Corn	Irrigation: 9000-100000; Ethanol extraction: 47-50; Biodiesel extraction: 14			Yergin and Frei (2009)
		Irrigation and ethanol extraction: 350-25000			Mielke et al. (2010)
		Ethanol extraction: 150-257			Williams and Simmons (2013)
	Soy	Extraction: 50000-270000			Yergin and Frei (2009)
		Irrigation and biodiesel extraction: 450-700 mm/y			Steduto et al. (2009)
		Biodiesel extraction: 33			Williams and Simmons (2013)
	Sugar	Irrigation and ethanol extraction: 1000-2000 mm/y			Steduto et al. (2009)
		Ethanol extraction: 641-954			Williams and Simmons (2013)
Coal		5-70	140-220		Yergin and Frei (2009)
				4-110	Mielke et al. (2010)
				40	Williams and Simmons (2013)
Gas	Traditional gas	Minimal	7		Yergin and Frei (2009)
		Minimal			Carrillo and Frei (2009)
				0-15	Mielke et al. (2010)
				0-17	Williams and Simmons (2013)
	Shale gas	36-54			Yergin and Frei (2009)

Fuel processing

Agricultural crops (e.g., sugar beet, maize and sugar cane) and forestry wastes can be converted to different usable forms of biofuel (e.g., ethanol and biodiesel) and gas (e.g., methanol). In general, water required for deriving biofuels is high compared to that for fossil fuels (e.g., coal, natural gas) (Hardy et al., 2012). Although, biofuel has a high water footprint, it can be one of the solutions to reduce carbon dioxide emissions (Mielke et al., 2010). Mann (2011) found that the water use to produce $100x10^6$ gal of ethanol per year can cover the requirements of approximately 5000 people. Similar to ethanol, biodiesel consumes more water than fossil fuels (Mann, 2011).

The quantity of water consumption for biofuels depends on irrigation requirements; for example, corn ethanol requires more water than any other type of fuel due to the irrigation requirements during growing stage (Mielke et al., 2010). Additionally, the quantity of water required for ethanol production depends on the soil type, yield, method of irrigation, irrigation requirements and climate in the region (Wu et al., 2009). Water is not only required for crop irrigation and production, but also for its conversion to biofuels (Gerbens-Leenes et al., 2008).

The process of deriving biofuel from agricultural crops uses only sugar or oil content of crops while the total biomass is used within electricity generation process (Mann, 2011). Therefore, converting biomass to biofuel is less efficient (requires more water) than burning it for electricity generation (bioelectricity process) as shown in Table 2.6. The table also shows that biodiesel production requires more water than producing ethanol. On the other hand, some types of fuel can produce water during the processing stage. Globally, the annual produced amount of water from oil and gas industry increases 10% (Khatib, 2007). Water to oil ratio is ranged between 1 and 40 with the lowest ratio is attributed to the Middle East region (Khatib, 2007).

Table 2.6 Average water requirements for providing electricity and liquid fuels from crops (Gerbens-Leenes et al., 2008)

Crop	Average water footprint for providing different forms of energy from crop (m^3/GJ)		
	electricity	ethanol	biodiesel
Sugar beet	46	59	
Maize	50	110	
Sugar cane	50	108	
Barley	70	159	
Rye	77	171	
Paddy rice	85	191	
Wheat	93	211	
Potato	105	103	
Cassava	148	125	
Soybean	173	394	
Sorghum	180		419
Rapeseed	383		409
Jatropha	396		574

2.8.2 Electricity generation

Table 2.7 presents the estimated quantity of water requirements for electricity generation based on the source type of energy. The quantity of water consumption for electricity generation is influenced by the efficiency of the power plant and climate of the region (Williams and Simmons, 2013). It also depends on the energy source used for electricity generation and the method of cooling (Western Resource Advocates, 2008). Nuclear reactor uses more water for cooling than the coal plant (Table 2.7) (Williams and Simmons, 2013). The cooling systems can be classified into one-through, wet recirculating and dry (Fisher and Ackerman, 2011).

The quantity of water used in each type of cooling system depends on the power plants thermal efficiency (i.e., water used for cooling per MWh of generated electricity is less with high thermal efficiency) (Williams and Simmons, 2013). One-through cooling system requires a significant amount of water and consumes a small amount of it; however, recirculating wet-cooled system requires only 2-5% of the water used in once-through system but consumes all of it (Fisher and Ackerman, 2011). Dry-cooled system consumes much less water than a recirculating wet-cooled system.

Water consumption for electricity generation from renewable energy sources is very diverse; for example, wind and solar photovoltaic panels use a minimal amount of water while concentrating solar power has high water consumption (Mielke et al., 2010). However, solar photovoltaic use may only suitable for small scale irrigation applications (Hamidat et al., 2003) and medium head domestic water pumping applications (Bhave, 1994). Hydroelectric power and geothermal energy (i.e., the heat under the earth's crust used for electricity generation and for heating) plants are very high water users (Mielke et al., 2010). In contrast, some studies considered geothermal energy as a low water user if water is recycled (Mann, 2011).

In terms of water consumption for electricity generation using thermoelectric technologies (i.e., coal, gas, oil and nuclear), nuclear power is the highest compared to the other types of thermoelectric technologies (Mielke et al., 2010).

Table 2.7 Summary of water requirement for electricity generation using different power sources

Power source		Raw materials (l/MWh)	Transformation to electricity (l/MWh)	Reference
Thermoelectric fuels	Coal	20-270	Closed-loop (wet) cooling system: 720-2700	Yergin and Frei (2009)
		120	1552	Carrillo and Frei (2009)
			Once through: 1200-1320, wet cooling: 1200-2040, dry cooling: 0-120	Mielke et al. (2010)
			Wet cooling: 2600	Burkhardt et al. (2011)
			2040	Scott and Pasqualetti (2010)
	Oil	1500	1216	Carrillo and Frei (2009)
			1600	Saidur et al. (2011)
	Natural gas	45	685	Carrillo and Frei (2009)
			Once through: 1200-1320, wet cooling: 1200-2040, dry cooling: 0-120	Mielke et al. (2010)
			Wet cooling: 1400	Burkhardt et al. (2011)
			1660	Scott and Pasqualetti (2010)
	Uranium	170-570	Closed-loop (wet) cooling: 720-2700	Yergin and Frei (2009)
			1569	Carrillo and Frei (2009)
			Once through: 1600-1720, wet cooling: 1600-3000, dry cooling: 0-120	Mielke et al. (2010)
			Wet cooling: 2900	Burkhardt et al. (2011)
			3140	Scott and Pasqualetti (2010)
Hydroelectric		Evaporative loss: 17000		Yergin and Frei (2009)
		Evaporative loss: 20000		Carrillo and Frei (2009)
		Evaporative loss: 6000-27000		Mielke et al. (2010)
Geothermal	Geothermal		5300	Yergin and Frei (2009)
			0-6000	Mielke et al. (2010)
Solar	Concentrating solar		2800-3500	Yergin and Frei (2009)
			4700	Burkhardt et al. (2011)
	Photovoltaic		Minimal	Yergin and Frei (2009)
			Minimal	Mielke et al. (2010)
			0	Vestas (2011)
Wind			Minimal	Yergin and Frei (2009)
			1	Carrillo and Frei (2009)
			4	Saidur et al. (2011)

2.9 Land-use, water and energy consumption within food supply chain

Water and energy consumption throughout food supply chain begins with irrigation and raising livestock then processing, packaging, transportation, distribution to retail stores and finally storage and cooking. Water used for food production accounts approximately 75% of the total withdrawal water in developing countries (Chaturvedi, 2000) and 90% of total freshwater consumption (Shiklomanov, 2000). Population growth and increase in per capita food expenditure leads to significantly increase in water and energy use within food supply chain (Canning et al., 2010). Additionally, using high energy-intensive technologies in food manufacturing to reduce labour costs increases the amount of energy used.

Water requirement for growing and producing food is influenced by a number of factors; for example, culturally favourite types of food, social factors, regional climatic conditions and technology used in food processing and irrigation (Gleick and Iwra, 1996). To meet daily calorie intake (i.e., 2700 kcal/p/d) comprising 2300 kcal/p/d of plant-based and 400 kcal/p/d of animal-based products, water requirements are 2.3 and 2.0 m^3, respectively (Falkenmark, 1997). Similarly, the energy use in meat production is 2.5-10 times higher than that required to produce the same amount of calories of cereal grains (Molden et al., 2007). Therefore, dietary change to more meat consumption especially in high income households will put more pressure on water and energy resources.

Additionally, agricultural land is needed for food production and grazing. Globally, the available land per capita is 0.23 ha/p for agriculture and 0.5 ha/p for grazing (Pimentel and Pimentel, 2006). However, exploiting the agricultural lands for growing biofuel crops will reduce the available land for growing other agricultural required crops, leading to increase in food prices (Alexander and Hurt, 2008). Another challenge is losing $10x10^6$ ha of agricultural land annually due to wind and water erosion (Preiser, 2005). Moreover, soil salinization resulting from irrigation causes the abandonment of another $10x10^6$ ha of agricultural land annually (FAO, 2006).

Food supply chain includes the following processes:

2.9.1 Production

The first stage in food supply chain involves the activities related to growing crops, raising livestock and fishing, such as irrigation, fertilisation, operating machinery and maintain infrastructure. Energy use within the production stage varies from 2.2 MJ/kg for potato to 51.3 MJ/kg for cheese (Lillywhite et al., 2013). The activities use water and energy for meat and agricultural production are explained as below:

Agricultural production

Pumping water for irrigation purposes can be energy-intensive. The energy required for pumping depends on the pumping depth (from water source level to the farmland), climate and crop type (Ziesemer, 2007). Approximately 66% of irrigation water is supplied from groundwater to cover the agricultural needs of the world (FAO, 2011a). An example is Punjab, India, which produces about 50% of the national output of rice and wheat (Hussain et al., 2010). The serious problem is the replenishment of the aquifers is slower than water being pumped by farmers from aquifers, leading to a drop in water levels in these aquifers. Consequently, increased energy consumption due to greater pumping depths will lead to increase in food prices. In general, agricultural products consume much more water along the production stage than that in the processing stage (Baleta and Pegram, 2014).

Another factor affect the energy consumption within the agricultural production stage is using farming machines (FAO, 2011a). Due to the high mechanical weeding activities, energy use per hectare of organic crops is much higher than that for conventional crops (Bos et al., 2014). However, small farmlands can be cultivated manually or using livestock in some regions.

Additionally, using fertiliser in order to increase agricultural crop production increases energy consumption throughout the agricultural production stage. The average quantity of fertiliser used per hectare of arable land has been increased from approximately 96 kg/ha in 2002 to 110 kg/ha in 2009 (FAO, 2013). The required energy to produce 1 kg of nitrogen fertiliser is approximately 41.9-62.8 MJ (11.6-17.4 kWh) (Ziesemer, 2007). Depending on the type of fertiliser, nitrogen-based fertiliser uses 10 times more energy than phosphors and potassium-based fertiliser (Khan and Hanjra, 2009).

Meat production

For all types of meat, the average energy consumption can be the highest within the primary production stage. It accounts over 65% of the total energy use within the supply chain (Lillywhite et al., 2013). Meat production stage involves the quantity of feed required to produce one kilogram of meat. Table 2.8 provides global average amount of feed required to produce one kilogram of livestock using different systems. The table shows that obtaining one kilogram of chicken meat required less feed than other types of meat.

Table 2.8 Impact of meat production system on feed requirement (Mekonnen and Hoekstra, 2010)

Livestock category	Feed conversion efficiency (kg dry mass feed/kg output)			
	Grazing	Mixed	Industrial	Overall
Beef cattle	70.1	51.8	19.2	46.9
Dairy cattle	3.5	1.6	1.1	1.9
Broiler chicken	9.0	4.9	2.8	4.2
Layer chicken	9.3	4.4	2.3	3.1
Pig	11.3	6.5	3.9	5.8
Sheep and goat	49.6	25.8	13.3	30.2

Table 2.9 presents the total energy (direct and indirect energy for feed, building and equipment) required to produce one unit of animal products. The average quantity of fuel required for catching one ton of fishes and invertebrates is approximately 620 litres (Tyedmers et al., 2005). Globally, the amount of energy expended on the fisheries forms around 1.2% of the total global fuel consumption (Tyedmers et al., 2005). This leads to more than $130x10^6$ ton of CO_2 gas emissions into the atmosphere.

Table 2.9 Energy requirements for producing animal products (FAO, 2011a)

Food product	Livestock feed conversion	Direct and indirect energy inputs
Chicken	4.2 kg/kg edible meat	25 - 35 MJ/kg meat
Pork	10.7 kg/kg edible meat	25 - 70 MJ/kg meat
Beef (feedlots)	31.7 kg/kg edible meat	80 - 100 MJ/kg meat
Laying hens	4.2 kg/kg eggs	450 - 500 MJ/year
Dairy milk	0.7 kg/litre milk	5 - 7 MJ/litre of fresh milk
Fish (trawler capture)		5 - 50 MJ/kg (mainly liquid fuel inputs)
Shrimps		107 - 121 MJ/kg

2.9.2 Processing and packaging

The amount of energy used for food processing involves grading, sorting, cooking, preserving, canning and other processes for converting raw products to consumables goods. In high GDP countries, total energy used for food processing and packaging is higher than that in the low GDP countries (FAO, 2011a). The process of converting raw products to secondary food products which use less energy may reduce the energy consumption in food processing (Wallgren and Hojer, 2009). Additionally, changing the food form to a more compact size and improve the technology used for packaging may reduce the energy required for packaging.

Various types of materials can be used within food packaging industry, such as plastic, metal, ceramic, paper and paperboard (Monforti-Ferrario et al., 2015). The impact of the materials (i.e., electricity, petroleum and coal products, plastic products, paper, gas and water) used in food manufacturing process is investigated by Gulati et al. (2013). Their study showed that the electricity has the highest impact on food prices in South Africa.

2.9.3 Transport and distribution

This stage in food supply chain involves the energy requirements to transport fertilisers to farmland, harvested crops to food processing industry and feed to poultry and livestock farms as well as food distribution to retail shops and stores and then to the consumer. Energy used for food transportation increases with importing various types of food from other countries to provide the seasonal food products (Garnett, 2003). In general, energy consumption is more efficient with using large vehicles than private cars. Apart from energy use for food transport, energy is also used for cooling. In Europe, energy is used for cooling approximately one third of food transported by vehicles (Monforti-Ferrario et al., 2015).

A large amount of carbon dioxide and other pollutants is emitted as a result of using fuel to transport food in all its forms (i.e., raw and processed) from farms to the consumer (Iles, 2005). Approximately 80% of the total energy consumption in food supply chain is attributed to the transportation and processing (Pollan, 2006). The energy used for transporting food in Sweden accounts approximately 14% of the total energy consumption within food supply chain (Wallgren and Hojer, 2009).

2.10 Modelling water-energy-food nexus at a city scale

City is the space for diverse activities that consume WEF, such as human daily activities, agriculture and energy generation. These activities incorporate the interactions between WEF. More than half of the world's population are living in cities (UN, 2015). Therefore, the majority of WEF consumption and the generated CO_2 emissions take place in the cities (Rees and Wackernagel, 1996; Beatley, 2012; Brugmann et al., 2014; Bulkeley et al., 2011). In addition to consuming natural resources, cities are also able to convert and reuse resources and play a major role into achieving global sustainability (Rees and Wackernagel, 1996). For example, the Jenfelder Au neighbourhood in Hamburg, Germany mixes black-water (i.e., wastewater from toilets) collected from households with organic waste to generate biogas for household uses (e.g., heating) (Gondhalekar and Ramsauer, 2017).

Greater understanding and consideration of the linkages between WEF (nexus) is one of the sustainable solutions for environmental changes (Leck et al., 2015). Nexus is also an option to achieve integrated urban planning and development, such as using treated domestic wastewater for agriculture and non-potable applications (Hoff, 2011). Previous studies addressed water-energy-food nexus and related governance issues at global and national level while limited attention was given to the city scale (Al-Zu'bi, 2017). The majority of previous studies considered the relationship between two elements and most notably are water and energy (Al-Ansari, 2016).

Regarding water-energy nexus, the most researched side is urban cycle of water. Energy use has been investigated for different water treatment systems, distribution, wastewater collection and treatment (Plappally and Lienhard, 2012; Mo et al., 2014; Nair et al., 2014; Spang and Loge, 2015). Additionally, water use within energy production chain (Tidwell et al., 2009; Perrone et al., 2011; Stillwell et al., 2011; Hussey and Pittock, 2012), and water use or water footprint of biofuels (Gerbens-Leenes et al., 2009; Yang et al., 2009, Delucchi, 2010). However, most overall water-related energy consumption takes place in a household (e.g., for water heating) (Reffold et al., 2008).

Additionally, Bou (2015) developed a basin-scale hydroeconomic model for water management including water-related energy in the entire water cycle using bottom-up approach. The model was applied in California to assess water-energy nexus at residential, urban and city scales. At residential scale, he found that more than 50% of water use is attributed to outdoor uses but most of water-related energy and GHG emissions are attributed to showering and tap uses. At urban scale, Bou found that only 5% of the water-related energy and 6% of GHG emissions in the urban water cycle are attributed to water treatment, pumping and wastewater treatment whereas the rest are related to household water end-uses. Regarding California statewide, he found that agricultural uses account 3.4% of the city water-related energy.

Venkatesh et al. (2014) compared water-energy-carbon nexus in urban water systems of four cities: Nantes, Oslo, Turin and Toronto in France, Norway, Italy and Canada, respectively. They did not include any city from the developing world. To date, analysing integrated systems in the developing countries is more challenging as data are relatively difficult to find (Lundin and Morrison, 2002). Flower et al. (2007) investigated the GHG emissions of Melbourne's urban water system. They found that household water end-uses cause more GHG emissions than the other processes of water supply chain. Shimoda et al. (2010) developed simulation models for a variety of new water heaters. Then, they integrated them into a city scale residential energy end-use model for

Osaka City to evaluate energy conservation and CO_2 emission of water heaters. The study demonstrated that water and energy are interlinked.

Most of the nexus studies have focused on water-energy relationship at residential sector with a little focus on agricultural, commercial and industrial sectors (Bou, 2015). Burt et al. (2003) analysed future energy requirements for pumping surface and groundwater to agricultural sector in California, based on different scenarios. Jackson et al. (2010) explored the impact of changing irrigation method on water use and energy consumption at a field scale in Australia. Zhuang (2014) examined the integrated management options for water and energy resources and their interactions through a system dynamics approach in Tampa Bay region, located on the west central coast of Florida and estuary along the Gulf of Mexico. Their model included domestic, agricultural, commercial and industrial sectors. However, the third element of nexus (i.e., food) was missing from their model. Walker et al. (2013) investigated water-energy nexus within U.S. manufacturing industries: food, beverage and tobacco, wood products, paper, petroleum and coal production, chemicals and primary metals.

Globally, agriculture is the largest water consumer. Water requirements for agriculture account for approximately 70% of the total world fresh water withdrawn from aquifers, streams, and lakes (Lawford et al., 2013) and 85% of global freshwater consumption (Shiklomanov, 2000). Therefore, agricultural sector should not be excluded from nexus study. Although, the role of food system in achieving sustainability objectives (i.e., mitigating GHG emissions and water impact) has been explored, most authors did not capture the interactions between WEF at a city scale (Ramaswami et al., 2017). Goldstein et al. (2016) noted that food demand and its related implications was underestimated in the city scale studies, due to excluding food processing industries and food demand in commercial sector. Food demand for only households (i.e., residential sector) was often captured at a city scale.

Food demand and its related water and energy requirements can be correctly estimated if data are available for food production and processing at a city scale rather than that at a national level (Ramaswami et al., 2017). This is because smaller scale reflects local diets, food demands by socio-economic status of households and local food industries. For example, some cities or regions rely on rainfall for irrigation purposes with much less energy consumption for pumping (Baynes et al., 2011). Punjab, India, produces about 50% of the national output of rice and wheat (Hussain et al., 2010). The serious problem is the replenishment of aquifers slower than water pumping by farmers from aquifers, leading to a drop in water levels in these aquifers (Devineni et al., 2013). Consequently, increased electrical consumption due to greater pumping depths will leading to increased food prices.

Energy use for meat production is high. Of all types of meat, beef has the highest energy inputs (up to 75 MJ/kg) and chicken has the lowest (only 35 MJ/kg). The energy footprints of pork and lamb are 40 MJ/kg and 43 MJ/kg, respectively (Carlsson-Kanyama et al., 2003), reconfirming that a dietary shift from red meat to chicken contributes to a sustainable society.

Water-energy-food nexus approach was applied to illustrate a potential scenario of alternative future urban development in the city of Munich, Germany (Gondhalekar and Ramsauer, 2017). They found that rainwater harvesting with reusing recycled wastewater can save 26% of present supplied freshwater. Additionally, energy recovery from wastewater and organic waste can provide 20% of household electricity demand. However, Gondhalekar and Ramsauer (2017) did not include industrial and commercial sectors uses for natural resources. Regarding food demand, they counted only cabbage, apple and grape grown in the city. Al-Zu'bi and Mansour (2017) discussed the role of green roof systems in reducing energy consumption for heating and cooling, enhancing water management (flood control) and contributing to food security in Arab cities (Cairo in Egypt and Amman in Jordan). Rasul (2016) investigated policy options in South Asia, suggesting that the focus of current policies is for short-term and mainly on increasing food production, without taking into account the impact on water and energy and long-term sustainability.

2.11 System dynamics modelling

There are various ways to categorise modelling approaches depending on the type of use (e.g., forecasting, simulation, optimisation), scale (e.g., local, regional, national, worldwide), conceptual framework (e.g., top-down, bottom-up) and also the availability of data (Herbst et al., 2012). However, nexus is dynamic because the demand for WEF, the connections between nexus elements as well as the factors affect nexus (e.g., human behaviour, pricing, technologies, land-use) change over time (Semertzidis, 2015). Therefore, system dynamics modelling approach is used to deal with the dynamic problems (Kenway, 2013).

System dynamics is a modelling and simulation approach using systems thinking (Assaraf and Orion, 2005; Forrester, 1994). It can capture the interactions between different components within the system, identify the stock-flow relationships, and investigate systems behaviour over time (Draper, 1993; Forrester, 1994; Frank, 2000).

System dynamics modelling was initially applied to industrial and business system management and later expanded to diverse problems (Kelly, 1998). It has been applied for modelling environmental and resources management, water supply, water use and water quality. Simonovic (2002) analysed the relationship between water use and socio-economic factors. Zhang et al. (2008) analysed the impact of planning options on water quality. Madani and Mariño (2009) analysed different policies to reduce water demand and increase supply/demand ratio. The effect of water management options to reduce water scarcity was analysed by Davies and Simonovic (2011).

System dynamics modelling has also been used for modelling energy. For example, Zhen (1992) used system dynamics modelling to predict the energy supply and demand in rural villages in north China. The relationship between electricity supply, resources and pollution is examined in Pakistan by Qudrat-Ullah (2005). Ford (2008) examined the reduction in carbon dioxide emissions with electricity market.

2.12 Conclusions

The key conclusions that can be drawn from the literature review are summarised as below:

- Limited effort has been made for investigating household consumption for WEF, particularly at end-use level in the developing countries, compared to that in the developed countries. The consumption can significantly differ between these countries.
- There is still a lack of knowledge on how household consumption for WEF relates to the demographic and economic characteristics of the household. More importantly, modelling domestic demand for water and energy as a function of household characteristics has not been effectively examined for the developing countries.
- The impact of seasonal variability (summer and winter) on the consumption for WEF at end-use level has not been addressed thoroughly. A few studies have addressed the seasonal variability of household food consumption but the results were inconsistent. Additionally, the seasonal variability impact has not been taken into consideration when modelling the consumption for WEF.
- Although, the household is a unit of demand and it can also be the most appropriate unit for influencing consumption practices, an integrated model capturing the interactions between WEF at end-use level at a household scale is missing. Most of the studies at a household level addressed only two elements of nexus.
- Food processing industries and food demand in a commercial sector have been excluded often in a city scale studies. As a result, food demand and its related implications might be underestimated.

CHAPTER THREE: CASE STUDY AND METHODOLOGY

3.1 Introduction

This chapter details the research methodology adopted in order to achieve the objectives set in Section 1.2. Figure 3.1 presents the layout of the methodology. A description of the case study (Duhok) located in the North of Iraq is provided in Section 3.2.

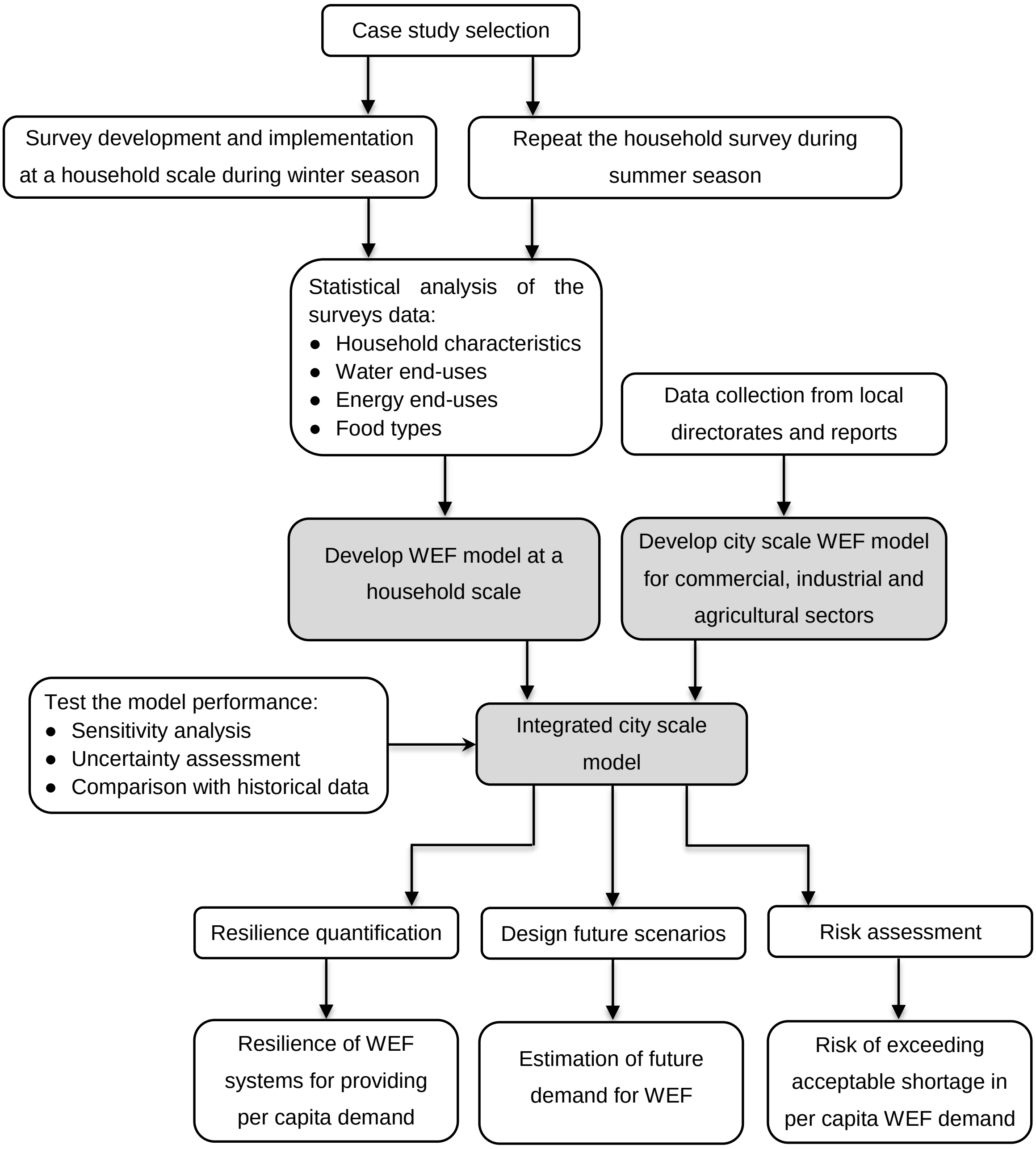


Figure 3.1 Layout of Methodology

The methodology for detailed surveys conducted at a household scale in Duhok is illustrated in Section 3.3. The surveys aimed to collect information on WEF consumption during winter and summer seasons. The statistical analysis used to analyse the survey data and the comparison between both seasonal surveys are presented in Section 3.4. This section also illustrates the statistical modelling techniques used to model daily per capita water and energy consumption as a function of household characteristics.

The steps undertaken to develop a system dynamics-based model capturing the interactions between WEF end-uses at a household scale are presented in Section 3.5. The approach used to model the city scale interactions between WEF in the other sectors (i.e., agricultural, commercial and industrial) is presented in Section 3.6.1 and 3.6.2.

The approaches used to test the performance of the developed models are presented in Section 3.7 and Section 3.8.

Finally, the chapter presents the methodology used to assess the risk and quantify resilience of WEF systems under the impact of seasonal variability (Section 3.9.2 and Section 3.9.5).

3.2 Case study selection

The city of Duhok is located in north western Iraqi Kurdistan between 36º48’ and 36º53’ north latitudes and 42º55’ and 43º0’ east longitudes (Figure 3.2) (Kurdistan Ministry of Planning, 2014). It has a population of around 295,000 inhabitants and spreads over 577 km^2, accounting 0.13% of total area of Iraq (KRSO, 2014). The city witnessed a rapid expansion in the area and growth in the population during the last decades and it has led to further urbanization growth in the city. This is due to the high fertility (5%) and the movement from rural areas to the city (Kurdistan Ministry of Planning, 2014).

Figure 3.2 Location of Duhok, Iraq (Kurdistan Ministry of Planning, 2014)

This city was selected as a case study due to its high growth rate of population and land-use as well as shifting its climate trend toward longer summer season. This put pressure on the demand for WEF. Additionally, the management strategies in the city should shift from a sectoral approach (i.e., manage WEF resources separately) to an integrated approach.

3.2.1 Climate

The climate of Duhok area can be considered as a Mediterranean climate with some variation due to the influence of the surrounding mountains (KRSO, 2014). The annual rainfall occurs mainly in winter and spring (between November and May) with most rainfall concentrated between December and March (approximately 550 mm/y) (Table 3.1). Temperature in the city varies between -2 ºC in winter and 44 ºC in summer as illustrated in Table 3.1 with very low humidity in summer season and relatively deep water table.

Table 3.1 Summary of climate data in Duhok (KRSO, 2014; Mohammed, 2010)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Maximum temperature (ºC)	17	20	26	29	37	42	44	43	41	36	26	22	
Minimum temperature (ºC)	-2	0	2	9	12	19	22	23	15	12	6	1	
Humidity (%)	67	66	64	59	41	22	25	28	30	44	56	69	
Average rainfall (mm/mon)	121	70	53	35	18	9	0	0	3	28	68	109	514
Wind speed (km/hr)	2	3	5	3	3	3	3	3	3	3	2	2	

3.2.2 Water resources

One of the water sources in the city is Duhok earth dam with a storage of 47.5 Million m^3 and a height 60.5 m, which is mainly used for agricultural purposes (Kurdistan Ministry of Water Resources, 2014). Domestic water ($66.1x10^6$ m^3/y) is supplied by the national water supply board through a water supply pipe from Khrabdeem, the main water treatment plant in Duhok (Table 3.2). In addition to the surface water supply, up to 100 wells pump around $8.3x10^6$ m^3/y for domestic use as presented in Table 3.3. Owing to the limited availability of treated water, intermittent supply mode is practiced in Duhok. Water is supplied to households from 3 to 4 times every week with each supply session lasting not more than 6 hr (Duhok Directorate of Water and Sewerage, 2014). People store water in overhead tanks and consume it for different activities including drinking.

Table 3.2 Average daily water supply to domestic sector in Duhok (Duhok Directorate of Water and Sewerage, 2014)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Khrabdeem water treatment plant supply (m^3/d)	158328	161976	162552	171502	186672	191640	209640	212136	210000	183500	165600	158400
Groundwater supply (m^3/d)	19820	20000	20490	21170	22770	23680	25730	26190	25730	23680	22770	21200

Table 3.3 Average daily groundwater abstraction in the city of Duhok for different end-uses (Duhok Directorate of Groundwater, 2012)

	Domestic	Industrial	Agricultural	Livestock
Number of groundwater wells	169	11	185	9
Groundwater supplied (10^6 m^3/y)	8.3	0.75	12	0.5

3.2.2.1 Water treatment and distribution

The treatment process varies according to the water source. In order to supply potable water to the city of Duhok, raw water is pumped from the Tigris River through a 2 m diameter pipe to a height of 30 m for treatment in Khrabdeem plant (Duhok Directorate of Water and Sewerage, 2014). The surface water intake source is located adjacent (200 m) to the treatment plant. The treatment process in Khrabdeem plant comprises the following stages (Figure 3.3):

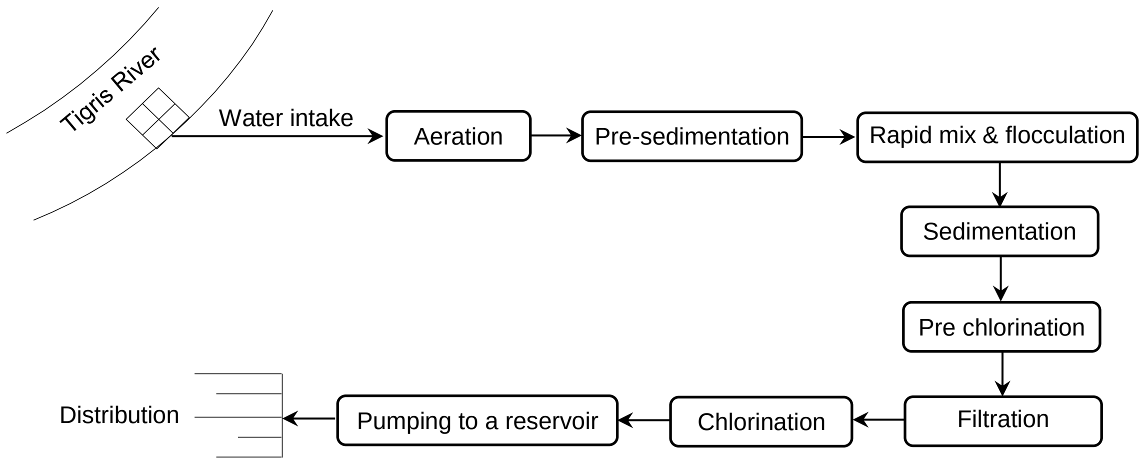


Figure 3.3 Water treatment stages in Khrabdeem water treatment plant

The treated water is pumped with a discharge 10500 m^3/hr from Khrabdeem plant to Sumail water reservoir (15000 m^3) for adding chlorine again. The conveyance distance from Khrabdeem water treatment plant to Sumail reservoir is 29 km. After the final treatment process in Sumail reservoir, the potable water is pumped to Masiek collection reservoir (25000 m^3) in Duhok, which is located 11 km from Sumail reservoir. The pumping elevation from Khrabdeem water treatment plant to Masiek reservoir in the city is 720 m. Finally, the potable water is distributed to the city by gravity system. Some other reservoirs are also supplied with potable water from Masiek reservoir to supply some towns, such as Sharia, Domez and Faida as shown in Figure 3.4.

Potable water is distributed to the city by water supply pipelines for 3 to 4 sessions per week with duration of supply varies between 4 and 6 hours per session. People are required to store water in overhead tanks.

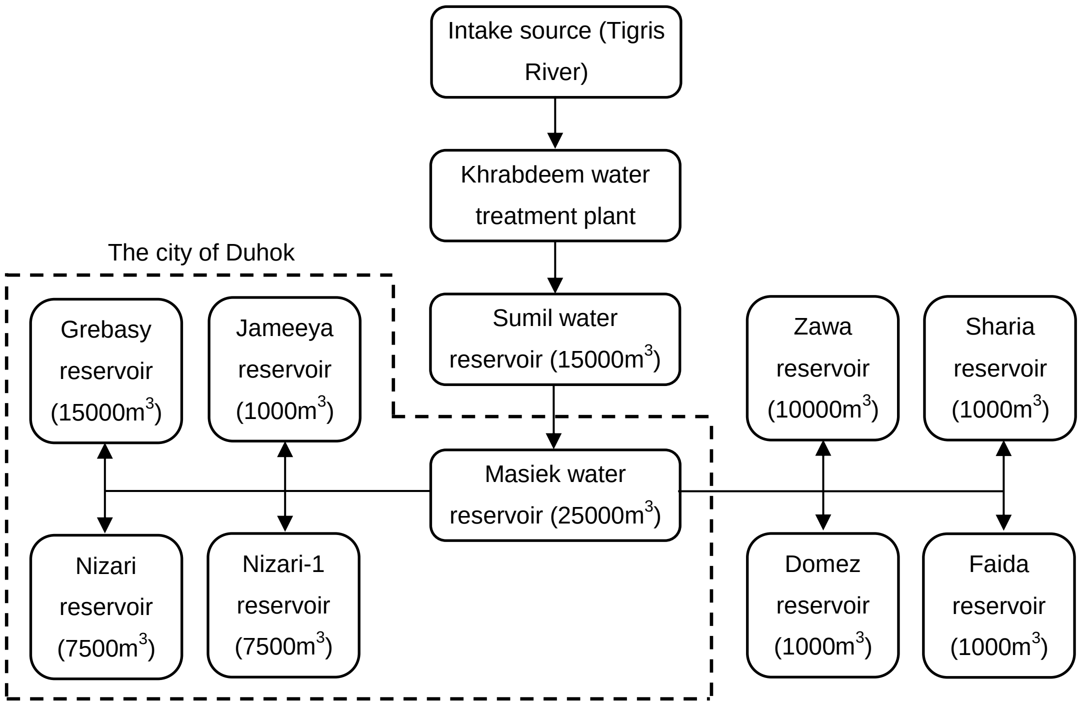


Figure 3.4 Water distribution system in Duhok

3.2.2.2 Energy for water treatment and pumping

Electricity consumption for pumping water and treatment process at Khrabdeen treatment plant to obtain 1.0 m^3 of drinking water is shown in Table 3.4. Energy required for pumping water from water source to Khrabdeem water treatment plant and to the storage reservoir is calculated using Equation 3.1 (Cheng, 2002). The quantity of energy required for treatment process in Khrabdeem treatment plant is estimated by Duhok Directorate of Water and Sewerage (2014). Table 3.4 clearly shows that the highest energy consumption within water supply chain is attributed to the pumping process.

$$E_p = \frac{Q \times \gamma \times H}{\epsilon} \qquad 3.1$$

where:

E_p= energy required for pumping water (kW),

Q= pumping flow rate (m^3/s),

γ= specific weight of water (9.81 kN/m^3),

H= the depth/height of water to be pumped (m), and

ϵ= pump efficiency (%) (Range between 74–85 % for large pumps (Faour, 2001)).

Table 3.4 Energy consumption for pumping and treatment process in Duhok

Surface water conveyance and treatment process in Duhok		Electricity consumption (kWh/m^3)
Conveyance	from water source to Khrabdeem treatment plant	0.082
Water treatment process	Aeration	0.060
	Pre-sedimentation	0.056
	Aluminum	0.006
	Rapid mix	0.196
	Flocculation	0.057
	Chlorination at Khrabdeem water treatment plant	0.001
	Filtration	0.000
	Backwash pumping	0.078
	Sludge pumping	0.026
	Chlorination at Sumail reservoir	0.001
	Water treatment subtotal	0.483
Pumping	from Khrabdeem plant to the storage reservoir in Duhok	1.962
Total energy consumption in all processes		2.527

3.2.3 Energy sources

The main energy sources in the city of Duhok are electricity, kerosene and liquefied petroleum gas (LPG). They are mainly consumed in four different sectors: domestic, commercial, agricultural and industrial. However, the dominant use of energy is in the domestic sector, accounting approximately 80% of the total electricity consumption in the city as shown in Table 3.5 (General Directorate of Duhok Electricity, 2014). The major sources for electricity generation for the whole Duhok governorate are three diesel fuel power stations, which are Kashi, Baadre and 29 MW with a generation capacity 1000, 150 and 29 MW/hr, respectively, and energy losses account approximately 36% of the total supplied electricity (General Directorate of Duhok Electricity, 2014).

Table 3.5 Summary of electricity consumption in all sectors in Duhok (General Directorate of Duhok Electricity, 2014)

Sector	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Domestic (%)	83.1	76.6	82.4	83.8	83.5	80.3	78.4	77.0	82.3	72.3	77.7	77.5
Government (%)	6.62	14.7	9.17	7.99	6.73	8.64	7.82	9.13	6.05	12	7.32	6.61
Commercial (%)	9.5	8.1	7.7	7.5	8.9	10.0	12.2	12.0	10.7	13.4	13.9	15.2
Industrial (%)	0.5	0.4	0.5	0.4	0.6	0.5	0.7	1.3	0.4	0.9	0.5	0.5
Agricultural (%)	0.2	0.1	0.2	0.2	0.3	0.6	0.9	0.6	0.5	1.3	0.6	0.2
Energy supplied (MW/hr)	222	218	180	130	138	168	198	203	176	118	146	235

3.2.4 Food sources

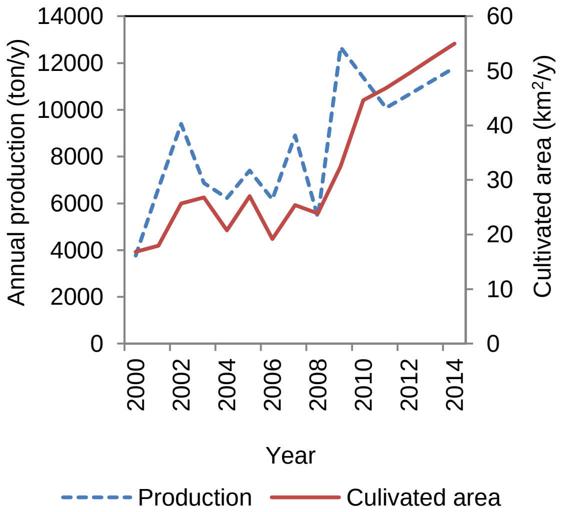
The area of rain-fed (158 km^2) and irrigated (30 km^2) arable land in Duhok represents approximately 32% of the total area of the city (Kurdistan Ministry of Agriculture, 2014), which can be used to grow a range of crops and achieve the food requirements. The arable land is unable to meet the existing city demand. A considerable fraction of food is imported due to the population growth, increase living standards, farmers' migration to the urban areas and water shortage for irrigation.

The total number of groundwater wells used for irrigation purposes accounts approximately 50% of the total number of groundwater wells in the city (Table 3.3). For livestock requirements, approximately 0.5x10^6 m^3/y is pumped from 3% of groundwater wells in the city (Duhok Directorate of Groundwater, 2012).

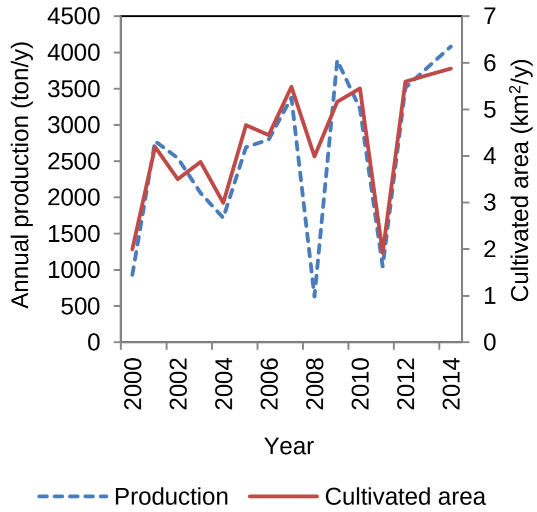
Figure 3.5 shows the production pattern for different types of crops in Duhok. The figure shows an upward cultivation trend for cereal grains (i.e., wheat and barley). Table 3.6 shows different crops and respective land used for their production (Kurdistan Ministry of Agriculture, 2014). The table shows that the most efficient utilization of land is for vegetables (i.e., eggplant).

40% of the total demand of oilseeds and pulses (e.g., lentil, chickpea and bean) is met by imports from abroad (Jaradat, 2003). The decrease in the pulses production can be due to their low yield (Figure 3.5) and high cost attributed to manual harvesting. For this reason, there is a shift toward more cultivation for cereal grains (Figure 3.5) which are harvested mechanically and have lower cost than pulses.

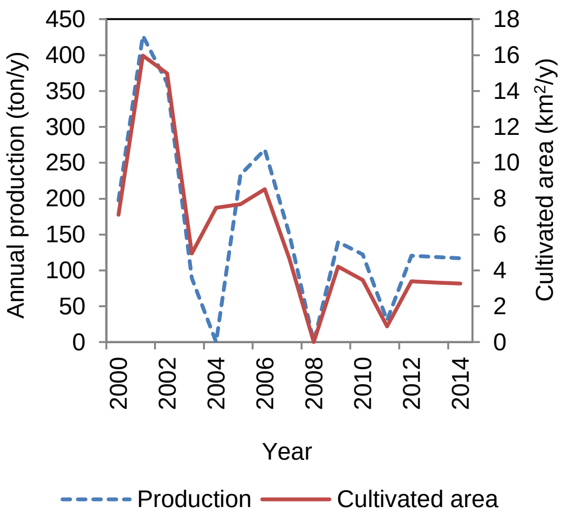
In terms of vegetables and fruits production, approximately 20% of the total cultivated area (18 km^2) in the city was exploited for growing varied crops in 2013 (Table 3.6). The highest produced fruits and vegetables were melon and tomato. In line with the increase in vegetables and fruits production in the city from approximately 13,000 tons in 2008 to 13,400 tons in 2013, the imported



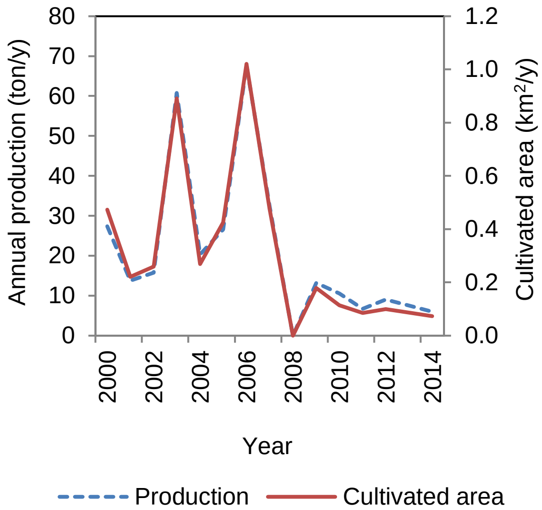
a. Wheat



b. Barley



c. Chickpea



d. Lintel

Figure 3.5 Trends of annual production and cultivated area of different types of crops in Duhok (Kurdistan Ministry of Agriculture, 2014)

quantity in Kurdistan region has also significantly increased from 384,000 to 923,000 tons (Kurdistan Ministry of Agriculture, 2014). The highest imported quantity was attributed to tomato and cucumber, accounting approximately 20 and 10% of the total imported vegetables and fruits, respectively.

Table 3.6 Annual production and cultivated area of all crops in the city of Duhok (KRSO, 2014)

year		2012				2013			
type	crop	production (ton)	cultivated area (Iraqi donam)	cultivated area (km^2)	yield (ton/km^2)	production (ton)	cultivated area (Iraqi donam)	cultivated area (km^2)	yield (ton/km^2)
cereal grains	wheat	11232	20909	52.27	214.9	11806	21999	55.00	214.7
	barley	3798.0	2296	5.74	661.9	4083.7	2352	5.88	694.6
pulses	chickpea	119.0	1332	3.33	35.6	117.0	1306	3.27	35.8
	lentil	7.5	36.0	0.09	87.5	6.0	29	0.07	82.8
vegetables and fruits	melon	4813.0	2928.0	7.32	657.5	6334.4	4574	11.44	553.9
	tomato	2171.0	605.0	1.51	1435.4	3143.9	827	2.07	1520.7
	water melon	606.0	202.0	0.51	1200.0	750.0	252.5	0.63	1188.1
	green onion	642.0	236.0	0.59	1088.1	655.5	280.0	0.70	937.1
	squash	264.0	87.0	0.22	1213.8	548.3	151.5	0.38	1446.9
	eggplant	440.0	118.0	0.30	1491.5	544.1	123.5	0.31	1761.9
	cucumber	137.0	91.0	0.23	602.2	381.7	220	0.55	694.5
	string beans, green	174.0	115.0	0.29	605.2	200.7	134.5	0.34	597.8
	green pepper	64.0	21.0	0.05	1219.0	91.3	27.5	0.07	1323.6
	okra	39.0	17.0	0.04	917.6	58.5	23	0.06	1026.1
	sunflower	0.0	0.0	0.00	0.00	17.2	36	0.09	188.9
	potato	0.0	0.0	0.00	0.00	9.6	2	0.005	1920
	green gram	0.0	0.0	0.00	0.00	2.4	16	0.04	60.0
	other vegetables					646	417	1.04	619.7

Available statistical figures for Duhok governorate in 2010 indicated that the number of sheep, goat, cow and buffalo was 722, 294.5, 52 and 0.5 thousand head, respectively (Kurdistan Ministry of Agriculture, 2014). The number of poultry and livestock facilities for meat and protein production in the city is shown in Table 3.7. In 2014, the production in Kurdistan region was approximately 69 thousand tons of poultry and 66 thousand tons of mutton; however, the consumption in the whole region was much higher (i.e., 110, 105 and 13 thousand tons of mutton, poultry and fish, respectively) than the produced quantity (Kurdistan Ministry of Agriculture, 2015).

Table 3.7 Summary of poultry farms and livestock facilities in the city of Duhok (Kurdistan Ministry of Agriculture, 2014)

Details	No. of facilities	Details	No. of facilities
The number of broiler	20	Calves fattening	1
Hatcheries	1	Sheep fattening	1
Poultry slaughter houses	1	Feed factory	1
Sheep and goat projects	4	Livestock slaughter houses	1
Cow projects	1		

3.2.5 Food waste

The dominant waste from a household in Duhok is food (e.g., peelings, trimmings, eggshells, bones, tea bags, food left uneaten and expired food), accounting approximately 30% of the total solid waste per capita (Table 3.8) (Duhok Directorate of the Municipalities, 2014). The total organic waste (e.g., food, plants and animal remains) is approximately 50% of the total household solid waste. The proportion of organic waste from the household in Duhok is higher than the average value in the low-income countries (41%) and it’s lower than that in the middle-income countries (58%) (UNDESA, 2010).

The average per capita solid waste in Duhok is approximately 400, 500 and 600 g/p/d in low, medium and high income areas (Duhok Directorate of the Municipalities, 2014). This is lower than the per capita solid waste in Baghdad (1110 g/p/d (Dheyaa, 2002)) and similar to the recorded value in Mosul city (540 g/p/d (Youseif, 1988)).

Table 3.8 Summary of disaggregated solid waste from household in Duhok (Duhok Directorate of the Municipalities, 2014)

Household waste type	Food	Other organic matters	Plastic	Metal	Glass	Paper	Textile	Rubber	Other
%	30	20	8	4	2	3	2	1	30

3.3 Data collection of water-energy-food consumption

3.3.1 Survey design

A detailed survey was prepared in the native language (Kurdish). The overall number of questions included in the survey was over 300. A multiple-choice format was used to answer some of the questions. Household characteristics, such as number of children, elders, adult males and females, household type, total built-up area, garden area, number of rooms, number of floors and monthly income were surveyed. The survey aims to collect information on WEF consumption at end-use level at a household. The full questionnaire is shown in Appendix A.

Water consumption of a household

In addition to the household characteristics, the survey was included over 40 questions regarding the frequency, duration of use and flow rate of each water-end-use (e.g., showering, bathing, hand wash basin tap usage, toilet flushing, dishwashing, clothes washing, cooking, garden watering, house floor washing, vehicle washing and swimming pool).

Energy consumption of a household

The survey included 85 questions to capture the energy consumption in a household. These questions were aimed to get information on the ownership level, duration of use and wattage of all appliances in each energy end-use (e.g., space heating, lighting, cooking, refrigeration, electronic and wet appliances).

Food consumption of a household

Furthermore, 179 questions regarding food consumption in a household were also included. An open format with numerical response was used to answer most of the questions. The questions were aimed to provide information on the frequency of cooking and consumed quantity of each type of food (e.g., cereal grains, meat, dairy, roots and tubers, vegetables and fruits, oilseeds and pulses, oils and fats and sugar). As well as the duration and water used for the cooking session of each food commodity.

3.3.2 Survey implementation

The survey was distributed to 419 selected households in Duhok, in February 2015 (Figure 3.6). The replies were received from 407 households.

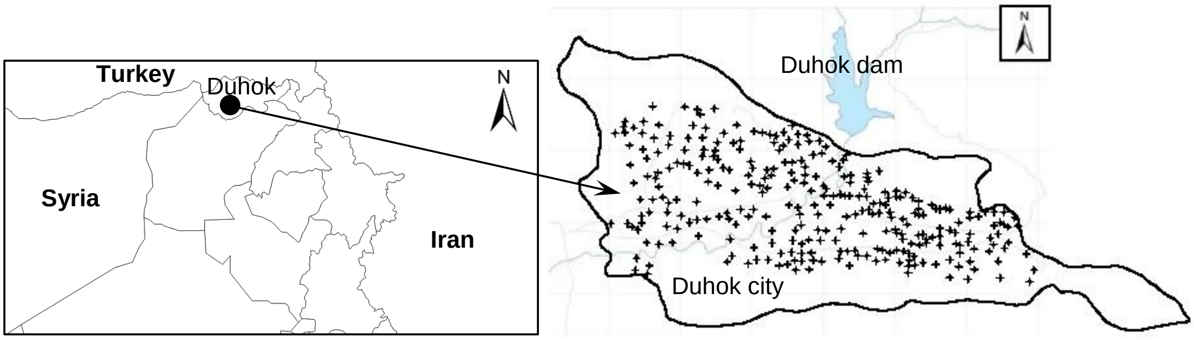


Figure 3.6 The distribution of surveyed households in the city of Duhok

3.3.3 Seasonal variation

In order to capture the seasonal variability of WEF consumption, the full survey explained in Section 3.3.1 was repeated in summer season in June 2015 (Appendix A). The summer survey is conducted in the same sample of households which were selected for winter survey. This is to ensure consistency of data and also to eliminate variations between samples due to the occupant's behaviour and household characteristics. The summer survey was distributed to 419 households and the answers received from 404 households.

Information were collected on all parameters of WEF end-uses. Additionally, water consumption by evaporative air-cooler was also recorded. Moreover, all energy end-uses in summer survey were similar to that in winter, except space heating appliances (i.e., electrical heater, kerosene heater and air-conditioner) which were replaced with space cooling appliances (i.e., fan, evaporative air-cooler and air-conditioner).

3.4 Survey analysis

3.4.1 Statistical analysis

The analysis of the collected data for WEF was performed using IBM SPSS Statistics (v. 22) package and included estimation of statistical parameters (i.e., average, median, standard deviation, minimum, maximum and distribution shape identification through kurtosis and skewness) for the characteristics of the surveyed households.

3.4.2 Impact of income on WEF consumption

In Iraq, a household socio-economic survey was conducted by Central Statistical Organisation (CSO) and Kurdistan Region Statistics Office (KRSO) in 2012. In the Iraqi survey, the monthly family income was divided into three groups (Table 3.9). This classification was based on the average family size of 6.7 persons. The last column in Table 3.9 shows per capita income for respective household groups and has been obtained by dividing the household income by the average family size. Using per capita figures of column three, the surveyed 407 households were divided into three income groups (Table 3.10).

Table 3.9 Income groups classification for Iraq (CSO and KRSO, 2012)

Income group	Income range in Iraqi Dinar (ID)	
	Per household	Per capita
Low	$<1x10^6$	$<15x10^4$
Medium	$1x10^6 – 2x10^6$	$15x10^4 – 30x10^4$
High	$>2x10^6$	$>30x10^4$

Table 3.10 Number of surveyed households at different income groups

Income group	Low	Medium	High
Number of households	92	176	139

Each income group was analysed separately to identify the influence of variation in income on the household WEF consumption.

3.4.3 Seasonal variability of WEF

To examine the seasonal variability of WEF end-uses, the frequency distribution and cumulative frequency of per capita average consumption are calculated for winter and summer surveys. Furthermore, a two-tiled t-test is used at 95% confidence interval. This test shows that there is no statistically significant difference between the consumption in winter and summer season when p value is higher than 0.05. In contrast, the difference is statistically significant if p value is less than 0.05.

3.4.4 Statistical modelling of per capita consumption with household characteristics

The analysed data of daily per capita consumption for water and energy from the 407 households was divided into calibration and validation sets. 70% of the data was used for calibration (i.e., training), while the remaining 30% was spared for validation (i.e., testing) purposes. The calibration data set was used to develop statistical models to predict per capita consumption as a function of household characteristics. The household characteristics were divided into two groups, that is:

- Demographic characteristics: number of children, elders, adult males and adult females.
- Physical characteristics: total household built-up area, garden area, number of rooms, number of floors and per capita income.

Two different techniques were used to build regression models in order to identify the models which are computationally efficient and provide reliable predictions. The two techniques applied are: multiple linear regression (STEPWISE) and evolutionary polynomial regression (EPR). These techniques have been used for modelling the water related applications (Haque et al., 2013; Doglioni et al, 2010) and achieved good results. These regression methods are explained in Section 3.4.4.1 and 3.4.4.2.

3.4.4.1 Multiple linear regression (STEPWISE) based models

Multiple linear regression technique has been used widely to explore the relationship between the dependent and several independent variables (Abdul-Wahab et al., 2005). The technique is looking for the combination of relevant independent variables to construct the best fit model based on strong statistical foundations. One of the multiple regression techniques is STEPWISE, which is a potential approach for selecting the best combination of independent variables (Cevik, 2007).

The STEPWISE multiple regression approach is applied using IBM SPSS Statistics (v. 22) software to determine the best subset model for daily per capita water and energy use estimation. Using the calibration set of data, the relationships between the independent variables (household characteristics) and the dependent variable (per capita consumption) were investigated and the values of correlation coefficient (R) are calculated. The selection or deletion of an independent variable for the regression model is based on the strength of relationship (i.e., the magnitude of the correlation coefficient) and also its contribution to the decrease of the residual sum of squares (Cevik, 2007). The regression coefficients and model are then statistically tested at the every iteration to select or delete the independent variable. The statistical testes are:

- The ANOVA (F-test) to examine the significance of the regression model. The model is statically significant when $p<0.05$, which means the overall regression model is a good fit for the independent variables entered in the model (Yasar et al., 2012).
- The t-test to examine the significance of the regression coefficients. The regression coefficients are statistically significant (i.e., different to zero) if $p<0.05$ (Yasar et al., 2012).

3.4.4.2 Evolutionary polynomial regression (EPR) based models

The evolutionary polynomial regression (EPR) is a modelling technique which combines the effectiveness of genetic algorithm with numerical regression to develop mathematical model expressions (Giustolisi and Savic, 2009). This technique has been used in a number of other applications, such as evapotranspiration process (El-Baroudy et al., 2010), rainfall-groundwater dynamics (Doglioni et al., 2010), water distribution and wastewater networks (Berardi et al., 2008), and have shown good performance.

The EPR MOGA-XL tool[1] (ver.1), which performs multi-objective genetic algorithm search for plausible models, is used to develop the models for daily per capita water and energy use estimation. The two objective functions that were used for the evolutionary search by EPR are:

- The minimization of the number of terms, and
- Maximization of the accuracy of the model to calibration set (i.e., minimization of the summation of square errors) (Giustolisi and Savic, 2009).

Various mathematical nonlinear expressions were chosen to model per capita water and energy consumption as a function of household characteristics (i.e., independent variables). However, the results of simple mathematical structure (Equation 3.2 in the EPR MOGA-XL tool) were the best in most cases. For each mathematical model, the candidate exponents for the independent variables (*ES*) and the maximum number of terms are selected through experimentation. The bias term is considered as zero. Finally, the number of generations within genetic algorithm is selected as 400.

$$Y = a_0 + \sum_{j=1}^{np} a_j \times f\left\{(X_1)^{ES(j,1)} \dots\dots (X_k)^{ES(j,k)}\right\} \qquad 3.2$$

where:

Y = the EPR estimated water/energy consumption,

a_0 = the bias term,

np = the total number of polynomial terms,

a_j = the coefficients of j_{th} polynomial term,

$f(X)$ = the polynomial function constructed by EPR,

ES = the matrix of unknown exponents, and

X_k = the k_{th} independent variable (household characteristics).

[1]http://www.hydroinformatics.it/index.php?option=com_docman&Itemid=105

3.5 Modelling WEF at a household scale

Figure 3.7 shows the structure of the developed dynamic simulation model for WEF at a household scale. A bottom-up approach was used to develop the model, comprising the interactions between WEF at end-use level. This approach has become very common for modelling sustainable livelihood issues at a household, city and national scales (Biggs et al., 2015). This approach helps to understand the contribution of each end-use in the total consumption. Furthermore, it is the only option to investigate the impact of new interventions and technologies on consumption (Swan and Ugursal, 2009). An end-use based model can identify the end-use with highest resource consumption. Therefore, the proposed model can support the development of retrofitting programs and prioritisation schemes for resource efficient devices.

The key variables of this model are population growth, family size and the impact of seasonal variability on WEF consumption. Another key variable is the impact of household income (i.e., low, medium and high) on WEF consumption. Many aspects of WEF are addressed in this model, such as, the generated wastewater and food waste from a household (Figure 3.7). The model also calculates the consumption of individual end-use of WEF.

The model components have over 300 variables in total and a simplified version of the model components is presented in Figure 3.7. The values of all input variables and parameters into the model depend on the trend and pattern of WEF end-uses for the particular region. The detailed explanation of these variables and the mathematical equations which describe the relationships between WEF are explained in Sections 3.5.1 to 3.5.5.

System dynamics modelling has been used to model environmental and water systems at various scales (Simonovic, 2002; Stave, 2003; Kojiri et al., 2008; Khan et al., 2009; Qi and Chang, 2011; Mereu et al., 2016). This particular model has been coded using SIMILE[2] modelling environment. SIMILE is a system dynamics modelling (SDM) software. The reason for using SIMILE in

[2] http://www.simulistics.com/

this work is its ability to model the interactions between various system components and capture the changes in the system behaviour over time. Additionally, SIMILE is able to host sub-models and simplify the complex process of interactions between the variables (Vanclay, 2014). The causal-loops between various model components are shown in Figure 3.8.

Within the developed model, stocks represent the accumulated change of a system component (e.g., family size and percentage of each income group (low, medium and high)). Flows represent the amount of increase or decrease in the family size and each income group. The factors that affect the system are represented as convertors, such as duration of winter and summer season, variation in the size of each income group, and the parameters that impact WEF end-uses (Section 3.5.1 to 3.5.5).

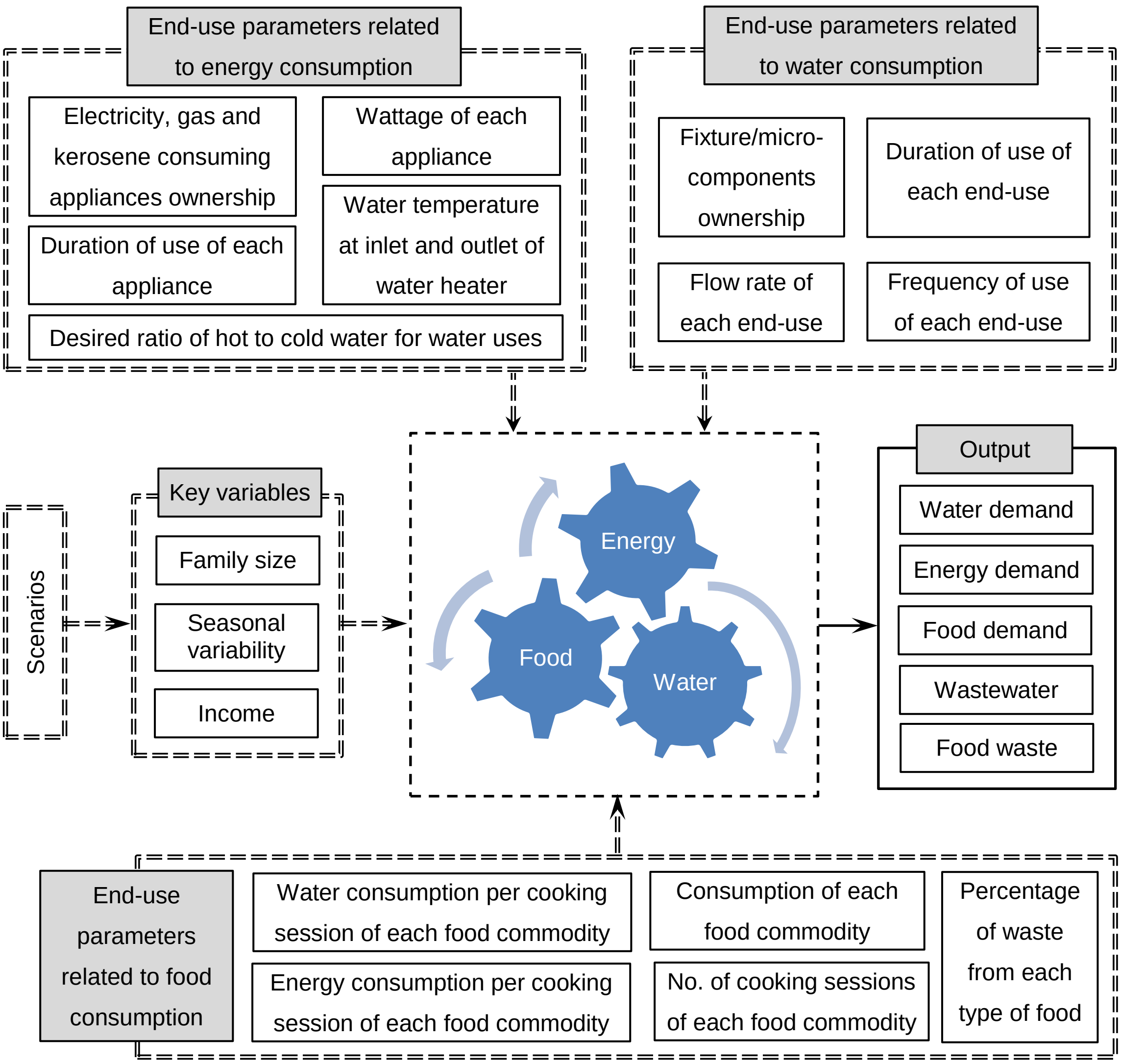


Figure 3.7 The structure of water-energy-food model at a household scale

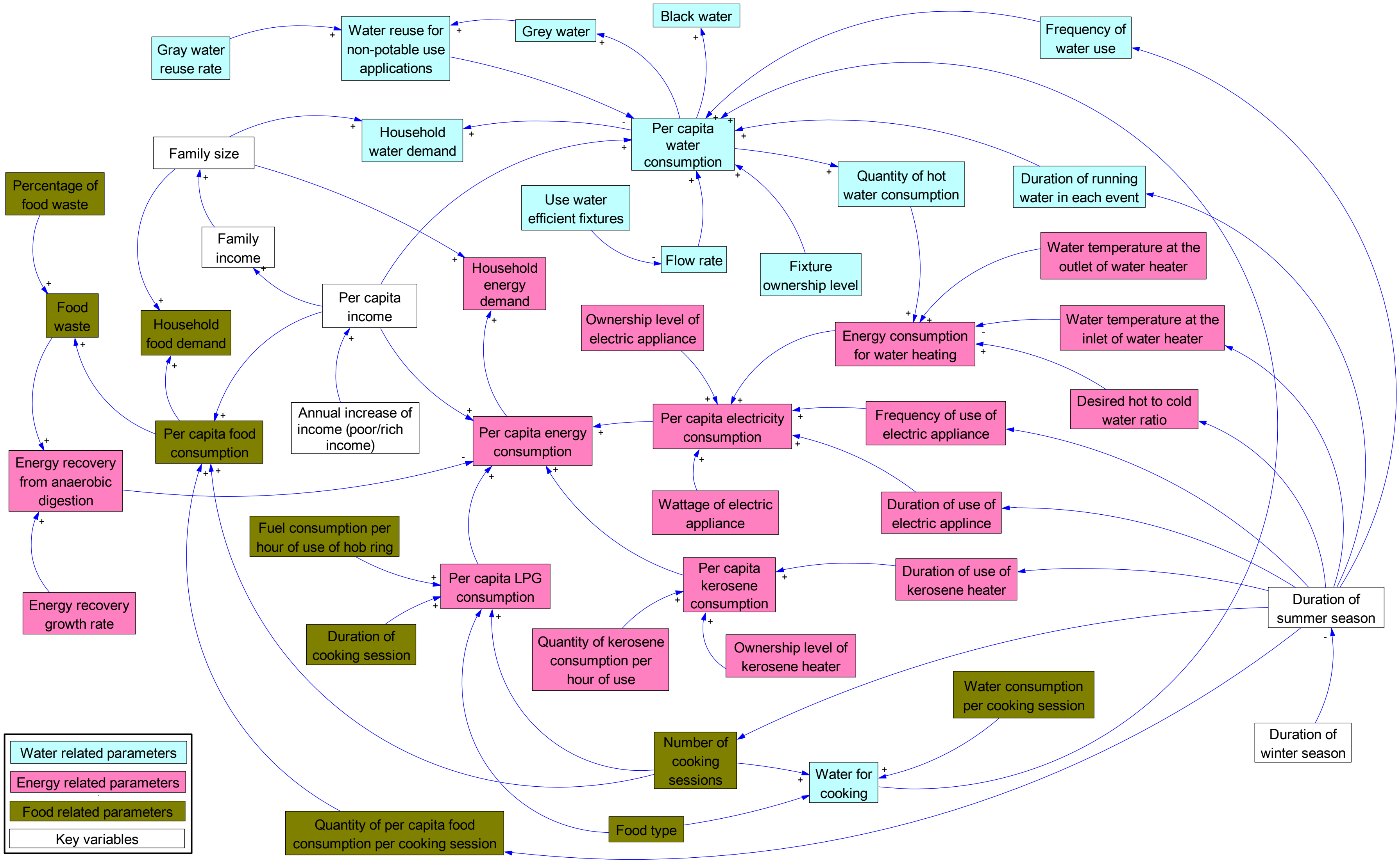


Figure 3.8 Relationship between water-energy-food parameters and key variables at a household scale

3.5.1 Modelling of household water consumption

Within the WEF model, household water consumption is disaggregated into various end-uses: showering, bathing, hand wash basin tap use, toilet flushing, dishwashing, clothes washing, cooking, house floor washing, vehicle washing, garden watering, and swimming pool. The model captures the influence of human behaviour for water end-uses, through involving the parameters of water end-use into the model. For example, the frequency of use and the duration of water run during each event of water use are included. The model involves also the flow rate of water end-use and the ownership level of water use fixtures and appliances (i.e., clothes washer, dishwasher and bathtub). Using these parameters in Equation 3.3, the quantity of water consumption of each water end-use (showering, hand wash basin tap use, manual dishwashing, cooking, house floor washing, vehicle washing and garden watering) can be calculated. Equation 3.4 has been used to quantify water consumption for clothes washing, toilet flushing and bath. The model also calculates black and grey water collected from a household as shown in Figure 3.9, using Equation 3.5 and 3.6.

$$We_{ii} = Fe_{ii} \times De_{ii} \times Re_{ii} \qquad 3.3$$

$$We_{ii} = Fe_{ii} \times Ve_{ii} \qquad 3.4$$

where:

We_{ii}= daily per capita average consumption for water end-use *ii* (l/p/d),

Fe_{ii}= daily per capita average frequency of water end-use *ii* (number of events/p/d),

De_{ii}= duration of water run during each event of water end-use *ii* (min/event),

Re_{ii}= average flow rate of water end-use *ii* (l/min), and

Ve_{ii}= quantity of water consumption during each event of water end-use *ii* (l/event).

$$WW_{grey} = WW_b + WW_{sh} + WW_{hw} + WW_{cw} \qquad 3.5$$

$$WW_{black} = WW_{dw} + WW_c + WW_{tf} + WW_{fw} + WW_{vw} \qquad 3.6$$

where: WW=wastewater, b=bathing, sh=showering, hw=hand wash basin tap use, cw= clothes washing, dw=dishwashing, c=cooking, tf=toilet flushing, fw, house floor washing, vw=vehicle washing.

Figure 3.9 shows the interactions between WEF end-uses at a household scale. The direction of an arrow shows water or energy consumption associated with each end-use. These interactions are addressed in the developed model. For instance, the energy consumption for water heating, water for space cooling (i.e., evaporative air-cooler), wet appliances (i.e., water pump, dishwasher, clothes washer), water and energy use for cooking and energy for food preservation.

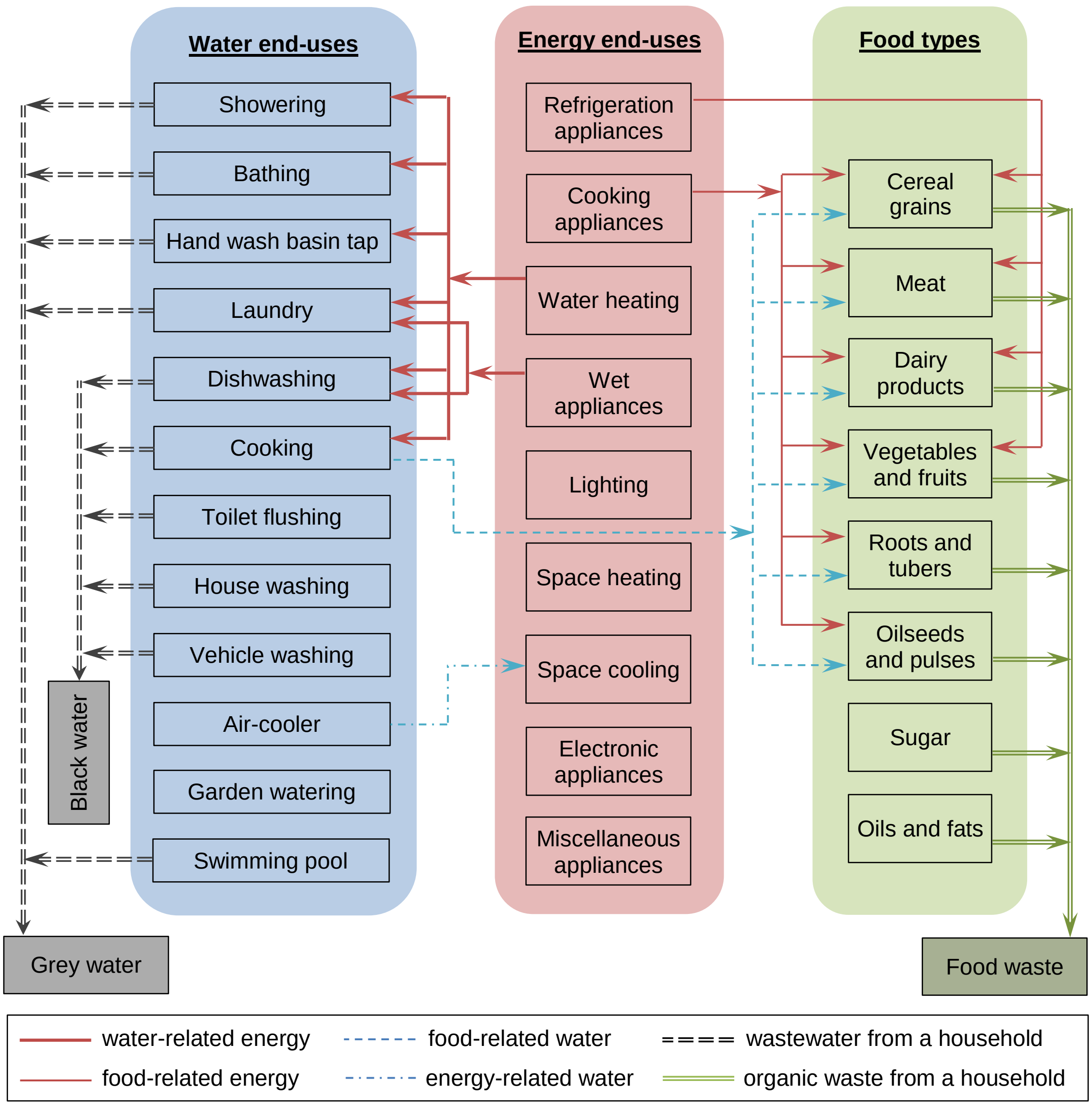


Figure 3.9 Modelling the interactions between WEF end-uses at a household scale

3.5.2 Modelling of household energy consumption

The household energy consumption (i.e., electricity, kerosene and LPG) is divided into several end-uses: space heating, water heating, lighting, and refrigeration, wet, electronic, cooking and miscellaneous appliances. Each energy end-use comprises different types of appliances, with the same purpose of use as listed in Table 3.11. The model involves the appliances presented in this table. The calculation of energy consumption in the developed model for water heating and other appliances is explained in Section 3.5.2.1 to 3.5.2.3.

Table 3.11 Summary of energy end-uses and the related appliances

Energy end-use		Appliances
Electricity end-uses	Space heating	Air-conditioner, electrical heater, kerosene heater, gas heater.
	Space cooling	Air-conditioner, evaporative air-cooler, fan.
	Lighting	Spot lights, tube lights.
	Wet appliances	Water pump, dishwasher, clothes washer.
	Refrigeration appliances	Chest-freezer, fridge-freezer.
	Electronic appliances	TV, radio, computer, video record, CD/DVD player, Video games.
	Miscellaneous appliances	Hair dryer, vacuum cleaner, sewing machine, iron.
	Cooking appliances	Electric hob, electric oven, electric kettle, microwave oven, toaster.
Kerosene and gas end-use appliances		Kerosene heater, kerosene hob, gas heater, gas hob and gas oven.

3.5.2.1 Energy consumption for water heating

Different types of energy (e.g., electricity, kerosene, and LPG) can be used for household water heating for various uses (i.e., bathing, showering, hand washing basin, laundry, dishwashing, and cooking). The amount of energy consumed for water heating depends on the household composition, inflow and outflow water temperature and fuel type (Aguilar et al., 2005). Another factor is wattage and efficiency of water heater (Isaacs et al., 2004). Additionally, energy consumption for water heating may vary with the seasons and climate (Goldner, 1994). Energy consumption for daily water heating can be calculated using a specific heat formula (Equation 3.7) (Gettys et al., 1989) as given below.

$$E_h = Q_h \times \rho \times S \times (T_{out} - T_{in})/3600 \qquad 3.7$$

where:

E_h = daily per capita energy consumption for water heating (kWh/p/d),

Q_h = daily quantity of hot water consumption per capita (m^3/p/d),

ρ = density of water (1000 kg/m^3),

S = specific heat capacity of water = 4.186 kJ/kg ºC,

T_{out} = water temperature at the heater outlet (ºC),

T_{in} = water temperature at the heater inlet (ºC), and

3600= conversion factor (from kJ to kWh).

Swan (2010) assumed that the delivered water temperature, T_{out}, is 55 ºC and T_{in} is equal to the annual average soil temperature. In order to achieve the preferred tap water temperature (40 ºC), it is assumed that 50% of the water used requires heating (i.e., bathing, showering, hand wash basin tap use, dishwashing, laundry and cooking) (Kenway et al., 2008; Fidar, 2010). For the case study in this paper, the average temperature of water supply (T_{in}) is approximately 12 ºC during the cold season (Duhok Directorate of Seismology and Meteorology, 2015). The average water temperature at the outlet of heater (T_{out}) is taken as 62 ºC, based on the survey findings.

The average per capita hot water consumption can be calculated based on the proportion of hot water required for each indoor end-use. Using the proportional value of per capita hot water consumption and Equation 3.7, the per capita electricity consumption for water heating can be calculated. In this study, the proportion of hot water is assumed to be 50% of the household water used for bathing, showering, hand wash basin tap use, dishwashing, laundry and cooking (Figure 3.10). The model is flexible to accommodate any hot to cold water ratio considering various climatic conditions in different regions of the world.

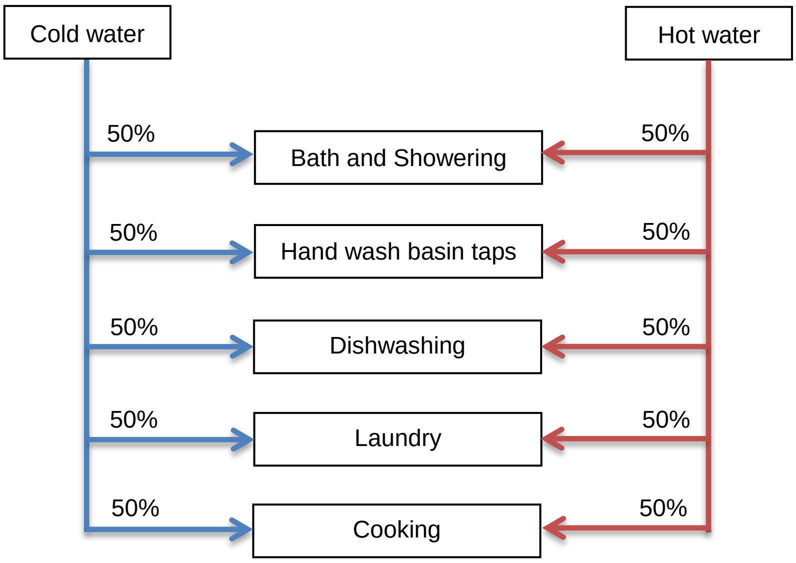


Figure 3.10 Summary of proportions of hot water required for each end-use

3.5.2.2 Energy consumption of electric appliances

To calculate the energy consumption of electric appliances, the energy consumption of each appliance is assumed to remain constant throughout its entire operating hours. The energy consumption of each appliance in use in a household is modelled as a function of ownership level (e.g., number of air-conditioners in use in a household), duration of use and wattage. Using these parameters and Equation 3.8, the energy consumption of each appliance presented in Table 3.11 can be calculated as below.

$$Ea_k = Na_k \times Da_k \times Wa_k \tag{3.8}$$

where:

Ea_k = daily per capita average energy consumption of appliance *k* (kWh/p/d),

Na_k = average ownership level of appliance *k* per household,

Da_k = daily per capita average duration of use of appliance *k* (hr/p/d), and

Wa_k = average wattage of appliance *k* (W).

In the developed WEF model, wattage values for appliances in Table 3.11 are based on the survey findings.

3.5.2.3 Kerosene and LPG consumption

In addition to the electricity consumption, the WEF model calculates household consumption for other types of energy uses, such as kerosene and LPG. Equation 3.9 is used to calculate per capita kerosene and LPG consumption for space heating. The energy consumption for food preparation is explained in Section 3.5.3.2.

$$\mathrm{E}_s = N_s \times D_s \times Q_s \tag{3.9}$$

where:

E_s = daily per capita average kerosene/LPG consumption for space heating (l/p/d),

N_s = average number of kerosene/LPG heaters in use in a household,

D_s = daily per capita average duration of use of kerosene/LPG heater (hr/p/d), and

Q_s = quantity of kerosene/LPG consumption by each heater per hour (l/htr/hr).

3.5.3 Modelling of household food consumption

Household food consumption is disaggregated into several groups: cereal grains, meat, dairy products, vegetables and fruits, roots and tubers, oilseeds and pulses, oils and fats, and sugar. Each food group comprises various commodities as shown in Table 3.12. The food commodities presented in this table are included in the WEF model. The daily per capita consumption of each of these food commodities is modelled as a function of the number of cooking sessions per day and the quantity of food consumed per cooking session (Equation 3.10).

In order to calculate the energy and water consumption for food preparation (Figure 3.9), the model included some other parameters, such as, the quantity of water and energy consumption per cooking session of each food commodity (Figure 3.7). The calculation of water and energy consumption for food preparation and generated food waste is explained in the following Sections (3.5.3.1 to 3.5.3.3).

Table 3.12 Summary of food groups and related food commodities

Food groups	Commodity
Cereal grains and products	Wheat flour, rice, burgul & jareesh, buns, cake, biscuits, macaroni & vermicelli
Meat	Chicken & turkey, sheep & goat, bovine, fish & seafood
Dairy products	Yogurt, cheese, egg, milk, butter
Roots and tubers	Potato, onion, carrots, garlic, radish
Vegetables	Tomato, cucumber, aubergine, courgette, okra, lettuce, sweet pepper, celery
Fruits	Water melon, orange, apple, melon, grape, pumpkin, banana
Oilseeds and pulses	Bean, chick pea, lentil
Oils and fats	Vegetable oils, animal fats
Sugar	Sugar

Note: Milk and oil consumption is modelled in l/p/d

$$F_r = (Nc_r/7) \times Fc_r \qquad 3.10$$

where:

F_r = daily per capita consumption of food commodity *r* (g/p/d),

Nc_r = number of cooking sessions of food commodity *r* per week (cs/w), and

Fc_r = average quantity of per capita consumption of food commodity *r* per cooking session (g/p/cs).

3.5.3.1 Water use for food preparation

The quantity of water consumption for food preparation is modelled as a function of number of cooking sessions per week and water consumption per cooking session (Equation 3.11). The model requires these parameters for each food commodity presented in Table 3.12. Using these parameters in Equation 3.11, the daily per capita water consumption for cooking each type of food can be calculated.

$$W_r = (Nc_r/7) \times Wc_r \qquad 3.11$$

where:

W_r = daily per capita average water consumption to prepare food commodity *r* (l/p/d),

Nc_r = average number of cooking sessions of food commodity *r* per week (cs/w), and

Wc_r = per capita average water consumption in each session of washing and cooking food commodity *r* (l/p/cs).

3.5.3.2 Energy use for food preparation

For each food commodity in the food consumption survey (Table 3.12), the number of cooking sessions per household per week and the duration of using hub ring in each session are surveyed (Appendix A). The collected data are used with Equation 3.12 to calculate the total duration of using hob ring per household.

$$Td = \sum_{r=1}^{z} \frac{Nc_r}{7} \times \frac{Dc_r}{60} \qquad 3.12$$

where:

Z = total number of food commodities consumed at a household,

Td = total duration of use of hob ring for food preparation per day (hr/hh/d),

Nc_r = number of cooking sessions of food commodity *r* per week (cs/w), and

Dc_r = duration of cooking session of food commodity *r* (min/cs) (Table E4.1 in Appendix E4).

The quantity of daily LPG consumption for food preparation is calculated using the number of days each gas cylinder lasts (Equation 3.13). These data are collected in the energy consumption survey (Appendix A). The capacity of each pressurized LPG cylinder supplied to the households is 26.2 l (Kurdistan Ministry of Natural Resources, 2015).

$$LPG_d = {}^{V_c}/_{N_d} \qquad 3.13$$

where:

LPG_d = daily LPG consumption for cooking purposes (l/hh/d),

V_c = LPG cylinder size (i.e., 26.2 l), and

N_d = number of days each gas cylinder lasts (d).

Using the results of Equation 3.12 and Equation 3.13, the quantity of LPG consumption per hour of using hob ring for cooking purposes (LPG_h) can be calculated as shown in Equation 3.14. In these calculations, the size of the hob ring used for cooking every type of food is assumed to be the same in all households.

$$LPG_h = \frac{LPG_d}{Td} \tag{3.14}$$

Finally, for each surveyed food commodity, the quantity of LPG consumption per cooking session is calculated using Equation 3.15. This equation uses the duration of cooking session of each food commodity and the calculated values from Equation 3.14.

$$LPG_{cs,r} = \frac{Dc_r}{60} \times LPG_h \tag{3.15}$$

where:

$LPG_{cs,r}$ = LPG consumption per cooking session of food commodity *r* (l/cs).

For modelling household energy consumption for food preparation, Equation 3.16 can be used. The required parameters in this equation are fuel consumption per hour for using hob ring (calculated using Equation 3.14) and the parameters values collected from the survey (i.e., Nc_r and Dc_r). Using these parameters for each food commodity (Table 3.12) in Equation 3.16, the energy consumption for food preparation can be calculated in the WEF model.

$$LPG_r = (Nc_r/7) \times (Dc_r/60) \times LPG_h \tag{3.16}$$

where:

LPG_r = daily average LPG consumption to prepare the food commodity *r* (l/d),

Dc_r = duration of cooking session of the food commodity *r* (min/cs), and

LPG_h = LPG consumption per hour of using hob ring for cooking purposes (l/hr).

3.5.3.3 Food waste from household

In each step of the food supply chain (production, processing, distribution and consumption), the percentage of food waste for each type of food is estimated by FAO (2011b), for different world regions. Table 3.13 shows the percentages of food waste for each type of food during the consumption step of food supply chain in different regions. The table shows that food waste at a consumption step in Sub-Saharan Africa, South and Southeast Asia is very low, compared to the other regions of the world. Using these percentages in Equation 3.17, the quantity of food waste from a household can be calculated in the WEF model.

The calculated food waste is influenced by the quantity of per capita food consumption, which is a function of household income and seasonal variability. The values in Table 3.13 can be used in the developed model to quantify food waste in the regions of interest.

Table 3.13 Percentage of waste from various types of food within the consumption step of food supply chain (FAO, 2011b)

Region	Cereal grains	Meat	Fish and sea food	Dairy products	Roots and tubers	Vegetables and fruits	Oilseeds and pulses	Oils and fats	Sugar
Europe including Russia	25	11	11	7	17	19	4	0	0
North America and Oceania	27	11	33	15	30	28	4	0	0
Industrialised Asia	20	8	8	5	10	15	4	0	0
Sub-Saharan Africa	1	2	2	0.1	2	5	1	0	0
North Africa, west and central Asia	12	8	4	2	6	12	2	0	0
South and Southeast Asia	3	4	2	1	3	7	1	0	0
Latin America	10	6	4	4	4	10	2	0	0

$$FW_r = PFW_r \times F_r \qquad 3.17$$

where:

FW_r = quantity of waste from food commodity *r* (g/p/d), and

PFW_r = percentage of waste from food commodity *r* (%).

3.5.4 Impact of income on WEF

Income and wealth can be a major factor influencing per capita WEF consumption. Kriström (2008) stated that income is the key driver for household energy consumption, reflecting increased affordability with an increase in income. Per capita water consumption also increases with the increase in household income (Willis et al., 2013). Although, other factors, such as occupant’s age, education level and house size can have a marginal impact on resources consumption (Hewitt and Hanemann, 1995; Grafton et al., 2011), the major consumption influencing factors are household income and seasonal variability (Anker-Nilssen, 2003; Okutu, 2012; Palmer et al., 2013). Therefore, the developed model investigates the impact of household income on WEF consumption.

The households are divided into three income groups (i.e., low, medium and high) based on the classification of CSO and KRSO (2012) (Table 3.9). Based on this classification, the parameters relating to WEF end-uses, which are presented in Section 3.5.1 to 3.5.3, are classified and defined in the model for each income group, individually. The values assigned to these parameters are derived from the two surveys conducted as discussed in Section 3.3. The input parameter values are presented in Table 4.9, Table 5.10 and Table 6.3. Consequently, the model estimates WEF consumption for low, medium and high income households.

3.5.5 Impact of seasonal variability on WEF

The household energy consumption varies seasonally due to changes in the energy requirements for space heating and cooling (Lam et al., 2008). Svehla (2011) showed a significant seasonal variation in refrigeration, cooking and the use of some other appliances. Most studies assumed that indoor water consumption, except for evaporative air-cooling, remains unchanged throughout the year (Rathnayaka et al., 2015). However, in addition to garden watering, swimming pool and evaporative air-cooling, indoor water end-uses do vary seasonally. An example is showering, which increases in summer (Rathnayaka et al., 2015).

The WEF model captures the impact of seasonal variability on the consumption of WEF at a household scale. In order to achieve this, modifications were made for different end-uses.

To estimate water consumption during the summer season, evaporative air-cooler end-use is added to the other water end-uses which are presented in Section 3.5.1. Consequently, the annual per capita average water consumption can be calculated using Equation 3.18.

$$TW_i = d_{w,i} \times \sum We_w + d_{s,i} \times \sum We_s \qquad 3.18$$

where:

TW_i = annual per capita total water consumption during year *i* (l/p/y),

We_w = daily per capita average water consumption by each end-use (Figure 3.9) during winter season (l/p/d),

We_s = daily per capita average water consumption by each end-use (Figure 3.9) during summer season (l/p/d),

$d_{w,i}$ = duration of winter season in year *i* (d), and

$d_{s,i}$ = duration of summer season in year *i* $(= 365 - d_{w,i})$ (d).

In terms of energy consumption during the summer season in the WEF model, the space heating appliances are replaced with space cooling appliances (i.e., fan, evaporative air-cooler and air-conditioner) (Table 3.11). Equation 3.19 is used in the WEF model to calculate the annual per capita energy consumption for each income group.

$$TE_i = d_{w,i} \times \sum Ee_w + d_{s,i} \times \sum Ee_s \qquad 3.19$$

where:

TE_i= annual per capita total energy consumption during year *i* (kWh/p/y),

Ee_w= daily per capita average energy consumption by each end-use (Figure 3.9) during winter season (kWh/p/d), and

Ee_s= daily per capita average energy consumption by each end-use (Figure 3.9) during summer season (kWh/p/d).

Similarly to Equation 3.18 for water and Equation 3.19 for energy, the model calculates the seasonal variability of food consumption and also the water and energy use for food preparation. This is achieved by using the parameters of each food commodity for each income group during winter and summer seasons. The parameters influencing consumption and their respective values for different seasons and income groups are available in Table 4.9, Table 5.10 and Table 6.3.

3.5.6 Family size

The analysis of our conducted survey (Section 3.3) strongly suggests that Duhok family size is influenced by family income. Therefore, in the WEF model, the impact of a family size (*FS*) is addressed as a function of increase/decrease in the family income (Equation 3.20).

$$FS = \sum_{g=1}^{3} P_g \times FS_g \qquad 3.20$$

where:

P_g= percentage of households in income group *g (g=low, medium and high*), and

FS_g= average family size of the income group *g*. FS_g values are constant as derived from the conducted survey and are shown in Table 3.14.

Table 3.14 Impact of income on average family size in Duhok, Iraq

Income group	Average family size
Low	4.82
Medium	7.10
High	8.45

3.6 Modelling water-energy-food at a city scale

The city scale model has been developed to quantify WEF demand for the following sectors:

- Domestic
- Agricultural
- Commercial
- Industrial

The WEF demand modelling for household scale in domestic sector is explained in the previous section (Section 3.5). This section focuses on the remaining sectors.

3.6.1 Model development for agricultural sector

3.6.1.1 Water requirements for irrigation purposes

Crop water requirement is the quantity of water needed to meet the water losses through evapotranspiration (FAO, 2005). The quantity water requirement for irrigation depends on the climate condition, crop type and its growth stage. Equations 3.21 and 3.22 can be used to calculate the quantity of irrigation water required for growing (i.e., from planting to the harvest stage) any type of crops under a specific climate conditions (Zhuang, 2014). Theses equations are used in the WEF model to quantify the total irrigation water requirements for various types of crops.

$$IWR = \sum_{c=1}^{n} \sum_{m=1}^{12} \left(ET_{c,m} - ER_m \right) \times A_c \qquad 3.21$$

$$ET_c = ET_o \times K_c \qquad 3.22$$

where:

$IWR =$ annual total irrigation water requirement for growing *n* crops (m^3/y),

$ET_{c,m} =$ water use for crop *c* during month *m* (crop evapotranspiration) (mm/mon),

$ER_m =$ effective rainfall during month *m* in the investigated region (mm/mon),

$A_c =$ cultivated land for crop c (km^2),

$ET_o =$ monthly reference evapotranspiration for the region under investigation (Equation 3.23) (mm/mon), and

$K_c =$ the crop c coefficient (unitless) (explained below).

Reference evapotranspiration (ET_o)

Reference evapotranspiration (ET_o) and crop coefficient (K_c) are the parameters required to calculate crop evapotranspiration (ET_c) (Equation 3.22). The Penman-Monteith method (Equation 3.23) can be used to determine the monthly average values of ET_o for the region under investigation (Allen et al., 1998). The impact of climate (i.e., air temperature, humidity, sunshine hours and wind speed) on evapotranspiration is incorporated into this method.

$$ET_{\circ} = \left[\left(\Delta (R_n - hf) + \rho_a C_p \frac{(e_s - e_a)}{r_a} \right) \Big/ \left(\Delta + \gamma \left(1 + \frac{r_s}{r_a} \right) \right) \right] / \lambda \qquad 3.23$$

where:

$\Delta =$ slope of saturation vapour pressure temperature relationship (kPa/°C),

$R_n =$ net radiation (MJ/m^2d),

$hf =$ soil heat flux (MJ/m^2d),

$\rho_a =$ mean air density at constant pressure (kg/m^3),

$C_p =$ specific heat of the air (MJ/kg°C),

$e_s - e_a =$ mean vapor pressure deficit of the air (kpa),

$\omega =$ Psychrometric constant (kPa/°C),

$r_s =$ the canopy surface resistance (s/m),

$r_a =$ aerodynamic resistance (s/m), and

$\lambda =$ latent heat of vaporization (KJ/kg).

Using Equation 3.23 directly will require information on all the above mentioned parameters. The region specific values for the parameters are embedded in CROPWAT 8.0 software[3]. Using climatic condition data for Duhok (Table 3.1), the monthly reference evapotranspiration ET_o has been calculated with CROPWAT 8.0 software as shown in Table 3.15. Then, a crop coefficient (K_c) is applied to adjust the calculated ET_o value for the type of crop (c) under consideration.

Table 3.15 Estimated monthly ET_o values for Duhok

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_o (mm/month)	37	42	81	102	158	192	208	192	147	102	54	40

Crop coefficient (K_c)

Crop coefficient (K_c) takes into account the crop type and its development stages. There may be several crop coefficients used for a single crop throughout an irrigation season depending on the crop's stage of development. Crop growth period is divided into four distinct growth stages: initial, crop development, mid-season and late season (Allen et al., 1998). The length of each of these stages depends on the climate, latitude, elevation and planting date in the region under investigation (Van der Gulik and Nyvall, 2001).

The values of K_c for each type of crop are collected from Food and Agriculture Organization report (Allen et al., 1998) and then analysed with *CROPWAT 8.0* software to provide adjustment for local climate conditions. Duhok climate data (Table 3.1) are used in *CROPWAT 8.0* software to determine the values of K_c in each growth stage for the crop under consideration. The K_c values are calculated for each crop grown in Duhok region and are shown in Table 3.16.

[3] http://www.fao.org/nr/water/infores_databases_cropwat.html

Table 3.16 Summary of crop coefficient K_c values (unitless) for different crops in Duhok

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alfalfa			0.59	1.16	0.47							
Barley	0.78	1.07	1.08	1.13	0.55						0.30	0.60
Beans	0.85	1.16	1.09	1.04	0.50						0.20	0.49
Cabbage	0.85							0.69	0.73	0.88	1.06	1.01
Grape		0.17	0.45	0.91	1.01	1.01	0.94	0.66	0.13			
maize				0.31	0.66	1.14	1.16	0.65				
Potato			0.29	0.71	1.10	1.04	0.31					
Sunflower			0.20	0.55	1.02	1.06	0.42					
Sweet melon			0.29	0.65	0.99	1.01	0.31					
Tomato			0.59	0.85	1.10	1.11	0.67					
Wheat	0.77	1.08	1.10	1.15	0.78	0.16					0.29	0.58

3.6.1.2 Energy requirements for irrigation purposes

Equation 3.1 is used in the WEF model to calculate the energy required for pumping water for irrigation purposes. The collected data from Duhok Directorate of Groundwater (2012) were used to calculate the average values of pumping flow rate.

3.6.2 Model development for commercial and industrial sectors

Gross domestic product (GDP) is the key measure for estimating the future demand for water and energy in commercial and industrial sectors (Kirtlan, 2009). The GDP is usually used to measure the growth rate of industrial sector (Shen et al., 2010). The correlation is linear between growth in GDP and industrial water demand in both developing and developed countries (Yamada and Otaki, 2006; Shen et al., 2010). A linear relationship between GDP growth rate and gas demand is used to forecast the annual future demand in commercial and industrial sectors (GNI, 2014). Kirtlan (2009) applied the same approach to estimate the future electricity demand in New Zealand. Moreover, water demand for industrial commodities in different regions of the world is estimated as a function of GDP growth rate (Ercin and Hoekstra, 2014).

Figure 3.11 shows the relationship between GDP values and energy consumption for commercial and industrial sectors in Duhok from 1999 to 2013.

The data in this figure are collected from General Directorate of Duhok Electricity (2014) and World Bank Group[4]. The results in this figure are consistent with those of Yamada and Otaki (2006); Shen et al. (2010); GNI (2014). It shows that the linear correlation is strong between GDP growth and energy consumption in both sectors. Additionally, with low GDP (i.e., less than 60 Billion USD), there is a slight variability in electricity demand for industrial sector.

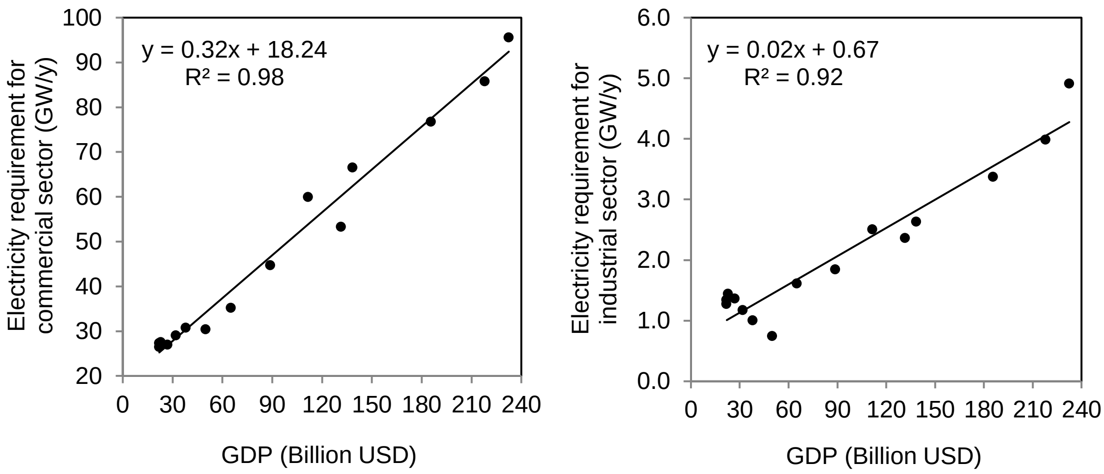


Figure 3.11 Relationship between GDP and energy consumption in commercial and industrial sectors in Duhok

Considering a linear relationship between GDP and resources consumption, the annual future water and energy requirement for industrial and commercial sectors can be calculated using Equation 3.24 to Equation 3.27. The commercial sector is divided into a number of subsectors (Table 3.17) to account for the variation in water and energy demand between the subsectors. Similarly, the industrial sector is disaggregated into various industries/subsectors (Table 3.18).

$$W_{com,i} = \sum_{u=1}^{k} \frac{GDP_i}{GDP_p} \times W_{p,u} \qquad 3.24$$

$$W_{ind,i} = \sum_{u=1}^{k} \frac{GDP_i}{GDP_p} \times W_{p,u} \qquad 3.25$$

[4] http://www.tradingeconomics.com/iraq/gdp

$$E_{com,i} = \sum_{u=1}^{k} \frac{GDP_i}{GDP_p} \times E_{p,u} \quad 3.26$$

$$E_{ind,i} = \sum_{u=1}^{k} \frac{GDP_i}{GDP_p} \times E_{p,u} \quad 3.27$$

where:

$W_{com,i}$ = annual future water requirements for commercial sector in year *i* (m^3/y),

$W_{ind,i}$ = annual future water requirements for industrial sector in year *i* (m^3/y),

$E_{com,i}$ = annual future energy requirements for commercial sector in year *i* (MW/y),

$E_{ind,i}$ = annual future energy requirements for industrial sector in year *i* (MW/y),

GDP_p = current gross domestic product (Billion USD),

GDP_i = gross domestic product in year *i* of the investigated period (Billion USD),

$W_{p,u}$ = the present demand for water in subsector *u* (m^3/y),

$E_{p,u}$ = the present demand for energy in subsector *u* (MW/y), and

k = number of subsectors.

The current water and energy consumption in commercial and industrial sectors is shown in Table 3.17 and Table 3.18, respectively. An equation similar to Equation 3.24 is used in the model to estimate the future demand for food in commercial sector in the city. Food is disaggregated into various commodities as presented in Table 3.19.

Table 3.17 Water and energy consumption in commercial and public subsectors in Duhok (KRSO, 2014)

Commercial subsectors	Water demand (1000 m^3/y)	Electricity demand (MW/y)	Kerosene Demand (m^3/y)	LPG demand (m^3/y)
Hotels, motels and restaurants	75.8	10693	1808	248
Schools, colleges and institutions	2291.8	18693	2337	0
Hospitals	80.8	12391	708	53
Retail shops	1712.9	39967	0	0
Offices and companies	293.5	7338	734	0
Commercial centres and malls	1939.8	9699	0	0
Other types of commercial buildings	40.3	1208	0	0

Table 3.18 Water and energy demand in industrial subsectors in Duhok (KRSO, 2014)

Type of industry		Water demand (m^3/y)	Electricity demand (MW/y)	Fuel demand (m^3/y)
Food industry	Dairy products	3660	30.7	23
	Cereal grains grinders	4392	515.3	357
	Bakery	231312	896.3	2747
	Beverage	65880	1024.8	769
Wool and fur		1464	24.9	7.3
Sewing industry		0	193.3	113
Carpentry		0	1.8	2.6
Printing house		45750	287.3	46
Plastics made products industry		48312	224.0	92
Cement and concrete industry		294264	1320.5	9244
Mining industry		22692	567.3	522
Other industries		38064	344.8	240

Table 3.19 Food consumption in commercial sector in Duhok (KRSO, 2014)

Food type	Food consumption (ton/y) in 2009	Food type	Food consumption (ton/y) in 2009
Rice	50	Oils and fats	37
Egg	189800 [a]	Tomato	14
Chicken	45	Flour	36
Fish sea	1.5	Bean	10
Mutton	37	Lintels	12
Dairy	11	Chickpea	14
Potato	15	Fruits	9
Sugar	23	Vegetables	72

[a] number of eggs

3.6.3 Water treatment and pumping

Energy requirements for water treatment are calculated in the WEF model using the quantity of total demand for potable water in domestic, commercial and industrial sectors and the average energy consumption for treatment 1 m^3 of raw water. Energy required for treatment process in the city of Duhok is 0.483 kWh/m^3 of raw water (Table 3.4). The energy required for pumping potable water in the city (E_p) is calculated using Equation 3.1.

3.6.4 Integrated city scale WEF model

The developed models capturing the interactions between WEF in domestic, agricultural, commercial and industrial sectors (Section 3.6.1 to 3.6.3) are integrated together to represent a city scale model. This is using the standard average family size (3.20) from the household WEF model with the population size (i.e., population size divided by average family size) to represent the domestic sector in Figure 3.12. The outputs from the household level model (i.e., wastewater and food waste) are treated as an input to the city scale model to quantify city scale WEF consumption for domestic sector. Figure 3.12 shows the interactions between WEF at a city scale. Total water and energy demand for the city are calculated using Equation 3.28 and Equation 3.29, respectively.

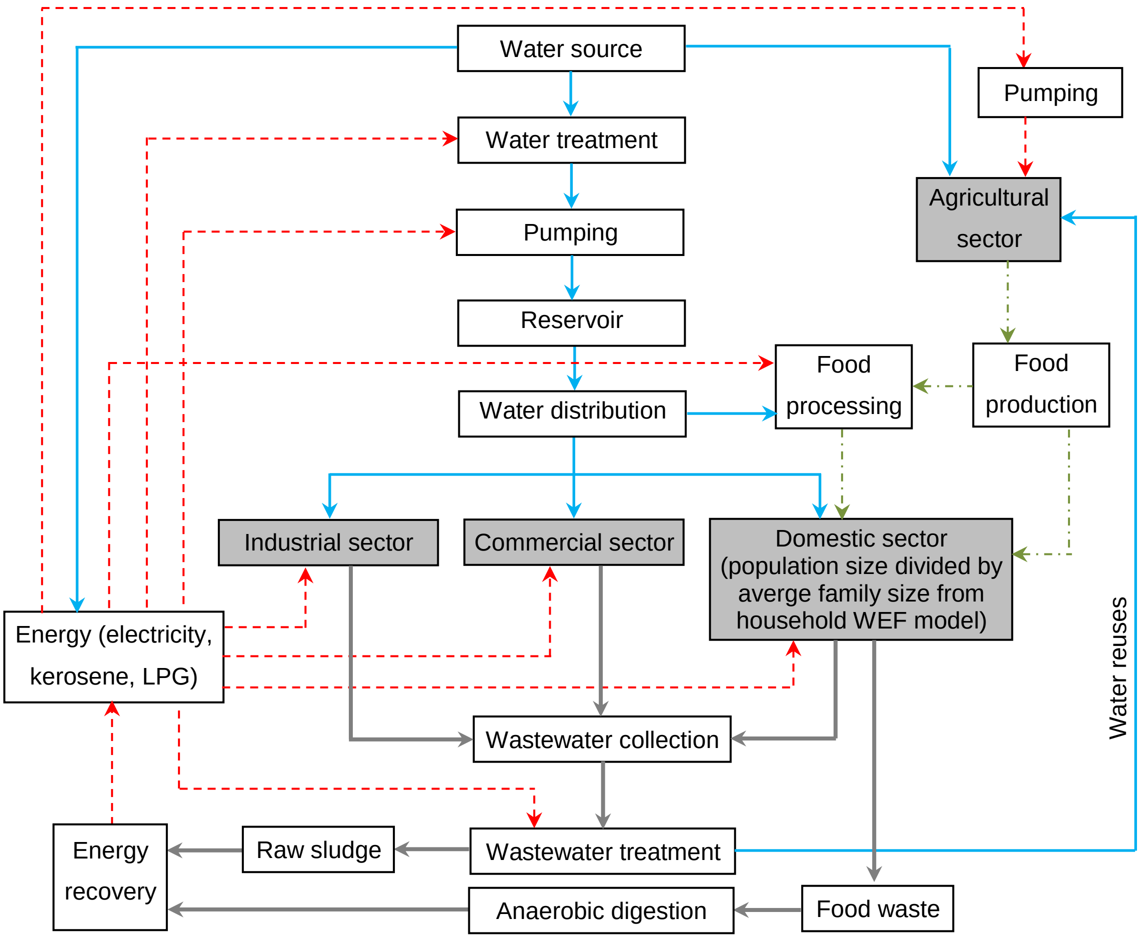


Figure 3.12 WEF interactions at a city scale

$$W_{cit} = W_{dom} + IWR + W_{com} + W_{ind} \quad 3.28$$

where:

W_{cit}= annual total water consumption for the city (m^3/y),

W_{dom}= total water consumption for domestic sector (m^3/y) (calculated using

Equation 3.18 and population size),

IWR= annual total water requirements for irrigation purposes (m^3/y) (calculated using Equation 3.21),

W_{com}= annual total water requirements for commercial sector (m^3/y) (calculated using Equation 3.24), and

W_{ind}= annual total water requirements for industrial sector (m^3/y) (calculated using Equation 3.25).

$$E_{cit} = E_{dom} + E_{com} + E_{ind} + (W_{dom} + W_{com} + W_{ind}) \times \frac{e_{wt}}{1000} + E_p + [WW_{dom} + \alpha \times (W_{com} + W_{ind})] \times \frac{e_{ww}}{1000} \quad 3.29$$

where:

E_{cit}= annual total energy consumption for the city (MW/y),

E_{dom}= annual total energy consumption for domestic sector (MW/y) (calculated using Equation 3.19 and population size),

E_{com}= annual total energy requirements for commercial sector (MW/y) (calculated using Equation 3.26),

E_{ind}= annual total energy requirements for industrial sector (MW/y) (calculated using Equation 3.27),

e_{wt}= energy required for treatment of 1 m^3 of raw water (kWh/m^3). 1000 is for converting kW to MW,

E_p= total energy requirements for pumping water to all sectors (MW/y) (calculated using Equation 3.1),

WW_{dom}= annual total wastewater generated in domestic sector (m^3/y) (Equation 3.5 and Equation 3.6 with population size),

α= friction of water that appears as wastewater (assumed to be 0.8), and

e_{ww}= energy required for treatment of 1 m^3 of wastewater (kWh/m^3).

Figure 3.13 shows the structure of the developed dynamic simulation model for WEF at a city scale. This figure presents the key variables and the parameters required to estimate the demand for WEF in each sector. Moreover, the outputs from the developed model are shown in the figure. The model has been coded using SIMILE[5] modelling environment. SIMILE is a system dynamics modelling software that is used for modelling the interactions between various system

[5] http://www.simulistics.com/

components and capturing the changes in this system behaviour over time. SIMILE is selected for its ability to host sub-models and simplify the complex process of interactions between the variables (Vanclay, 2014). The causal-loop diagram of the developed model for water-energy-food at a city scale is shown Figure 3.14. It should be noted that the model is designed to only quantify WEF consumption and production within the city and excludes any WEF imports.

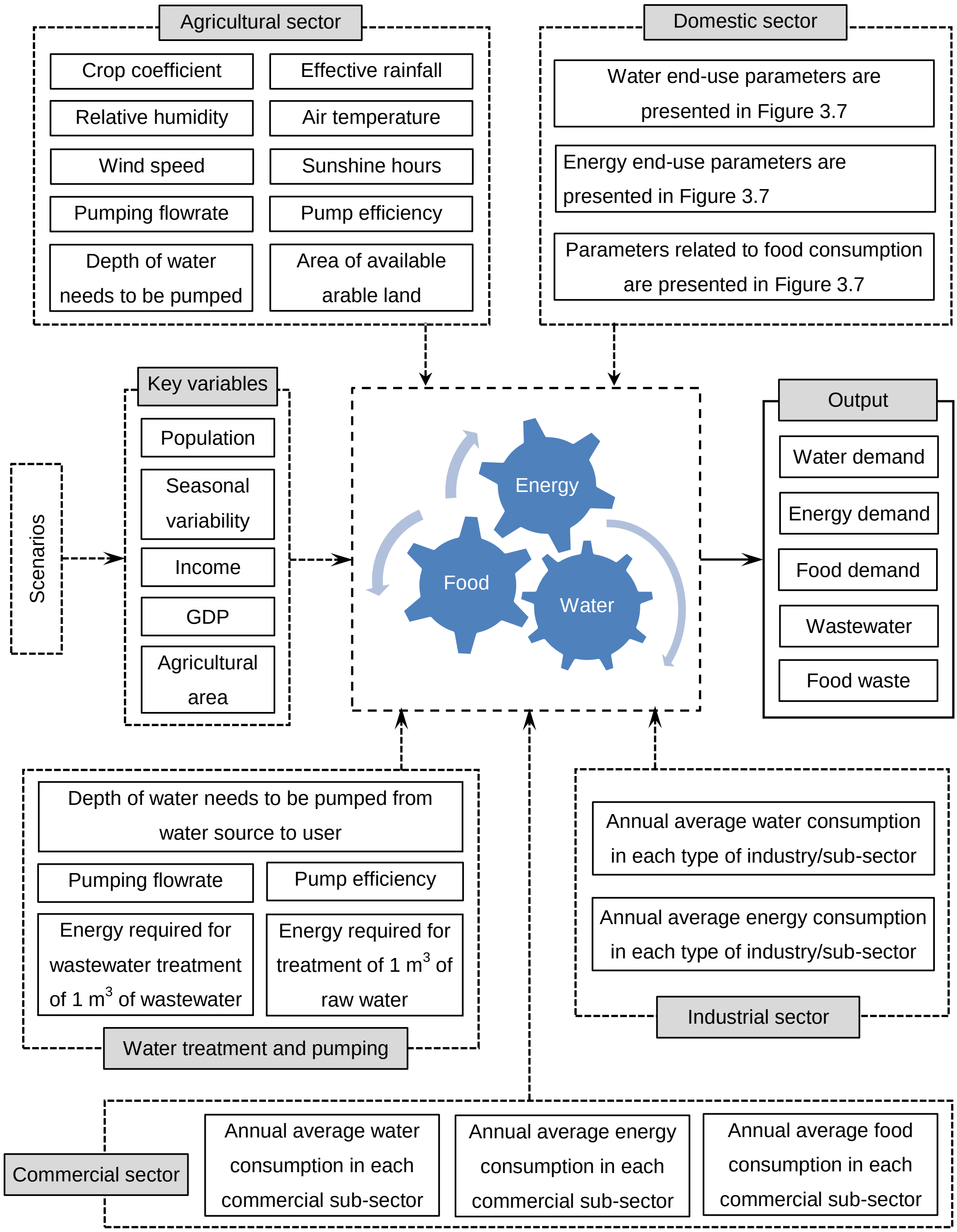


Figure 3.13 The structure of water-energy-food model at a city scale

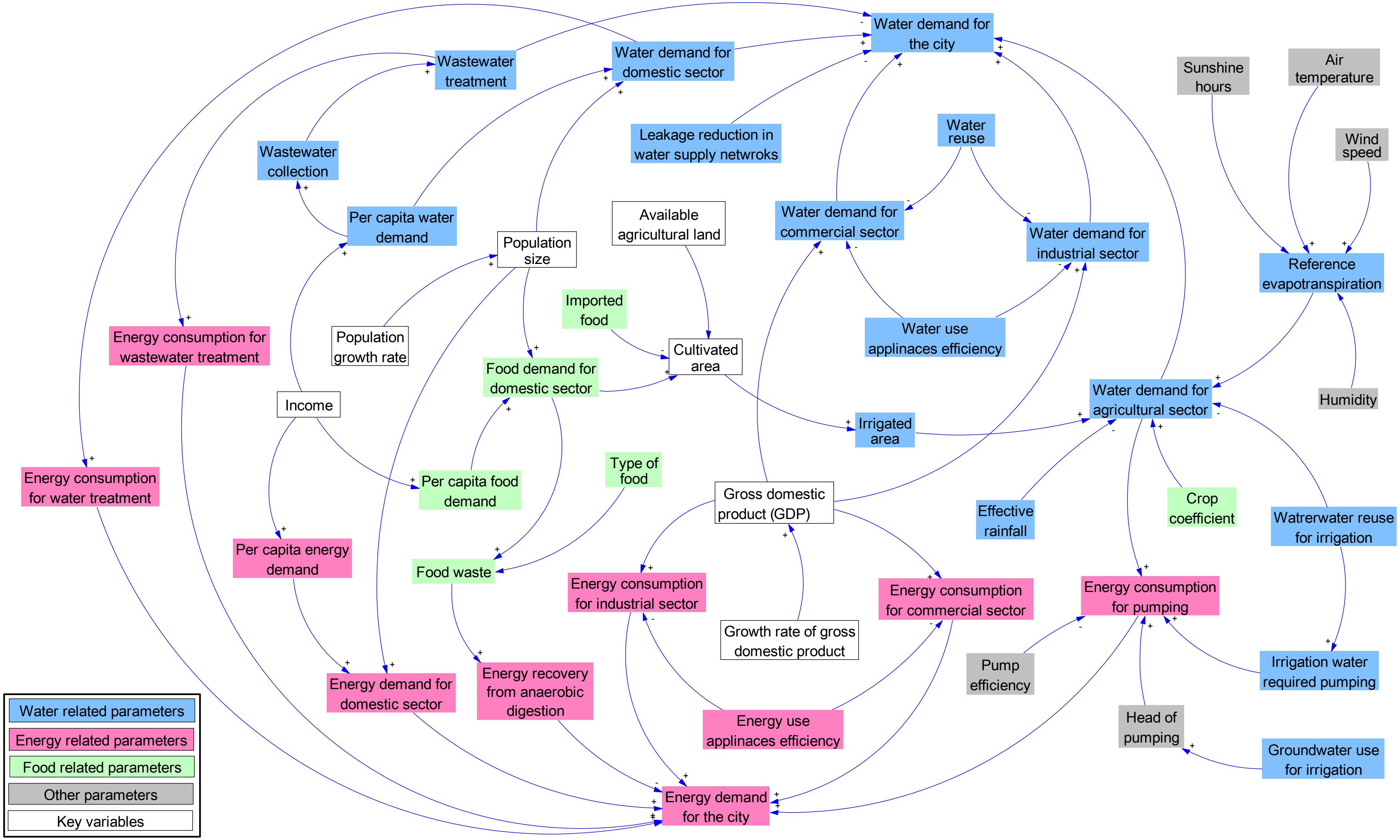


Figure 3.14 Relationship between water-energy-food parameters and key variables at a city scale

3.6.5 Model input parameters

Table 3.20 presents a summary of model input parameters. Each input parameter, labelled with an asterisk (*), could have six values depending on the season (summer and winter) and household income (low, medium and high). The input parameter values for WEF demand estimation at household level are provided in Table 4.9, Table 5.10 and Table 6.3, respectively. The values in these tables have been derived from a detailed survey conducted for the chosen case study, Duhok, Iraq (Section 3.3).

The values of parameters for other sectors (i.e., agricultural, industrial and commercial) are collected from local directorates, authorities and reports as shown in Tables 3.17-3.19.

Table 3.20 Summary of model input parameters

A. Key variables	
Population size	
Proportion of low, medium and high income households	
Duration of summer and winter seasons	
Total available agricultural land	
Cultivated area for each type of crop	
GDP value	
B. Domestic sector	
Input parameters	Note
Frequency of use of water end-use (Fe_i) *	*Water end-uses*: showering, hand wash basin tap use, manual dishwashing, cooking, house washing, vehicle washing and garden watering. The values are shown in Table 4.9.
Duration of use of water end-use (De_i) *	
Flow rate of water end-use (Re_i) *	
Frequency of use of water end-use (Fe_i) *	*Water end-uses*: bathing, toilet flushing and clothes washing. The values are shown in Table 4.9.
Quantity of water consumption during each event of water end-use (Ve_i) *	
Ownership level of electric appliance (Na_i)	Table 3.11 lists the *Electric appliances* which are included in the model. The values are shown in Table 5.10.
Duration of use of electric appliance (Da_i) *	
Wattage of electric appliance (Wa_i)	
Ownership level of kerosene and gas use appliance (N_d)	Table 3.11 lists the *Kerosene and gas use appliances* which are included in the model. The values are shown in Table 5.10.
Duration of use of kerosene & gas using appliance (D_s) *	
Quantity of kerosene/gas consumption by the appliance (Q_s)	

Table 3.20 Summary of model input parameters

Water temperature at inlet of water heater (T_{in})	Section 5.4.2 discusses the values used in the model for T_{in}, T_{out} and *desired ratio of hot to cold water*. The values are given in Table 3.21.
Water temperature at outlet of water heater (T_{out})	
Desired ratio of hot to cold water for water uses	
Number of cooking sessions of a food commodity (Nc_i) *	Table 3.12 lists the *Food commodities* which are included in the model. The values are shown in Table 6.3
Quantity of consumption of the food commodity per cooking session (Fc_i) *	
Average water consumption per cooking session of the food commodity (Wc_i) *	
Duration of cooking session of the food commodity (Dc_i) *	
Fuel consumption per hour of using hob ring for cooking (E_h) *	
Percentage of waste of the food commodity	The percentages are shown in Table 3.13.
C. Agricultural sector	
Crop coefficient for each stage of the crop development (K_c)	Table 3.16 presents the values of K_c for each type of crop grown in the city.
Average total effective rainfall	Table 3.1 shows the monthly average values.
Monthly reference evapotranspiration for the region under investigation (ET_o)	Table 3.15 presents the monthly ET_o values for the city.
Average pumping flow rate for irrigation purposes (Q)	The parameters values for pumping water for irrigation purposes are collected form Duhok Directorate of Groundwater (2012).
Depth of water to be pumped for irrigation purposes (H)	
Pump efficiency (γ)	
D. Commercial sector	
Annual average water consumption per commercial sub-sector	The list of commercial subsectors and their water and energy consumption is given in Table 3.17.
Annual average electricity consumption per commercial sub-sector	
Annual average fuel consumption per commercial sub-sector	
Annual average LPG consumption per commercial sub-sector	
Annual average consumption of each type of food in commercial sector	Food types and their consumption in commercial sector are given in Table 3.19.
E. Industrial sector	
Annual average water consumption per industry group	The list of industries included in the model and their water and energy consumption is given in Table 3.18.
Annual average electricity consumption per industry group	
Annual average fuel consumption per industry group	
Annual average LPG consumption per industry group	

Table 3.20 Summary of model input parameters

F. Water treatment and supply	
Average pumping flow rate from water source to water treatment plant (*Q*)	Section 3.2.2.1 presents the information of average pumping flow rate and depth of pumping.
Depth of water to be pumped from the water source to the water treatment plant (*H*)	
Average pumping flow rate from the water treatment plant to a storage reservoir (*Q*)	
Height of water to be pumped from the water treatment plant to the storage reservoir (*H*)	
Pump efficiency (γ)	
Energy consumption for water treatment process	Table 3.4 shows the stages of water treatment process and the related energy consumption.

The non-survey-based data used in the WEF model and their spatial resolution are provided in Table 3.21.

Table 3.21 Summary of non-survey based data for household WEF model

Parameters	Unit	Value	Spatial resolution	Reference
Water temperature at inlet of water heater	°C	12 ºC during the cold season	Local	Duhok Directorate of Seismology and Meteorology (2015)
Classification of household income groups	ID	Table 3.9	National	CSO and KRSO (2012)
Capacity of LPG cylinder	l	26.2	National	Kurdistan Ministry of Natural Resources (2015)
Waste from each type of food	%	Table 3.13	Regional	FAO (2011b)
Average wattage of spot lights	Watt	40	National	Iraqi Ministry of Electricity (2010)
Average wattage of tube lights	Watt	60	National	Iraqi Ministry of Electricity (2010)

Note: l=litres of LPG , ID=Iraqi Dinar

3.6.6 Model assumptions

The key assumptions include:

1) Although, some electric appliances operate on different power ratings, the model reports an average energy consumption of each appliance throughout its entire operating hours rather than capturing short time scale variability.
2) Electricity is the main source for water heating at a household level. This is based on the household survey findings.
3) The hot to cold water ratio is assumed to be 1:1 for each end-use that required hot water in Duhok households. However, the model is flexible to accommodate any hot to cold water ratio considering various climatic conditions in different regions of the world.
4) The average temperature of water supply (T_{in}) is approximately 12 ºC during the cold season (Duhok Directorate of Seismology and Meteorology, 2015). The average water temperature at the outlet of heater (T_{out}) is taken as 62 ºC, based on the survey findings.
5) The size of hob ring used for cooking every type of food is the same in all income households.
6) The capacity of LPG cylinder is assumed as 26.2 l. This is the predominant cylinder size in Iraq (Kurdistan Ministry of Natural Resources, 2015).
7) There is no leakage in the household.
8) The survey results indicated that bath and swimming pool ownership is very low. It is assumed as zero.
9) For commercial and industrial sectors in Duhok, the relationship is linear between historical records of GDP and energy consumption. For future predictions, same linear relationship has been assumed.
10) Irrigation water requirements in the city are quantified without considering the excess in water use for irrigation, water losses in distribution and the contribution of groundwater supply through capillary rise.

3.7 Sensitivity analysis

The uncertainty is embedded in parameters and equations used in system dynamics-based model (Qi and Chang, 2011). Therefore, sensitivity analysis should be performed to understand the contribution of uncertainty of each input parameter to the model output. Sensitivity measures to what extent the magnitude of model output could change over the practical range of variation of the input parameters (Jacobs, 2004). Sensitivity analysis methods have been used in various fields and complex systems, such as, engineering, economics, physics, environmental science, social sciences, medical decision making, and others (Kewley et al., 2000).

One of the powerful methods for sensitivity analysis is one factor at a time method (Hamby, 1994). This method identifies most sensitive parameter among those may be affecting the model output (Nearing et al., 1990; Saltelli and Annoni, 2010). It takes into account the parameter's variability and the associated impact on model output. This method does not account for interactions between the input parameters (Frey and Patil, 2002; Saltelli and Annoni, 2010), but provides a clear indication how a single parameter influences the overall outcome.

In one factor at a time sensitivity method, the range of variation in input parameter is considered as the standard deviation (σ) below and above the average ($\bar{X}$) (Cullen and Frey, 1999). The upper (X_U) and lower (X_L) values of each input parameter can be calculated using Equation 3.30 and Equation 3.31, respectively. Then, the upper and lower values of each input parameter have been used with the developed model to estimate the sensitivity of the model output to the input parameter under consideration (Morgan and Henrion, 1990). This is by using the upper/lower value of each parameter independently while all other input parameters are held constant (Morgan and Henrion, 1990).

$$X_U = \bar{X} + \sigma \qquad 3.30$$

$$X_L = \bar{X} - \sigma \qquad 3.31$$

3.8 Uncertainty assessment (Monte Carlo simulation)

In order to test the uncertainty of the model output results, Monte Carlo simulation method has been applied. Monte Carlo simulation method is a well-established method for overall assessment of the uncertainty (Khatri and Vairavamoorthy, 2009). This method generates an estimate of the overall uncertainty in the predictions due to all the uncertainties in the input parameters (Macdonald and Strachan, 2001). It investigates the model response to a combination of uncertain multiple input parameters.

The steps undertaken to analyse the uncertainty of the WEF model results are as below:

1) For each input parameter/variable into the WEF model, random values were selected from the distribution of possible values for input parameter under consideration.
2) The random values of input parameters were used with the developed WEF model and the expected value of the output was calculated. This is to examine the model response to a combination of uncertain multiple input parameters.
3) The process was repeated for a number of iterations to calculate set of results for each output.
4) The probability distribution of model output was then calculated, using the set of results for the model output under consideration. The generated output distribution from random sampling of input parameters is useful in assessing model and parameter uncertainties (Helton et al., 1991).
5) The average and standard deviation statistics are calculated using the set of results for the model output under consideration.
6) The relative width (Equation 3.32) of each model output is quantified using its calculated statistics. Schaffner et al., (2009) used the width of probability density (relative width) as a measure for the uncertainty of model outputs.

$$Relative\ width = standard\ deviation/average \qquad 3.32$$

3.9 Model application

3.9.1 Global Scenario Group (GSG) scenarios

The implications of GSG[6] scenarios on the future demand for WEF and the generated organic wastes as well as the agricultural land-use in Duhok are investigated. The GSG scenarios are: Market Force (MF), Fortress World (FW), Great Transition (GT) and Policy Reform (PR). The definitions of these scenarios are provided in Table 3.22. These scenarios for world development have been extensively used in global, regional and national studies (Hunt et al., 2012). Numerous studies and assessments have relied on GSG scenarios, such as OECD (2001), WWV (2000) and UNEP (2002).

Table 3.22 Summary of GSG scenarios (Kemp-Benedict et al., 2002)

Scenario	Definition	Implications
Market Force	the globalized governance, trade liberisation and consumerist values lead to free market behavior.	high growth in population, productivity, economy, GDP and income and also inequality between rich and poor countries, and within each country. The consumption for water, energy and wastes will increase.
Fortress World	the powerful world forces, faced with a dire systemic crisis, impose an authoritarian order where elites retreat to protected enclaves, leaving impoverished masses outside.	rapid deterioration in environmental conditions, pollution, climate change, water scarce, food insecurity and health crisis with a large socio-economic divide between rich and poor.
Policy Reform	the world establishes the necessary regulatory, economic, social, technological, and legal mechanisms to meet social and environmental sustainability goals, without major changes in the state-centric international order, modern institutional structures, and consumerist values.	achieve internationally recognized goals for poverty reduction, climate change stabilisation, ecosystem preservation, freshwater protection, and pollution control. As a result, greenhouse emissions decline, growth continues in developing countries for two decades as redistribution policies raise incomes of the poorest regions and most impoverished people.
Great Transition	social values move toward internationalism rather than localism and also concerned with environmental conservation, which leads to high growth and development, and service directed change.	increase in wastewater reuse and a decline in fossil fuel energy use and intensive agriculture leading to a reduction in the leakage and water demand.

[6] http://www.gsg.org

The characteristics of GSG scenarios and their average annual growth rate values are estimated for different regions in the world by Tellus Institute. For the case study located in Iraq, values associated with the Middle East have been used as given in Table 3.23. The growth rates in this table reflect percentage change in consumption. Using the annual growth rate values for these indicators with the WEF model, the annual demand for WEF has been simulated for 35 years ahead. The time horizon of 35 years is the most often considered timeline in scenarios (Hunt et al., 2012; Ercin and Hoekstra, 2014) and also recommended for socioeconomic planning (Simonovic and Fahmy, 1999).

Table 3.23 Summary of annual growth rate (%) of indicators of GSG scenarios for Middle East region[7]

Scenarios		Market Force		Policy Reform		Fortress World		Great Transition	
Period		2005-2025	2025-2050	2005-2025	2025-2050	2005-2025	2025-2050	2005-2025	2025-2050
Average annual growth rate of indicators (%)	Population	2.0	1.3	1.9	1.2	2.1	1.4	1.8	1.0
	GDP	3.2	2.2	3.5	2.0	3.2	1.6	3.4	0.6
	Income	2.1	2.0	2.5	2.2	1.8	1.8	2.9	2.0
	Poor/rich income ratio	0.03	0.03	0.2	0.15	-0.1	-0.3	0.60	0.50
	Built-up area	2.1	1.5	1.9	1.2	2.4	2.0	1.7	0.4
	Agricultural area	1.4	0.8	1.5	1.2	1.4	0.7	1.5	1.2
	Meat consumption	0.7	0.6	0.9	0.7	0.7	0.2	0.9	0.3
	Crop consumption	0.1	0.1	0.1	0.0	0.1	-0.1	0.1	-0.1
	Fish consumption	0.0	0.0	0.0	0.0	0.0	-0.4	0.0	-0.4
	Household energy use	1.8	1.8	1.1	0.4	1.8	1.0	0.8	-0.9
	Household water use	1.4	1.3	0.0	-0.6	1.4	0.6	0.0	-0.6
	Household fuel demand	1.6	0.9	1.2	-0.2	1.3	0.2	1.1	-1.4

[7] http://www.gsg.org

3.9.2 Risk-based assessment of WEF under seasonal uncertainty

The risk-based approach aims to identify the probability of exceeding acceptable level of shortage in per capita demand for WEF in any year of the desired time horizon (i.e., simulation period), resulting from future seasonal variability. In this study, the seasonal variability is a function of increase or decrease in the duration of summer season. This approach explores the impact of uncertain change in future weather conditions on the demand for WEF. Only probability of risk is considered in this approach as detailed in Borgomeo and Hall (2014). The approach can also assess the implications of possible demand management strategies for WEF. The procedure for estimating the risk of exceeding acceptable level of shortage in per capita water demand due to seasonal variability is explained in the following and shown in Figure 3.15:

1) Identify the annual total quantity of available water from all sources (e.g., surface water, groundwater) in the region under investigation.
2) Using the historical records for the region under investigation, establish the pre-dominant season (i.e., summer or winter). The extent of climate variability is then represented by assuming the increase in the days for summer or winter (i.e., *1, 2, 3,…, n days*) per year.
3) Simulate the domestic water demand using the assumed values for the variation in the duration of summer/winter season with the WEF model. Hence, the number of simulations of future water demand is *n* (i.e., $s_1, s_2, s_3, \dots, s_n$), representing the impact of change in duration of summer/winter season by *1, 2, 3,…, n days*. The future water demand is simulated for the desired time horizon (e.g., until 2050) with one year time step. For each simulation (s) of water demand, the WEF model calculates the quantity of per capita water demand (Wd_i) in each year (i) of the simulation period using Equation 3.33.

$$Wd_i = TW_i/365 \qquad 3.33$$

where:

Wd_i= daily average per capita water demand during year i (l/p/d), and

TW_i= annual per capita total water consumption during year i (l/p/y) (Calculated using Equation 3.18).

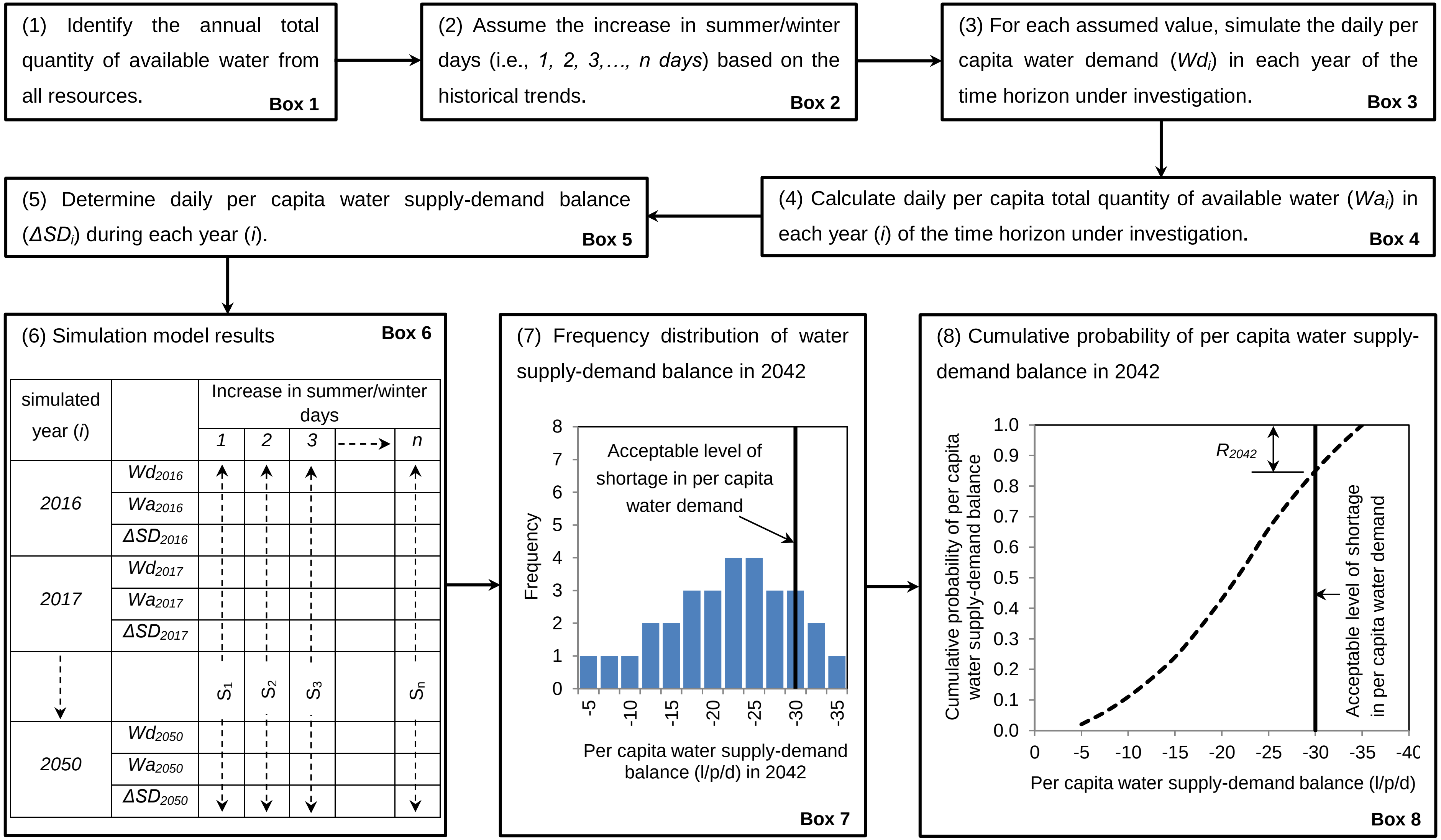


Figure 3.15 Methodological framework to estimate the risk of exceeding acceptable level of shortage in per capita demand

4) Calculate the daily per capita total quantity of available water (Wa_i) in each year (i) of the simulation period, using Equation 3.34 in the WEF model.

$$Wa_i = \frac{Annual\ total\ available\ water\ in\ the\ investigated\ area}{Population\ size\ in\ year\ i\ of\ the\ simulation\ period \times 365} \qquad 3.34$$

5) Determine daily per capita water supply-demand balance (ΔSD_i) during each year (i) of the simulation period using Equation 3.35. Similarly, the values of ΔSD_i are quantified for each simulation (i.e., $s_1, s_2, s_3, \dots, s_n$).

$$\Delta SD_i = Wa_i - Wd_i \qquad 3.35$$

6) Organise the simulation results from Step 1 to Step 5 in a form as given in Figure 3.15 (Box 6).
7) Find the frequency distribution of supply-demand balance (ΔSD_{2016}, ΔSD_{2017},… ΔSD_{2050}) for each year (i.e., 2016, 2017,…, 2050) of the simulation period. The values of supply-demand balance in a particular year (i) of all simulations (i.e., $s_1, s_2, s_3, \dots, s_n$) are used to obtain the frequency distribution of year i. This will result in the number of frequency distribution diagrams equal to the number of years of the simulation period. These distributions represent the uncertainty around the frequency of shortage (i.e., negative ΔSD_i value) in per capita water demand due to seasonal variability. The positive value of ΔSD_i represents the quantity of available water greater than per capita demand. The frequency distribution of water supply-demand balance for year 2042 is shown in Figure 3.15 (Box 7).
8) Obtain the cumulative probability of each year (i) of the simulation period under consideration (e.g., 2042), represented as $F(\Delta SD_i)$. This is achieved using the frequency distribution of ΔSD_i calculated in Step 7 for the year i under consideration. For example, the frequency distribution of ΔSD_i in 2042 is used to obtain the cumulative probability of per capita water supply-demand balance in 2042 Figure 3.15 (Box 8).
9) Calculate the risk (R_i) of exceeding acceptable level of shortage in per capita water demand during year i of the simulation period using Equation 3.36 as given in Borgomeo and Hall (2014). It is calculated using the cumulative probability of year i and the acceptance level of risk (i.e., acceptable level of

shortage in per capita water consumption, not causing discomfort of public unrest) for the region under investigation. For example, in Figure 3.15 (Box 8) if we assume that the acceptable level of shortage is 30 l/p/d in per capita water demand then the probability of shortage will be 15%. The values of risk may change from year to year due to population growth and seasonal variability which impact the demand and available water per capita.

$$R_i = 1.0 - F(\Delta SD_i) \tag{3.36}$$

10) Finally, water demand management (WDM) strategies can be implemented using the WEF model to explore how each strategy can decrease the risk of exceeding acceptable shortage in per capita water demand. In addition, the water-related energy can be calculated for each demand management strategy to select the suitable one.

3.9.2.1 Seasonal variability in the city of Duhok

The duration of summer season in Iraq is considered to be from April to October, based on the weather and climate information[8]. In the north of Iraq, the climate trend is toward more warm days and nights as illustrated in Table 3.24. This is in agreement with the increase in average temperature (UK Met Office et al., 2011). For the case study located in the north of Iraq, the duration of summer season is assumed to increase by 1 to 30 days (i.e., 1, 2, 3,….., 30 days) by 2050, based on the weather forecasts in Table 3.24. This is to assess the risk of exceeding acceptable level of shortage in per capita demand for water and energy under seasonal variability uncertainty.

Table 3.24 Summary of trend of climate change in the north of Iraq (UK Met Office et al., 2011)

	Warm nights	Cool nights	Warm days	Cool days
Percentage of change per decade (%)	2.0 to 3.5	-1.0 to -2.0	1.0 to 2.0	-0.5 to -1.0

[8] https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,Bagdad,Iraq

3.9.3 Impact of water demand management (WDM) strategies

Maksimovic et al. (2013) discussed using various technologies for water management in different countries. Most studies have not considered the impact of climate change when investigating demand management strategies for WEF (Nanduri and Saavedra-Antolínez, 2013). The risk-based assessment approach used in this study can consider the impact of seasonal variability when investigating demand management strategies for WEF. The performance of a number of WDM strategies is investigated to decrease the risk of exceeding acceptable level of shortage in per capita water demand due to future seasonal variability. The WDM strategies considered include:

- Strategy A: the use of water efficient fixtures in a household.
  The flow rate of water end-uses is assumed to decrease by 5%.
- Strategy B: the use of recycled grey water for non-potable applications (i.e., garden watering, car washing and toilet flushing).
  It is assumed that 100% of grey water (Figure 3.9) collected from households is reused for non-potable applications.
- Strategy C: leakage reduction in water distribution network by 5.0%.

3.9.4 Impact of energy management (EM) strategies

In order to decrease the risk of exceeding acceptable level of shortage in per capita energy demand due to seasonal climate variability, a number of EM strategies are applied. The WEF model is used to investigate the performance of the management strategies, which are:

- Strategy D: Alternative additional energy through anaerobic digestion of food waste.
  Using anaerobic digestion to break down 1 ton of organic waste in the absence of oxygen can yield approximately 245-525 m^3 of methane (Raposo et al., 2012). The yield can vary depending on the quality of food waste used as a feedstock (Katrini, 2012). Methane gas can be used as a renewable form of natural gas for cooking and heating and also can be burnt to produce electricity and heat (Katrini, 2012). Equation 3.37 was used to calculate the quantity of energy generated from anaerobic digestion

of food waste. Per capita food waste and population size in this equation are calculated using the WEF model.

$$E_{fw} = \frac{C_{fw} \times Pop \times 365}{1000} \times M_{fw} \times \frac{C_m}{3600} \qquad 3.37$$

where:

E_{fw}= energy generated from anaerobic digestion of food waste (MWh/y),

C_{fw}= daily per capita average quantity of food waste (kg/p/d),

Pop= population size for the city under investigation,

M_{fw}= methane gas produced per 1 ton of food waste = 400 m^3/ton (Raposo et al., 2012),

C_m= calorific energy of methane gas = 39.6 MJ/m^3 (Cao and Pawłowski, 2012), and

3600= conversion factor from J to Wh.

- Strategy E: Energy recovery from anaerobic digestion of municipal wastewater sludge.

  Daily average quantity of sewage sludge produced per capita is approximately 1.5 kg/p/d (De Mes et al., 2003). Methane yield from 1 ton of sewage sludge ranges between 116 and 318 m^3 (Iacovidou et al., 2012). These figures are used in Equation 3.38 to calculate the quantity of energy generated from anaerobic digestion of wastewater sludge.

$$E_{wws} = \frac{C_{wws} \times Pop \times 365}{1000} \times M_{wws} \times \frac{C_m}{3600} \qquad 3.38$$

where:

E_{wws}= energy generated from anaerobic digestion of wastewater sludge (MWh/y),

C_{wws}= daily average quantity of wastewater sludge produced per capita (kg/p/d), and

M_{wws}= methane gas produced per 1 ton of wastewater sludge = 200 m^3/ton (Iacovidou et al., 2012).

- Strategy F: use of both strategies D and E.

3.9.5 Resilience of water and energy systems under the impact of seasonal variability

Resilience has many definitions. In engineering systems, resilience focuses on ensuring continuity and efficiency of system function during and after failure (Butler et al., 2014; Lansey, 2012). Ayyub (2014) interpreted resilience as the ability of the system to return to a stable state after a perturbation.

In this study, Simonovic and Peck (2013) approach is used to quantify systems resilience under the impact of seasonal variability in the city of Duhok, Iraq. This approach can explore the impact of uncertain change in the future weather conditions on the system resilience. In this study, resilience is the ability of WEF systems to absorb disturbance (WEF supply deficit) and minimise the duration of system failure caused due to uncertain seasonal variability. The aim in this context is to maintain acceptable functionality level (minimum WEF demand) and rapidly recover from failure once it occurs. In this approach, resilience is quantified as a dynamic measure.

Using this approach with the developed WEF model, various demand management strategies (Section 3.9.3 and 3.9.4) are investigated to identify the efficient strategy that increases system resilience and reduces failure consequences. The seasonal variability in this study represents the increase/decrease in the number of summer season days. The procedure to quantify resilience of a water system for providing per capita demand under the impact of seasonal variability is illustrated by the following steps and are shown in Figure 3.16:

1) Identify the annual total quantity of available water from all sources (e.g., surface water, groundwater) in the region under investigation.
2) Using the historical records for the region under investigation, establish the pre-dominant season (i.e., summer or winter) and the climate trend whether it is toward longer/shorter summer season. The extent of seasonal variability is then represented by assuming the increase in the number of days ($j=1, 2, 3, \ldots, n$ *days)* for summer or winter per year.
3) Using the assumed values for the variation in the duration of summer/winter season with the WEF model, simulate the domestic water demand. Hence, the number of simulations of future water demand is n (i.e., $s_1, s_2, s_3, \ldots, s_n$),

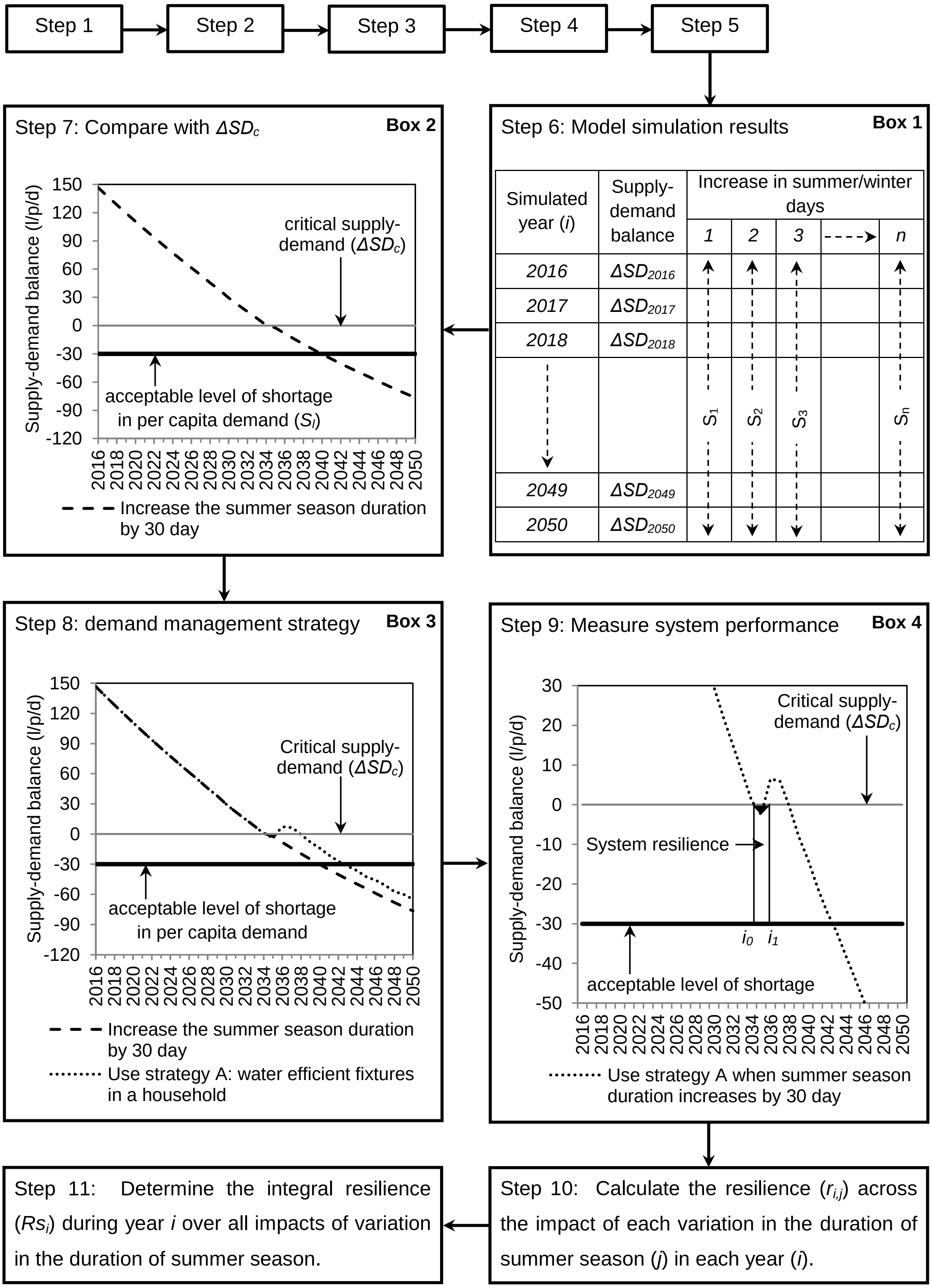


Figure 3.16 Methodology of system resilience quantification under the impact of seasonal variability

representing the impact of change in duration of summer/winter season by *1, 2, 3,…, n days*. The future water demand is simulated for the desired time horizon (e.g., until 2050) with one year time step. For each simulation (*s)* of water demand, the WEF model calculates the quantity of per capita water demand (Wd_i) in each year (*i*) of the simulation period using Equation 3.33. The values of We_w and We_s required to quantify Wd_i can be identified based on surveys or historical records for the region under investigation.

4) Calculate the daily per capita total quantity of available water (Wa_i) in each year (*i*) of the simulation period, using Equation 3.34 in the WEF model.
5) Determine daily per capita water supply-demand balance (ΔSD_i) during each year (*i*) of the simulation period using Equation 3.35. Similarly, the values of ΔSD_i are quantified for each simulation (i.e., $s_1, s_2, s_3,\ldots., s_n$).
6) Organise the simulation results from Step 1 to Step 5 in a form as given in Figure 3.16 (Box 1).
7) Compare each simulation (i.e., $s_1, s_2, s_3,\ldots., s_n$) of ΔSD_i with the critical level of water supply-demand balance (i.e., ΔSD_c=0). This is to identify the starting point of system disturbance (i.e., the system unable to provide normal per capita water demand, ΔSD_i<0) and the end of system disturbance ($\Delta SD_i \geq 0$). The model simulation in Figure 3.16 (Box 2) shows the impact of population growth and an increase in summer season duration by 30 day on per capita supply-demand balance. The results in Figure 3.16 (Box 2) indicate that the system is unable to provide normal per capita water demand after the year 2034.
8) When there is disturbance in the system, repeat the procedure with using a water demand management strategy to identify if the system is able to recover (i.e., provide normal per capita water demand under the impact of seasonal variability, $\Delta SD_i \geq 0$). Figure 3.16 (Box 3) shows the model simulation results when strategy A (i.e., use of water efficient fixtures in a household) was applied on the water system. The results in this figure indicate that the water system is able to recover and provide normal per capita water demand ($\Delta SD_i \geq 0$) for longer period.
9) Measure the performance (ρ_j) of the water system under the impact of seasonal variability when a management strategy is applied, using the simulation of ΔSD_i in Figure 3.16 (Box 3). The performance represents the

shaded area between the beginning of the system disruption at year i_o and the end of disruption recovery process at year i as shown in Figure 3.16 (Box 4). The shaded area represents the loss of system resilience. Mathematically, system performance can be calculated using Equation 3.39 (Simonovic and Peck, 2013).

$$\rho_{i,j} = \int_{i_o}^{i} \left(\Delta SD_c - \Delta SD_{i,j}\right) di \qquad 3.39$$

where:

$\rho_{i,j}$= system performance in year i under the impact of population growth and an increase in summer season duration by j days,

$\Delta SD_{i,j}$= supply-demand balance at year i under the impact of population growth and an increase in summer season duration by j days, and

ΔSD_c= critical supply-demand balance = 0 l/p/d.

Similarly, quantify the performance of the water system under the impact of each increase in summer season duration, individually, and during each year of the simulation.

10) Quantify the resilience ($r_{i,j}$) across the impact of each variation in the duration of summer season (j) in each year (i). This is using the system performance values ($\rho_{i,j}$) calculated in Step 9 with Equation 3.40 (Simonovic and Peck, 2013). The values of $r_{i,j}$ will range between 0 (i.e., no performance is available) and 1 (i.e., no degradation in system performance). This approach is based on the notion that the system performance which varies with time, defines a particular resilience component of a system under consideration.

$$r_{i,j} = 1 - \left(\frac{\rho_{i,j}}{(\Delta SD_c - S_l) \times (i - i_o)}\right) \qquad 3.40$$

where:

$r_{i,j}$ = system resilience in year i under the impact of increase in summer season duration by j days, and

S_l= acceptable level of shortage in per capita water demand = 30 l/p/d.

When the system performance does not deteriorate ($\rho_{i,j}$=0), the loss of resilience is 0 (i.e., no disruption in the system). On the other hand, when all of system performance is lost, the loss of resilience is at the maximum value and consequently the system resilience is 0.

11) Finally, determine the integral resilience (*Rs*$_i$) in year *i* of the time horizon under investigation. This is using the $r_{i,j}$ values calculated in Step 10 for the year under consideration with Equation 3.41 (Simonovic and Peck, 2013). This value of resilience (*Rs*$_i$) incorporates all impacts of variation in the duration of summer season (j=*1, 2, 3,…, n days*).

$$Rs_i = \left(\prod_{j=1}^{n} r_{i,j}\right)^{1/n} \qquad 3.41$$

where:

n = total number of impacts (increase in the duration of summer season by 1, 2, 3,..., n days).

3.10 Conclusions

This chapter presented the various components of the methodology. These include details on the WEF consumption survey at end-used level conducted in the city of Duhok and the development of a household level and city scale WEF models. The results of the WEF survey are discussed in Chapter 4 to 6. The validity of the WEF model is tested in Chapter 7. The application of the model for different scenarios is presented in Chapters 8 and 9.

CHAPTER FOUR: WATER CONSUMPTION

4.1 Introduction

Water scarcity is a major issue in many developed and developing countries. Rapid population growth, urbanization and climate change related uncertainties are some of the factors influencing land use patterns and need to be considered during water resources management planning. Since 2007, the fraction of urban population has exceeded the rural fraction and is largely attributed to the economic migration (UN, 2015). In order to accommodate this rapid increase in urban population on limited urban land, there is a considerable upward shift towards developing apartments in multi-storey buildings with the associated change in physical household characteristics (e.g., built-up area, number of rooms and area of front garden). These characteristics can in turn influence domestic water consumption. Additionally, the interactions between climate change and land use and management can affect the availability of freshwater resources (Houghton-Carr et al., 2013), as a result of change in the amount of returned evapotranspiration to the atmosphere and also runoff and groundwater pathways (Holman and Hess, 2014). Emphasis is growing on the implementation of demand management measures, water reuse and better understanding of our water consumption behaviours and factors influencing or contributing to domestic water consumption.

The modelling of domestic water demand has been effectively examined and analysed in the developed countries, while less effort has been made for the developing countries (Nauges and Whittington, 2010). This can be due to the household's access to more than one type of water sources in the developing countries. Abu Rizaiza (1991) developed water demand models for households supplied by water distribution network and tankers, separately, to estimate water demand in four cities in Saudi Arabia. Also, Cheesman et al. (2008) separated water demand for households with a private connection only and households combining private connection and well water. Different household characteristics are used for water demand modelling and estimation in the developing countries, such as, walking time to water source (Persson, 2002), number of women in the household (Mu et al., 1990), family size (Larson et al., 2006), education level (Madanat and Humplick, 1993), income (Nauges and

Strand, 2007) and reliability of water from other sources (Nauges and van den Berg, 2009). However, physical household characteristics (e.g. built-up area, garden area, number of rooms and number of floors) should be taken into account to develop effective models for domestic water demand estimation.

The domestic water consumption in Iraq is investigated in some studies. For example, Al-Samawi and Hassan (1988) and Isehak (2001) investigated the residential water demand in Basrah and Baghdad city, respectively. Al-Anbari et al. (2009) analysed the residential water consumption for Hilla city, and found that the number of occupants and hand wash basin taps have a significant impact on the household water consumption.

This chapter examines water consumption for over 400 households, of different types, and explores the influence of various household characteristics on per capita consumption patterns currently prevailing in urban areas of an Iraqi city, Duhok. The collected water consumption data has been used to develop statistical models demonstrating the influence of household characteristics on the total per capita daily water consumption. A selection of statistical models is used to investigate the impact of four future scenarios (i.e., Market Forces, Fortress World, Policy Reform and Great Transition) on likely changes in per capita consumption. Finally, the chapter investigates the impact of seasonal variability on per capita water consumption, using the collected data of water consumption survey during summer season.

4.2 Household characteristics

The analyses of household characteristics of 407 residential units (92% houses and 8% apartments) are summaried in Table 4.1. It shows that the average household occupancy is 7.04 persons, which is approximately equivalent to the average standard family size (6.7 persons) in Duhok as reported by CSO and KRSO (2012). In terms of family composition, the average number of adult females, adult males and children are 2.33, 2.27 and 2.22, respectively. The average number of elders (≥ 65 years) was very low (0.22), accounting only 3.2% of the survey sample. These findings are consistent with those of CSO and KRSO survey (2012) (Table 4.1).

Table 4.1 Summary of statistical parameters of household characteristics for the whole survey (407 households)

Household characteristics	Unit	Mean	CSO and KRSO survey (2012)
Household size (occupancy)	No./hh	7.04	6.7
Number of children (<15 years)	No./hh	2.22	2.47
Number of adult males members (15-65 years)	No./hh	2.27	1.96
Number of adult females members (15-65 years)	No./hh	2.33	2.01
Number of elders (>65 years)	No./hh	0.22	0.25
Household type	%	Houses (91.9%) Apartments (8.1%)	Houses (95.8%) Apartments (4.2%)
Total built-up area of all floors	m^2/hh	314.6	283.1
Garden area per household	m^2/hh	29.56	-
Number of rooms in the household	No.	4.19	-
Number of floors in the household	No.	1.48	-
Monthly family income per household	1000 ID/mon	1857.6	1644.9

Note: hh = household, ID = Iraqi Dinar (1000 ID ≈ £ 0.5)

The socio-economic characteristics of the households show that the average built-up area of all floors is between 100 and 500 m^2 with approximately 30 m^2 occupied by the garden. Of the 407 households, 58% were single-story, 36% where double-story and 6% where triple-story. The average number of rooms is over 4. The variation in the family income was high and ranged from $3x10^5$ ID/mon (≈ £150) to $44.7x10^5$ ID/mon (≈ £2200) with average per capita income equivalent to $25x10^4$ ID/month (≈ £125). The frequency distributions and detailed statistical analysis for all household characteristics are shown in Appendix B1 and B2, respectively.

4.2.1 Influence of household characteristics on the average total water consumption

The relationship between household characteristics and total household water consumption is investigated. The correlation coefficient can be used to assess the strength of relationship between variables (Kerns, 2010). The analyses of the data suggest a strong positive relationship between household occupancy (i.e., the number of people in the household) and total water consumption (R = 0.87) whilst there is a negative relationship between per person usage and household occupancy.

Water consumption increases with the increase in the total household built-up area, number of rooms and garden area with a correlation coefficient of 0.94, 0.96 and 0.77, respectively (Figure 4.1). This finding is consistent with those of Cavanagh et al. (2002) who found that the household built-up area and number of rooms increased water consumption in the developed countries (e.g., the U.S. and Canada). The plots showing relationship between household total water consumption and other household characteristics are shown in Appendix C1.

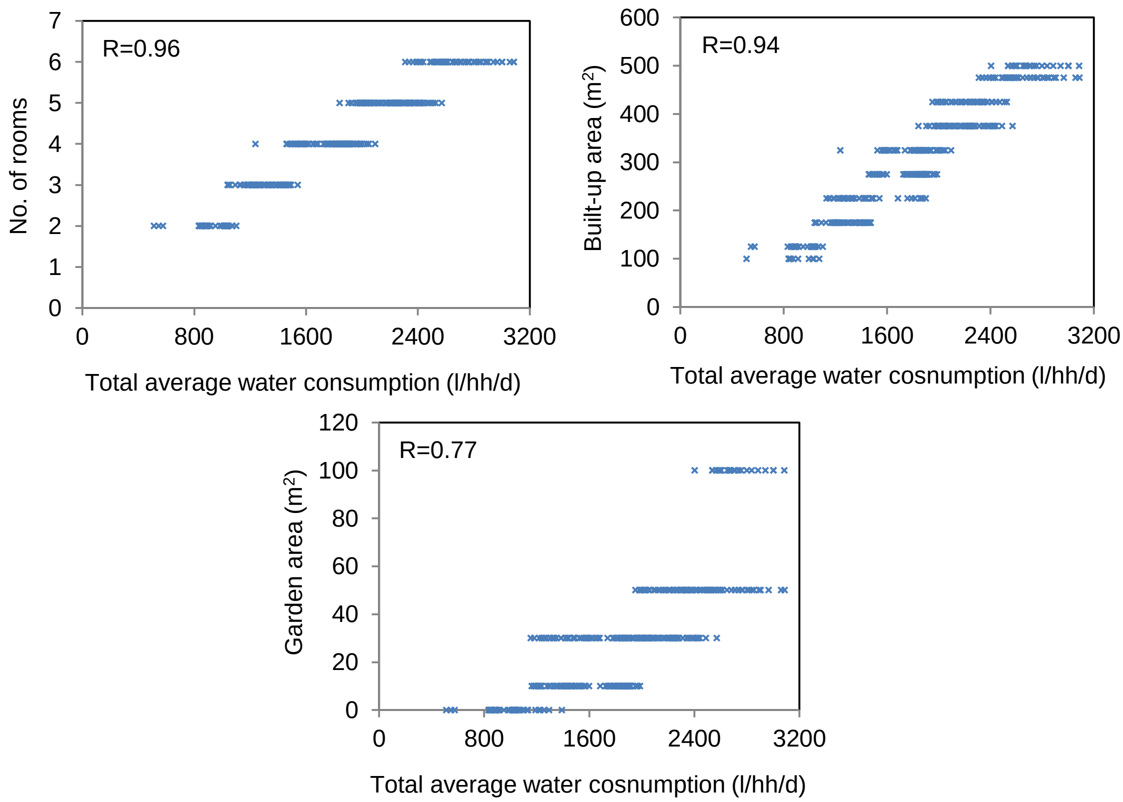


Figure 4.1 Relationship between household water consumption and household characteristics

4.2.2 Influence of household characteristics on per capita average water consumption

The frequency distribution of daily per capita average water consumption for the whole sample is shown in Figure 4.2, suggesting that the average is about 271 l/p/d. This is broadly similar to the recorded daily per capita average water consumption (277 l/p/d) in the city (Duhok Directorate of Water and Sewerage, 2014). The average daily per capita water consumption for houses is approximately 274 l/p/d and that for apartments is about 247 l/p/d. The higher consumption for houses is mainly because of additional outdoor water use.

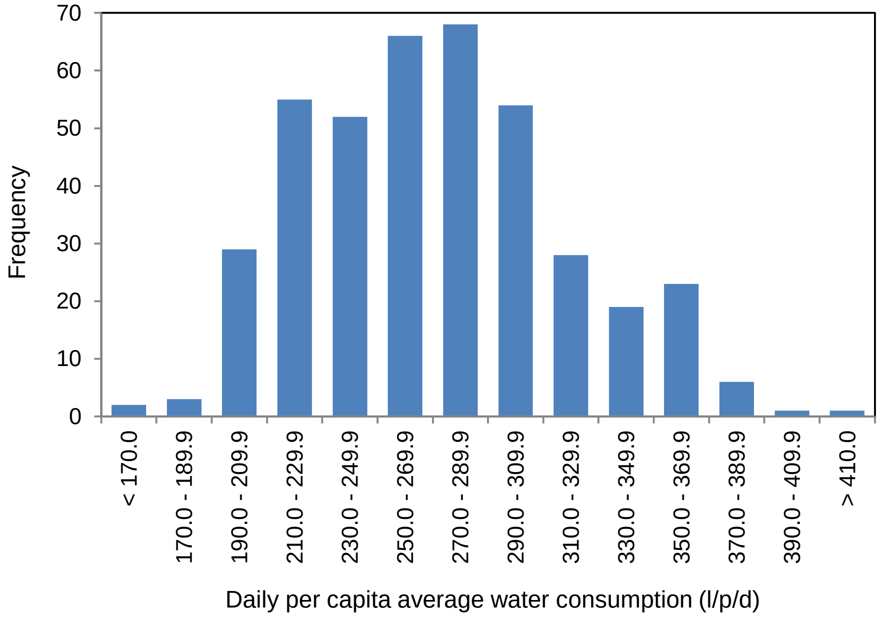


Figure 4.2 Frequency distribution of average per capita water consumption

In agreement with Edwards and Martin (1995), the daily per capita consumption increases with increase in the total built-up area of the household; however, it decreases with the increase in the number of household occupants (Figure C2.1 and Figure C2.7 in Appendix C2). The decline in per person usage suggests household uses of water such as clothes washing, dish washing and water used for cooking and cleaning are more efficient on a per person basis for higher occupancy households. The influence of children is higher than elders. In other words, increased number of children in the household leads to a higher reduction in per capita consumption than elders.

On the other hand, increased number of male adults in the household reduces per capita consumption and the increase in female members increases per capita consumption (Figure C2.3 and Figure C2.4 in Appendix C2). This increase in per capita consumption with the increase in number of females in a household appears to be because of the fact that many female members most of times stay at home and have primary responsibility to look after family.

4.2.3 Influence of per capita income on the average water consumption

The surveyed households are divided into three income groups (i.e., low, medium and high) (Section 3.4.2). Water consumption in each income group is analysed. The results of analysis show that the average per capita consumption increases with the household income (i.e., 241, 272 and 290 l/p/d in low, medium and high income group, respectively). Although, the average per capita water consumption rises with the increase in the household income, the fraction of water used for different activities broadly remains the same in all the surveyed households regardless of the income group (Figure 4.3). The figure shows that the highest fraction of water consumption is via hand wash basin taps. This is in contrast to many countries in the developed world where about one-third of water is used to flush toilets (POST, 2000).

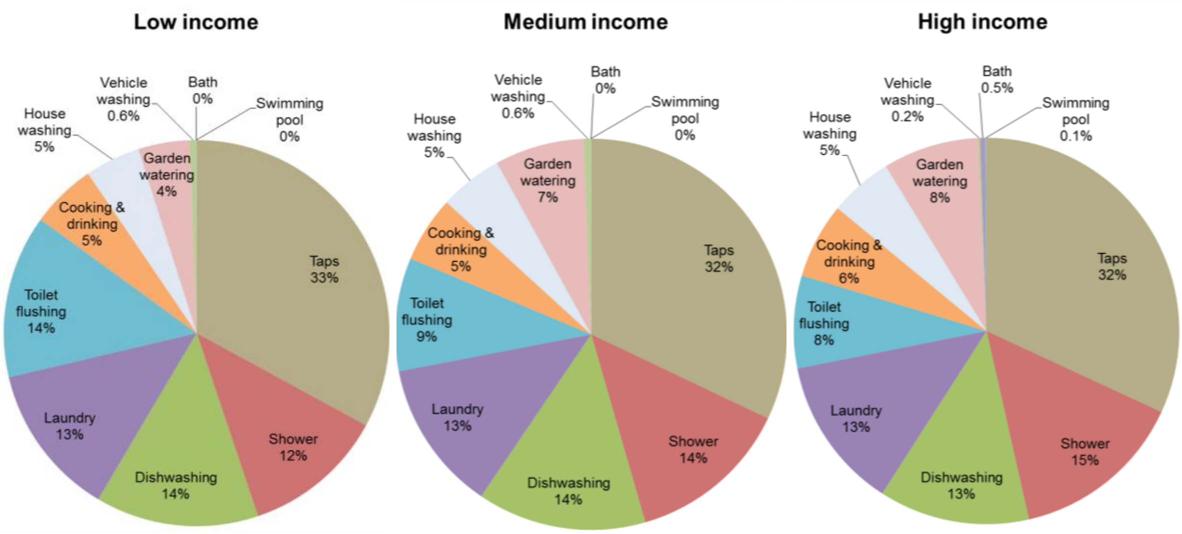
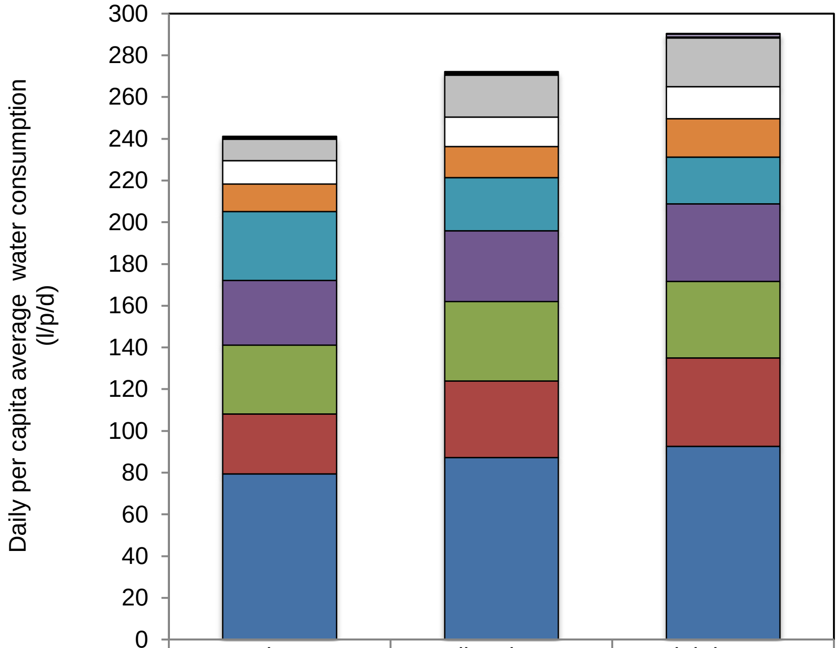


Figure 4.3 Summary of percentages of water end-uses in all income groups

4.3 Average per capita water use for different end-uses

A household's total water consumption is disaggregated into a number of end-uses: showering, bath, hand wash basin tap usage, toilet flushing, dishwashing, laundry, cooking, house washing, garden watering, vehicle washing and swimming pool. The average daily use of each of these components in all income groups is illustrated in Figure 4.4. A notable feature in this figure is the considerable variation in daily water end-use per person between income groups. It is apparent from this figure that the swimming pool use in all income groups is low (less than 0.2 l/p/d). Of the 407 surveyed households, only two houses were found to have a swimming pool and, therefore, they will not be included in any further analysis.

Another finding is the per capita water consumption for outdoor purposes (garden watering, vehicle washing and swimming pool) is less than 10% of total daily usage in all income groups. However, the consumption for outdoor purposes may become much higher in the summer season.



	Low income	Medium income	High income
Swimming pool	0	0	0.19
Bath	0	0	1.36
Vehicle washing	1.4	1.65	0.53
Garden watering	10.38	20.09	23.3
House washing	11.18	14.23	15.41
Cooking and drinking	13.2	14.85	18.33
Toilet flushing	32.99	25.45	22.51
Laundry	30.91	33.99	37.14
Dishwashing	32.98	37.98	36.69
Shower	28.74	36.67	42.31
Taps	79.43	87.27	92.59

Note: All the data presented in this table are in liter per capita per day.

Figure 4.4 Impact of per capita monthly income on water end-uses in Duhok

4.4 Influence of per capita income on water end-uses

The summary of average values of water end-use parameters per person (e.g., frequency, duration of use and flow rate) is illustrated in Table 4.2. It shows the comparison between these parameters in low, medium and high income households. Statistical analysis (mean, median, standard deviation, variance, minimum, maximum, skewness, kurtosis and confidence interval) for parameters presented in Table 4.2 are shown in Tables C3.1-C3.4 (Appendix C3). The key findings are explained in the following sections (4.4.1 to 4.4.9).

4.4.1 Shower and bath

Shower and bath use are positively related to family income (Gato, 2006). Throughout the study of 407 households, there were no baths recorded in low and medium income families. There were only 10 baths recorded in high income households with a very low frequency (once a week) in use. Water consumption in bath will not be considered in the further analysis. The exclusion of bath from high income group does not significantly affect the mean per capita consumption as shown in Table 4.3.

The daily per capita water use for showering is the function of the frequency, the duration and the flow rate of shower. Although, the frequency of showering is high (0.61 shw/p/d) in the high income group, the flow rate of shower (8.39 l/min) is lower than that recorded in the low and medium income groups (Table 4.2). Most of the high income households were found to be constructed recently and therefore they are likely to have more water efficient appliances (e.g., shower heads). The duration of shower was found to be less sensitive to income groups. However, frequency of showering tends to increase with increase in per capita income.

Table 4.2 Summary of mean values of water end-use parameters

End-use	Parameter/variable	Unit	Overall survey	Low income	Medium income	High income	Comparison with past studies
Bathing	Frequency of taking bath per capita per day	bt/p/d	0.004	0	0.00	0.01	0.044 (Blokker et al., 2009)
	Volume of water use in each bath	l/bt	132.00	0.00	0.00	132.00	100 in France (Estrela et al. 2001)
Showering	Frequency of showering per capita per day	shw/d	0.49	0.34	0.47	0.61	0.73 (Athuraliya et al., 2012)
	Duration of each shower	min/shw	8.64	8.87	8.72	8.38	7.55 (Gato, 2006)
	Flow rate	l/min	9.02	9.48	9.27	8.39	16 in France (OFWAT, 1997)
Hand wash basin taps	Frequency of using taps per capita per day	tpu/p/d	10.46	9.96	10.31	10.98	4.1 (Blokker etal., 2009)
	Duration of tap use	sec/tpu	60.81	58.31	61.02	62.20	21.3 (Gato, 2006)
	Flow rate	l/min	8.14	8.13	8.24	8.02	2.6 (Athuraliya et al., 2012)
Toilet flushing	Frequency of toilet use per capita per day	fl/p/d	4.65	5.39	4.66	4.14	4.2 (Roberts, 2005)
	Water use in each flush	l/fl	5.51	6.01	5.36	5.38	9.5 in the UK (OFWAT, 1997)
Dish washing	Frequency of washing dishes per day	wsh/d	3.00	3.00	3.00	3.00	2.1 (Jacobs and Haarhoff, 2004b)
	Duration of running water in each wash	min/p/wsh	1.47	1.16	1.50	1.64	
	Flow rate	l/min	8.36	9.54	8.39	7.54	5.4 (Marinoski et al., 2014)
Laundry	Frequency of laundry per day	wsh/d	1.48	0.83	1.46	1.93	0.69 (Athuraliya et al., 2012)
	Volume of water per washing load	l/wsl	167.32	190.02	161.01	160.28	80 in the UK (Estrela et al. 2001)
House floor washing	Frequency of house washing per day	wsh/d	0.69	0.51	0.69	0.80	
	Duration of each wash	min/p/wsh	2.13	1.79	2.1	2.38	
	Flow rate	l/min	9.80	12.20	9.88	8.12	
Vehicle washing	Frequency of vehicles washing per day	wsh/d	0.07	0.06	0.10	0.04	
	Duration of each wash	min/wsh	1.39	1.81	1.34	1.1	
	Flow rate	l/min	12.82	12.79	12.75	13.08	10.2 (Marinoski et al., 2014)
Swimming pool	Frequency of filling swimming pool per day	No./d	0.001	0.00	0.00	0.002	
	Volume of water provided to fill swimming pool	m^3	36.00	0	0	36.00	
Garden watering	Frequency of garden watering per day	wtr/d	0.13	0.07	0.14	0.14	0.4 (Roberts, 2005)
	Duration of each watering	min/wtr	13.01	13.11	11.88	14.49	20 (Athuraliya et al., 2012)
	Flow rate	l/min	11.67	11.64	11.94	11.34	10.2 (Marinoski et al., 2014)
Cooking	Volume of water consumed in cooking	l/p/d	13.66	11.20	12.85	16.33	10-20 (Gleick and Iwra, 1996)
Total water consumption		l/p/d	271.39	241.22	272.18	290.36	180 in urban residential areas (Stephenson, 2003)

Note: l=liter, p=person, d=day, min=minute, sec=second, bt=bath, shw=shower, tpu=tap use, fl=flushes, wsh=washes, wsl=washing load, wtr=watering

Table 4.3 Summary of water end-uses parameters of high income households (Without and without bath)

End-use	Parameters	Unit	Household without bath	Household with bath
Bathing	Frequency of taking bath per capita per day	bt/p/d	0.00	0.14
	Volume of water use in each bath	l/bt	0.00	132.00
	Daily water consumption for bath per person	l/p/d	0.00	18.86
Showering	Frequency of showering per capita per day	shw/p/d	0.62	0.51
	Duration of each shower	min/shw	8.33	9.00
	Flow rate	l/min	8.43	7.79
	Daily water consumption for showering per person	l/p/d	42.82	35.74
Hand wash basin taps	Frequency of using taps per capita per day	tpu/p/d	11.06	9.90
	Duration of tap use	sec/tpu	62.36	60.13
	Flow rate	l/min	8.07	7.38
	Daily water consumption from taps per person	l/p/d	94.08	73.25
Toilet flushing	Frequency of toilet use per capita per day	fl/p/d	4.19	3.40
	Water use in each flush	l/fl	5.41	5.00
	Daily water consumption for flushing toilet per person	l/p/d	22.94	17.00
Dish washing	Frequency of washing dishes per day	wsh/d	3.00	3.00
	Duration of running water in each wash	min/p/wsh	1.62	1.77
	Flow rate	l/min	1.08	1.03
	Daily water consumption for dishwashing per person	l/p/d	36.57	38.34
Laundry	Frequency of laundry per day	wsh/d	13.37	15.70
	Volume of water per washing cycle	l/wsl	160.16	161.90
	Daily water consumption for laundry per person	l/p/d	37.28	35.30
House floor washing	Frequency of house washing per day	wsh/d	0.80	0.89
	Duration of each wash	min/wsh	19.27	22.00
	Flow rate	l/min	8.14	7.96
	Daily water consumption for house washing per person	l/p/d	15.42	15.24

Note: l=liter, p=person, d=day, min=minute, sec=second

4.4.2 Hand wash basin tap use

In all income groups, hand wash basin uses are the highest water users accounting for approximately 32% of the total water use (Figure 4.3). Similarly to showering hand wash basin water consumption is influenced by the number of times the basin is used.

As with shower, the flow rate from hand wash basin taps decreases with the increase in household income. This confirms that the high income group households are relatively new and fitted with water efficient appliances. The frequency of hand wash basin use rises with the increase in income. The duration of use is similar in low, medium and high income families. The duration of hand wash basin tap use for all income groups is about 60 seconds per event. When multiplied with the frequency of hand wash basin tap use, the total daily per capita tap duration becomes 9.68, 10.49 and 11.38 min/p/d for low, medium and high income households, respectively. The duration of the daily hand wash basin tap use obtained in this study is much higher than the values found in the literature of developed countries. It ranges between 6.66 and 8.33 min/p/d in Yarra valley, Australia (Roberts, 2005) and much lower than this (i.e., 2.73 min/p/d) in the Netherlands (Gato, 2006). The high tap duration can be attributed to additional water using activities in the Islamic culture (e.g., ablution before each prayer time).

4.4.3 Toilet flushing

In line with the observation made above, again high income group households appear to have water efficient toilet (5.4 l/fl) in comparison to low income households (6.0 l/fl). This increases the average daily per capita toilet consumption in low income group to 33.0 l/p/d, it being higher than that in medium (25.5 l/p/d) and high (22.5 l/p/d) income families.

The frequency of toilet per capita daily use was higher in low income families (5.4 fl/p/d) than that in medium (4.7 fl/p/d) and high (4.1 fl/p/d) income families. From the data presented in Table 4.2, it appears that in the medium and high income households water consumption for personal hygiene related activities is higher. This is reflected in higher frequencies of shower, clothes wash and hand wash basin use indicating an increased emphasis on cleanliness. The less emphasis (inability) on cleanliness in low income group may be a cause of increased water borne diseases; consequently the frequency of toilet use might increase. Another reason for lower toilet use frequency for high income group is the high number of people in employment working away from home during the day.

4.4.4 Dishwashing

Dishwashing accounted for the second highest end-use being approximately 14% of total water use in all income groups (Figure 4.3). Although, 7% of the 407 households own dishwasher, they still wash dishes manually. The daily water consumption for dishwashing is a function of flow rate, duration and number of washes. The frequency of washing dishes is same in all income groups, i.e., after each meal (breakfast, lunch and dinner). The flow rate of kitchen tap decreases with the increase in household income from 9.5 l/min in low income to 7.5 l/min in high income households (Table 4.2).

However, the variability in total water use for dishwashing between income groups is due to the duration of each dishwashing session, which is dependent on the number of dishes and indirectly the size of the family. For example, the duration of each wash in six occupants family for each income group was found to be 6.3, 9.3 and 10.5 min for low, medium and high income group, respectively.

4.4.5 Laundry

The main parameters to identify water consumption for laundry washing are the volume of water used per washing cycle and the frequency. The volume of water used in each wash is fixed depending upon the brand, style, and size of the washing machine in each house. The analysis shows there is a difference in the average volume of water used per wash between income groups, accounting approximately 160 l/wsl in medium and high income houses and much higher in low income (190 l/wsl) (Table 4.2). It looks that in comparison with lower income group; medium and higher income households have water efficient washing machines.

The second parameter (the frequency of laundry per household per week) can be influenced by the number of occupants. The collected data suggests that it rises with the increase in household income, indicating more emphasis on hygiene with increased income. Therefore, the difference in total amount of laundry water consumption is significantly high between income groups. It is 146, 235 and 310 l/hh/d in low, medium and high income families, respectively.

4.4.6 House washing

About 5% of the total water consumption is used for house washing (Figure 4.3). The house washing activities include floor washing, washroom and kitchen cleaning. The analysis shows that the frequency and duration of household washing increase with the rise in the household income. The frequency is 3.6, 4.8 and 5.6 wsh/w with duration of each wash approximately 8.4, 14.2 and 19.5 min in low, medium and high income households, respectively. This suggests that the emphasis on cleanliness and hygiene increases with the increase in the household income or due to the size of household area.

4.4.7 Cooking

According to the studies of the NRC (1989) and Black (1990), food preparations in both developed and developing countries would require about 10 to 20 l/p/d of water; for example, in Sri Lanka, daily per capita average water consumption for cooking is 16 l/p/d (Sivakumaran and Aramaki, 2010). The Duhok survey shows that average value for water required for food preparation lies within the values found in the literature. However, water consumption for food preparation increases with the increase in the family income, accounting 11.2, 12.9 and 16.3 l/p/d in low, medium and high income households, respectively (Table 4.2).

4.4.8 Garden watering

Outdoor water use (garden watering, car washing and swimming pool) is related to the size of the residential dwelling area (Gato, 2006). In terms of the frequency of garden watering, it is much lower in low income group than that in the medium and high income groups (Table 4.2). Most of the houses recorded only one irrigation event per week. This may be because of the timing of the survey, which was conducted during winter time. In order to quantify the seasonality impact, the survey was repeated during June (2015) to account for water consumption variations in the summer (Section 4.6).

The duration of each watering session in the high income group is the highest (approximately 2 hr/wtr). This appears to be mainly because of the larger garden area (average of 51.8 m^2) in comparison with low (9.3 m^2) and medium (22.6 m^2) income households. However, the flow rate from the outside tap for the garden watering is broadly similar (11.5 l/min) in all households regardless of their income group (Table 4.2).

Therefore, the total volume of water used for garden irrigation in high income households is clearly the highest (192 l/hh/d) with less consumption in medium (134 l/hh/d) and low (59 l/hh/d) income houses. However, the households may change their irrigation pattern in summer which varies seasonally and consequently increase garden watering use.

4.4.9 Vehicle washing

In terms of water use for vehicle washing, the highest consumer is medium income families (75.6 l/hh/w), which is probably because of less ownership in low income families (47.2 l/hh/w). On the other hand, people in high income households prefer their cars washed at washing services rather than doing it themselves (28.0 l/hh/w). Because of this, water consumption for vehicle washing in high income group is low. It can be seen from the data in Figure 4.4 that the average per capita water use for vehicle washing is relatively small in all income groups but this may increase in the summer season due to the frequent dust storms.

4.5 Statistical modelling of daily per capita water usage with household characteristics

Using the training set (70% of the surveyed households), statistical models are developed to estimate daily per capita water consumption as a function of household characteristics. The household characteristics were divided into demographic and physical characteristics. The detailed procedure applied for modelling daily per capita water consumption is explained in Section 3.4.4. The modelling techniques applied are multiple linear regression (STEPWISE) and evolutionary polynomial regression (EPR).

4.5.1 Models based on multiple linear regression (STEPWISE)

The presented procedure of STEPWISE multiple regression approach in Section 3.4.4.1 is applied to determine the best subset model for daily per capita water use estimation. Using the calibration (training) set of data, the relationships between household characteristics and per capita water consumption were calculated and the values of correlation coefficient (R) are shown in Table 4.4. From the table, it can be seen that the strongest relationship of per capita consumption is with the number of children in the household and per capita income.

Table 4.4 Correlation coefficients between household characteristics and per capita water consumption

		Correlation coefficient value (R)								
		Demographic characteristics				Physical characteristics				
		No. of children	No. of adult females	No. of adult males	No. of elders	No. of rooms	No. of floors	Total built-up area	Garden area	Income
Per capita water consumption (l/p/d)	All investigated households	-0.560	0.467	-0.474	-0.204	-0.028	-0.064	0.008	0.013	0.602
	Low income households	-0.745	-0.279	-0.263	-0.408	-0.773	0.000	-0.664	-0.361	0.777
	Medium income households	-0.808	0.467	-0.766	-0.270	-0.859	-0.638	-0.699	-0.330	0.844
	High income households	-0.501	0.196	-0.807	-0.254	-0.766	-0.532	-0.678	-0.443	0.803

Note: l/p/d=litres per capita per day

Using STEPWISE approach with the calibration set of data of whole investigated households, three models were developed based on demographic, physical and whole characteristics (i.e., Model 1, 2 and 3 in Table 4.5, respectively). The similar procedure is repeated using the calibration set of low, medium and high income households data. These models are shown in Table 4.5 and they are statistically significant ($p<0.05$).

The predictions from these models were plotted against the actual per capita water consumption values obtained from the study as shown in Figure 4.5. The figure shows that the trend-lines of validation and calibration set are relatively identical in all cases. Additionally, the R^2 value improves further when the water consumption data was disaggregated into low, medium and high income groups.

Table 4.5 Models and coefficients of determination (R^2) using multiple linear regression method (STEPWISE)

	Model	R^2	
		Calibration set	Validation set
All investigated households	Model based on demographic characteristics of the household $TW_w = 294.53 - 10.50 \times C_w + 15.23 \times AF_w - 13.50 \times AM_w - 14.85 \times E_w \quad \ldots (1)$	0.54	0.63
	Model based on physical characteristics of the household $TW_w = 294.69 - 27.86 \times RO_w - 31.76 \times F_w + 0.58 \times G_w + 0.49 \times I_w \quad \ldots (2)$	0.74	0.74
	Model based on all (demographic and physical) characteristics of the household $TW_w = 287.50 - 15.24 \times C_w - 11.03 \times AF_w - 24.48 \times AM_w - 20.06 \times E_w + 12.76 \times RO_w - 17.26 \times F_w + 0.43 \times G_w + 0.25 \times I_w \quad \ldots (3)$	0.87	0.88
Low income households	Model based on demographic characteristics of the household $TW_l = 324.43 - 22.26 \times C_l - 36.09 \times AF_l - 28.68 \times E_l \quad \ldots (4)$	0.88	0.82
	Model based on physical characteristics of the household $TW_l = 230.11 - 44.39 \times RO_l + 0.58 \times G_l + 1.00 \times I_l \quad \ldots (5)$	0.82	0.77
	Model based on all (demographic and physical) characteristics of the household $TW_l = 267.12 - 17.27 \times C_l - 25.01 \times AF_l - 20.22 \times E_l - 14.01 \times RO_l + 0.62 \times G_l + 0.54 \times I_l \quad \ldots (6)$	0.95	0.84
Medium income households	Model based on demographic characteristics of the household $TW_m = 416.05 - 18.69 \times C_m - 15.04 \times AF_m - 28.07 \times AM_m - 25.39 \times E_m \quad \ldots (7)$	0.92	0.93
	Model based on physical characteristics of the household $TW_m = 368.39 - 56.80 \times RO_m + 0.69 \times G_m + 0.55 \times I_m \quad \ldots (8)$	0.86	0.87
	Model based on all (demographic and physical) characteristics of the household $TW_m = 418.81 - 17.52 \times C_m - 21.19 \times AF_m - 20.29 \times AM_m - 24.85 \times E_m - 26.98 \times RO_m + 29.05 \times F_m + 0.50 \times G_m + 0.26 \times I_m \quad \ldots (9)$	0.96	0.94
High income households	Model based on demographic characteristics of the household $TW_h = 422.56 - 11.97 \times C_h - 10.92 \times AF_h - 23.15 \times AM_h - 16.57 \times E_h \quad \ldots (10)$	0.84	0.92
	Model based on physical characteristics of the household $TW_h = 268.18 - 24.73 \times RO_h + 0.40 \times I_h \quad \ldots (11)$	0.76	0.73
	Model based on all (demographic and physical) characteristics of the household $TW_h = 317.01 - 10.46 \times C_h - 10.81 \times AF_h - 19.93 \times AM_h - 11.59 \times E_h + 0.20 \times G_h + 0.21 \times I_h \quad \ldots (12)$	0.90	0.92

where:
TW = daily per capita water consumption (l/p/d),
C = number of children in the household,
AF = number of adult females in the household,
AM = number of adult males in the household,
E = number of elders in the household,
RO = number of rooms in the household,
F = number of floors in the household,
HH = total household built-up area (m^2),
G = total garden area (m^2),
I = per capita monthly income (Thousand ID),
w = whole sample,
l = low income households,
m = medium income households, and
h = high income households.

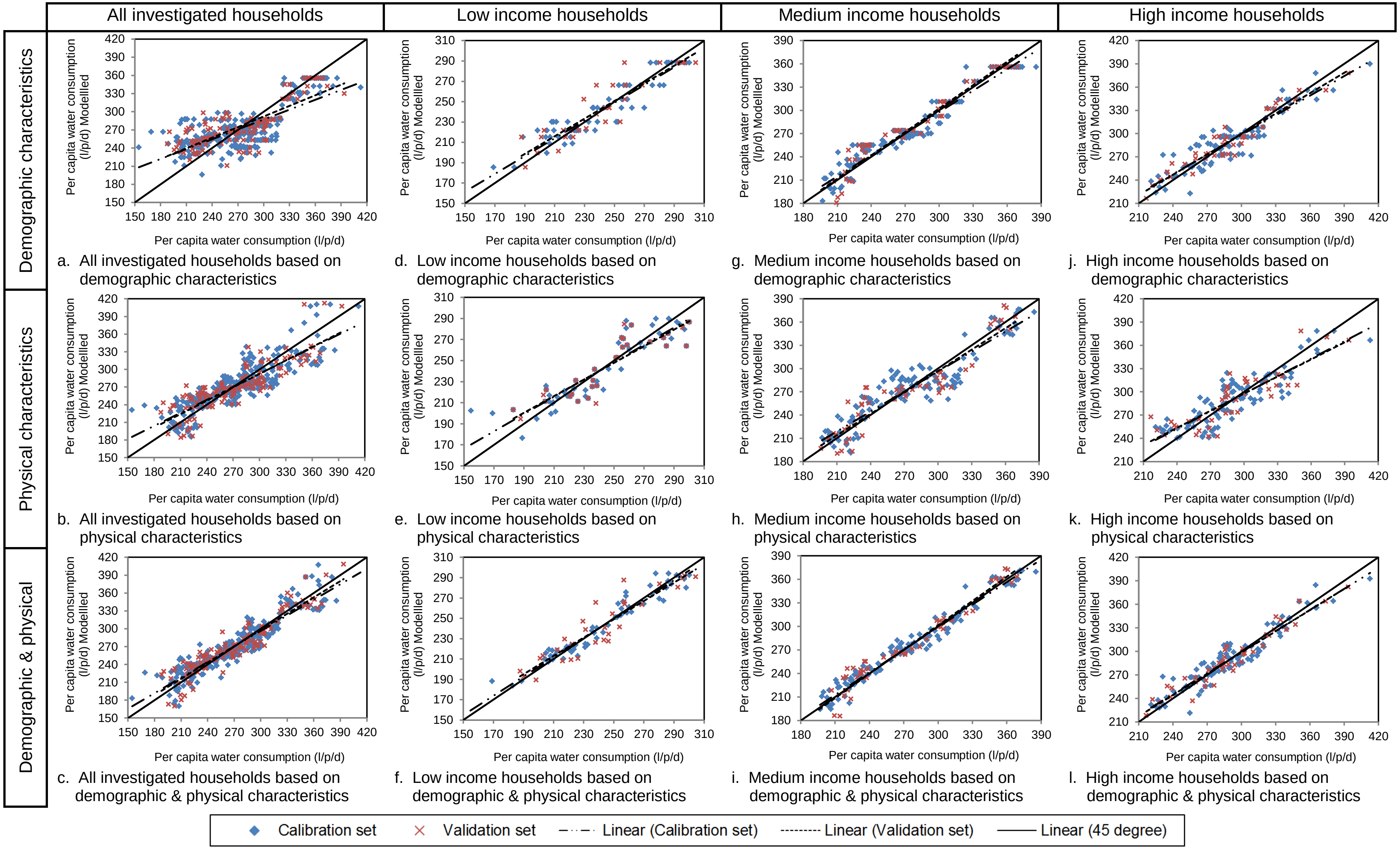


Figure 4.5 Relationship between actual and predicted daily per capita water consumption using STEPWISE method

4.5.2 Models based on evolutionary polynomial regression (EPR)

The procedure of evolutionary polynomial regression explained in Section 3.4.4.2 is applied to model daily per capita water consumption as a function of household characteristics. Using the calibration set of data (70% of the whole investigated households) with the EPR MOGA-XL tool, three nonlinear regression models are developed as a function of demographic, physical and all characteristics (Model 1, 2 and 3 in Table 4.6, respectively). Similarly, three mathematical models were developed for each income group (low, medium and high) using their calibration set of data as shown in Table 4.6. These models have been chosen due to achieving the highest coefficient of determination (R^2).

The predictions from EPR models were plotted against the actual per capita water consumption values as shown in Figure 4.6. For all models in this figure, the trend-lines of calibration and validation set of data are relatively identical. From this figure, it can be concluded that the R^2 value increases when the models were developed for each household income group. Moreover, the R^2 value increases significantly when all (demographic and physical) household characteristics were included in the model rather than only demographic or physical characteristics.

Table 4.6 Models and coefficients of determination (R^2) using evolutionary polynomial regression method (EPR)

	Model	R^2	
		Calibration set	Validation set
All investigated households	Model based on demographic characteristics of the household $TW_w = 235.05 - 16.87 \times E_w^{0.5} + 32.6 \times AF_w - 0.63 \times AF_w^{2.5} \times AM_w - 4.65 \times C_w^2 \times AF_w^{0.5} + 1.27 \times C_w^{2.5} \times AM_w^{0.5}$ ……… (1)	0.63	0.69
	Model based on physical characteristics of the household $TW_w = -173.7 + 45.37 \times I_w^{0.5} + 0.22 \times G_w^{0.5} \times I_w^{0.5} - 0.29 \times RO_w \times I_w + 6.2 \times 10^{-6} \times RO_w^3 \times I_w^2$ ……… (2)	0.85	0.83
	Model based on all (demographic and physical) characteristics of the household $TW_w = 4.32 + 33.99 \times I_w^{0.5} - 0.75 \times I_w - 15.19 \times E_w - 11.57 \times AF_w^{0.5} \times AM_w - 12.26 \times C_w$ ……… (3)	0.92	0.93
Low income households	Model based on demographic characteristics of the household $TW_l = 299.88 - 11.13 \times AF_l^2 - 8.14 \times AF_l^{2.5} \times AM_l^{2.5} \times E_l^{0.5} - 8.26 \times C_l^{0.5} \times AM_l^{1.5} - 2.89 \times C_l^2 \times AF_l^{0.5} + 0.53 \times C_l^2 \times AF_l^3 \times AM_l^2 \times E_l^3$ ……… (4)	0.90	0.89
	Model based on physical characteristics of the household $TW_l = 102 + 13.4 \times RO_l^{0.5} \times I_l^{0.5} + 0.03 \times RO_l \times HH_l \times G_l^{0.5} \times I_l^{0.5} - 13.2 \times RO_l^2 \times F_l^3 \times G_l^{0.5} - 4.3 \times 10^{-9} \times RO_l^{0.5} \times HH_l^3 \times G_l^{1.5} \times I_l - 0.5 \times RO_l^3 \times I_l^{0.5}$ ……… (5)	0.85	0.79
	Model based on all (demographic and physical) characteristics of the household $TW_l = 279.8 - 0.03 \times AM_l^{2.5} \times E_l \times RO_l^{4.5} \times F_l^2 + 10^{-11} \times AM_l^5 \times RO_l^5 \times HH_l^2 \times G_l^{0.5} \times I_l^{1.5} + 0.002 \times AF_l^{2.5} \times AM_l \times RO_l \times F_l \times I_l^{1.5} - 0.02 \times AF_l^5 \times F_l^{3.5} \times HH_l^{0.5}$ $\times I_l^{0.5} - 0.41 \times C_l^{0.5} \times AM_l^{1.5} \times RO_l \times HH_l^{0.5}$ ……… (6)	0.97	0.83
Medium income households	Model based on demographic characteristics of the household $TW_m = 567.9 - 65.11 \times AM_m^{0.5} - 6.23 \times AM_m \times E_m^{2.5} - 104.86 \times AF_m^{0.5} - 14.3 \times C_m^{1.5} + 0.21 \times C_m^3 \times AF_m^{0.5} \times AM_m^{0.5}$ ……… (7)	0.96	0.95
	Model based on physical characteristics of the household $TW_m = 557 + 0.0002 \times F_m^2 \times HH_m^{0.5} \times I_m^2 + 6.6 \times RO_m^{0.5} \times HH_m^{0.5} + 6 \times 10^{-11} \times RO_m^{0.5} \times F_m^3 \times G_m^{0.5} \times I_m^{4.5} - 146.8 \times RO_m^{1.5} - 7.1 \times RO_m^{1.5} \times F_m^{0.5} \times I_m^{0.5}$ ……… (8)	0.89	0.89
	Model based on all (demographic and physical) characteristics of the household $TW_m = 336.6 + 0.001 \times G_m^{0.5} \times I_m^{1.5} - 0.002 \times AF_m^{0.5} \times AM_m \times E_m^2 \times I_m^{1.5} - 3.26 \times AF_m^{0.5} \times AM_m^2 - 16.8 \times C_m \times AF_m^{0.5} + 2.5 \times 10^{-12} \times C_m^4 \times AF_m^2 \times AM_m^2 \times RO_m$ $\times F_m^5 \times HH_m^2 \times I_m^{0.5}$ ……… (9)	0.98	0.94
High income households	Model based on demographic characteristics of the household $TW_h = 403.87 - 39.83 \times AM_h^{1.5} + 13.48 \times AM_h^2 - 7.75 \times AF_h^{0.5} \times E_h - 0.35 \times AF_h^3 - 1.85 \times C_h^{1.5} \times AF_h$ ……… (10)	0.86	0.92
	Model based on physical characteristics of the household $TW_h = 25.3 + 10^{-5} \times HH_h^3 - 5 \times 10^{-10} \times F_h^{0.5} \times HH_h^3 \times I_h^{1.5} + 7 \times 10^{-10} \times F_h^{3.5} \times HH_h^3 \times G_h^{0.5} \times I_h^{0.5} - 3 \times 10^{-7} \times RO_h^{1.5} \times F_h \times HH_h^3 + 4 \times 10^{-5} \times RO_h^{2.5} \times I_h^2$ .. (11)	0.79	0.76
	Model based on all (demographic and physical) characteristics of the household $TW_h = 227 + 7.2 \times I_h^{0.5} - 27 \times AM_h + 0.0006 \times AM_h^{1.5} \times RO_h^{0.5} \times G_h^{0.5} \times I_h - 3 \times 10^{-9} \times AF_h^{1.5} \times AM_h^{0.5} \times E_h^{0.5} \times F_h^{2.5} \times I_h^3 - 0.009 \times C_h^{1.5} \times AF_h^{1.5} \times RO_h \times I_h^{0.5}$. (12)	0.91	0.92

where:

TW =	daily per capita water consumption (l/p/d),	RO =	number of rooms in the household,	w =	whole sample
C =	number of children in the household,	F =	number of floors in the household,	l =	low income households,
AF =	number of adult females in the household,	HH =	total household built-up area (m^2),	m =	medium income households, and
AM =	number of adult males in the household,	G =	total garden area (m^2),	h =	high income households.
E =	number of elders in the household,	I =	per capita monthly income (Thousand ID),		

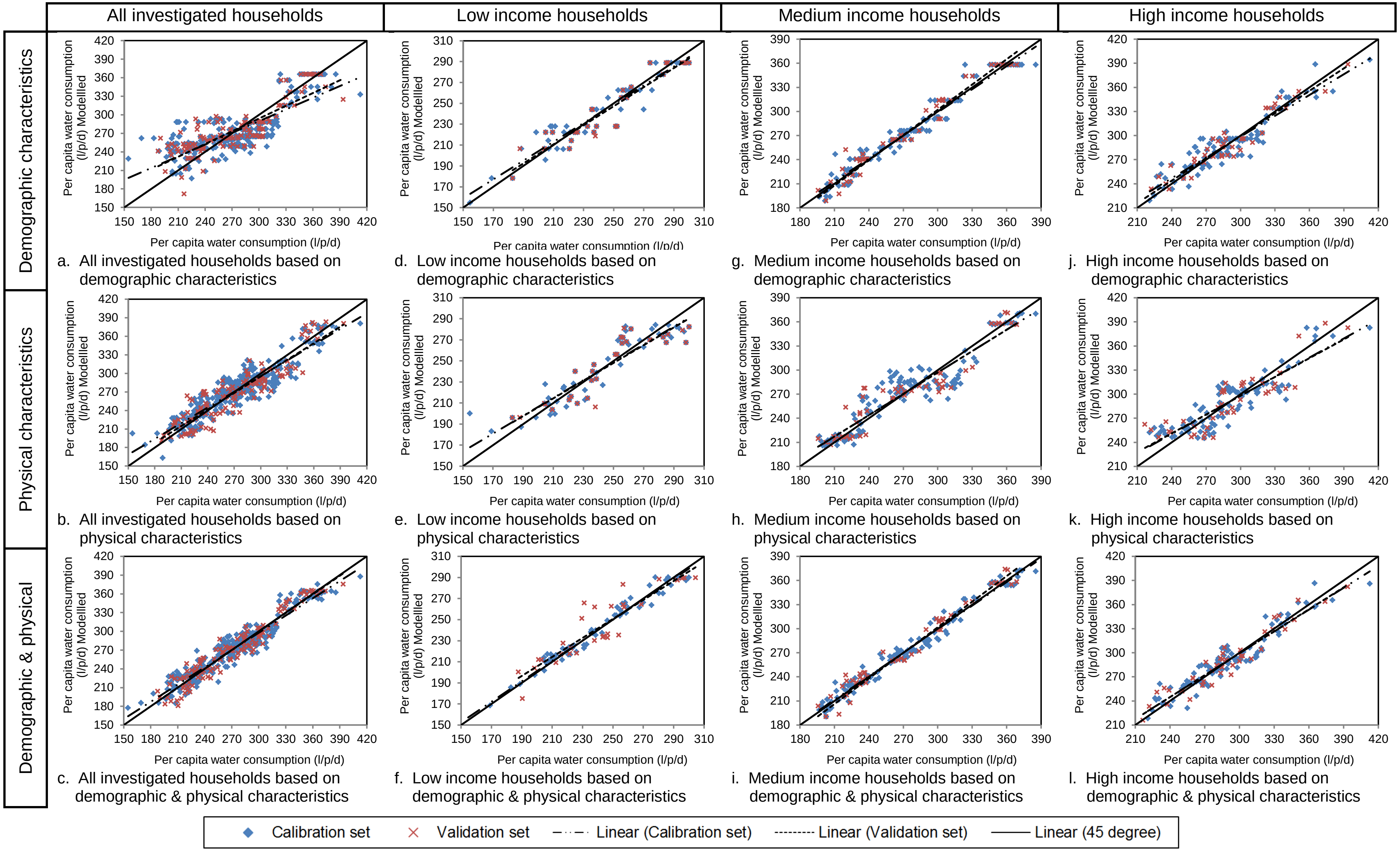


Figure 4.6 Relationship between actual and predicted daily per capita water consumption using EPR method

4.5.3 Comparison of models

The twelve models developed in EPR and STEPWISE were compared using R^2 values as shown in Table 4.7. From the table it can be seen that the R^2 values of both modelling techniques are relatively high (over 0.8) for most cases. However, the R^2 of EPR based model improved considerably when the number of polynomial terms and the exponents was increased. On the other hand, STEPWISE based model also offers good predictions.

Both modelling approaches suggest the strong influence of demographic characteristics on per capita water consumption when the data was disaggregated into household income groups and the role of household physical characteristics is minimal.

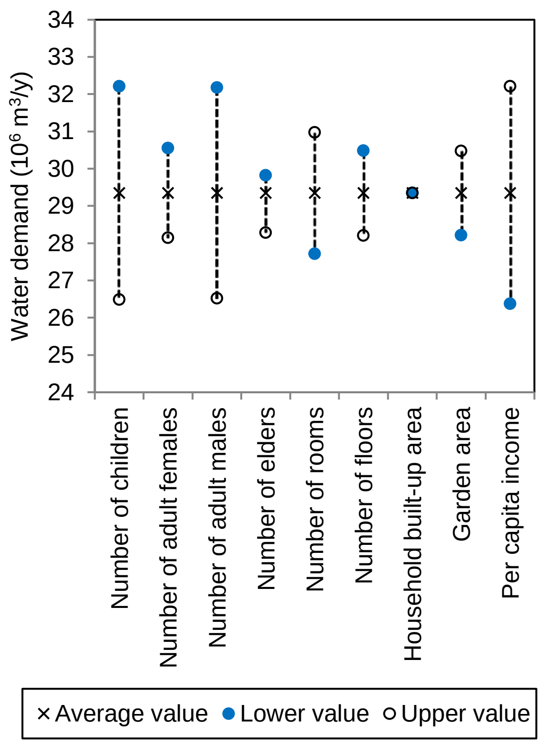
Table 4.7 Coefficients of determination (R^2) of the final regression models

	Per capita water consumption modelled with household demographic characteristics		Per capita water consumption modelled with household physical characteristics		per capita water consumption modelled with demographic and physical characteristics	
	STEPWISE	EPR	STEPWISE	EPR	STEPWISE	EPR
All investigated households	0.54	0.63	0.74	0.85	0.87	0.92
Low income households	0.88	0.90	0.82	0.85	0.95	0.97
Medium income households	0.92	0.96	0.86	0.89	0.96	0.98
High income households	0.84	0.86	0.76	0.79	0.90	0.91

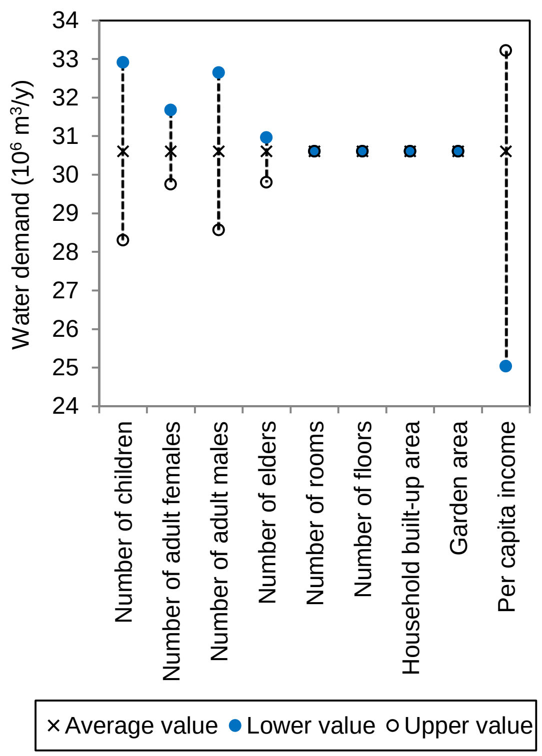
4.5.4 Sensitivity analysis

Sensitivity measures to what extent the magnitude of a dependent variable (i.e., estimated total water demand) could change over the practical range of variation of the input independent variables (e.g., household characteristics) (Jacobs, 2004). Sensitivity analysis provides insights into the applicability of the model under consideration. Additionally, it identifies the effect of each household characteristic on the estimated water demand.

Jacobs (2004) considered the range of variation of each input parameter (i.e., household characteristic) as the standard deviation below and above the average (Section 3.7). The sensitivity for each input parameter is tested using three values (i.e., average, average + standard deviation and average - standard deviation). The low and high value of each household characteristic are calculated using the average and standard deviation statistics in Table B2.2 (Appendix B2). The calculated upper and lower value of each household characteristic have been used with STEPWISE and EPR developed models to estimate the annual total water demand as shown in Figure 4.7. The figure shows that the developed models are very sensitive to per capita income, number of children and number of adult males in the households.



A. STEPWISE model



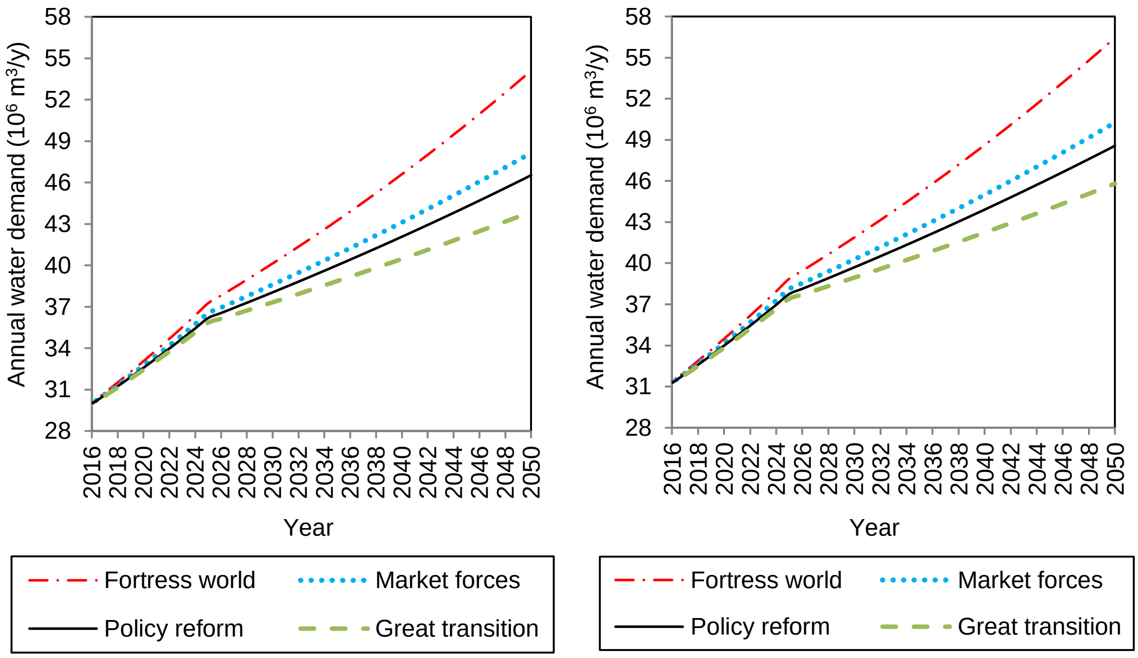
B. EPR model

Figure 4.7 Sensitivity analysis of input parameters for STEPWISE and EPR based domestic water demand prediction models for Duhok

4.5.5 Model application

The implication of four alternative scenarios on the domestic water demand estimation is explored. These are Market Forces, Fortress World, Great Transition and Policy Reform. Section 3.9.1 presents the definition and more detailed information of these scenarios.

The expected annual growth rate values of all indicators for GSG scenarios relevant to the Middle East region are shown in Table 3.23. Using average annual growth rate values of population, income and built-up area indictor with STEPWISE and EPR developed models, annual demand has been simulated for 35 years ahead and is shown in Figure 4.8. The figure shows that of the four considered scenarios, the total domestic water demand would be highest in the Fortress World scenario. This is mainly because of relatively higher increase in population and built-up area in this scenario (Table 3.23).



A. STEPWISE model **B. EPR model**

Figure 4.8 Impact of GSG scenarios on total domestic water demand

4.6 Seasonal variability of water consumption (summer survey):

In the extant literature, the influence of variability of household characteristics and appliance efficiency on water end-use is widely addressed (Foekema and Engelsma, 2001; Inman and Jeffrey, 2006; Blokker et al., 2009; Pakula and Stamminger, 2010; Richter, 2011). However, the variability of household water end-uses between winter and summer has not been investigated thoroughly (Rathnayaka et al., 2015). Daily water consumption during summer season can vary between 1.2 and 1.6 times the average annual daily consumption (Jacobs and Haarhoff, 2004b). In order to capture the seasonal variability of water consumption, the full survey explained in Section 3.3.1 was repeated in summer season in June 2015 (Appendix A).

The summer survey is conducted in the same sample of households which were selected for winter survey. This is to ensure consistency of data and also to eliminate variations between samples due to the occupant's behaviour and household characteristics. The summer survey was distributed to 419 households and the answers received from 404 households. Information were collected on the frequency, duration of use and flow rate of each water end-use. Additionally, water consumption by evaporative air-coolers was also recorded.

4.6.1 Average per capita water consumption in summer season

The frequency distribution and cumulative frequency of per capita average water consumption for all surveyed households during winter and summer are shown in Figure 4.9. From this figure, it can be seen that the number of households which consumes more than 250 l/p/d is increased from 65% in winter to 91% of households in summer. Further analysis of summer survey shows that the daily per capita average water consumption increases to 333 l/p/d during summer months compared to that in winter season (271 l/p/d) (Table C3.1 and C3.5 in Appendix C3). These values of both seasonal surveys are consistent with those of KRSO (2014), which showed that per capita consumption ranges between 283 and 343 l/p/d over the year.

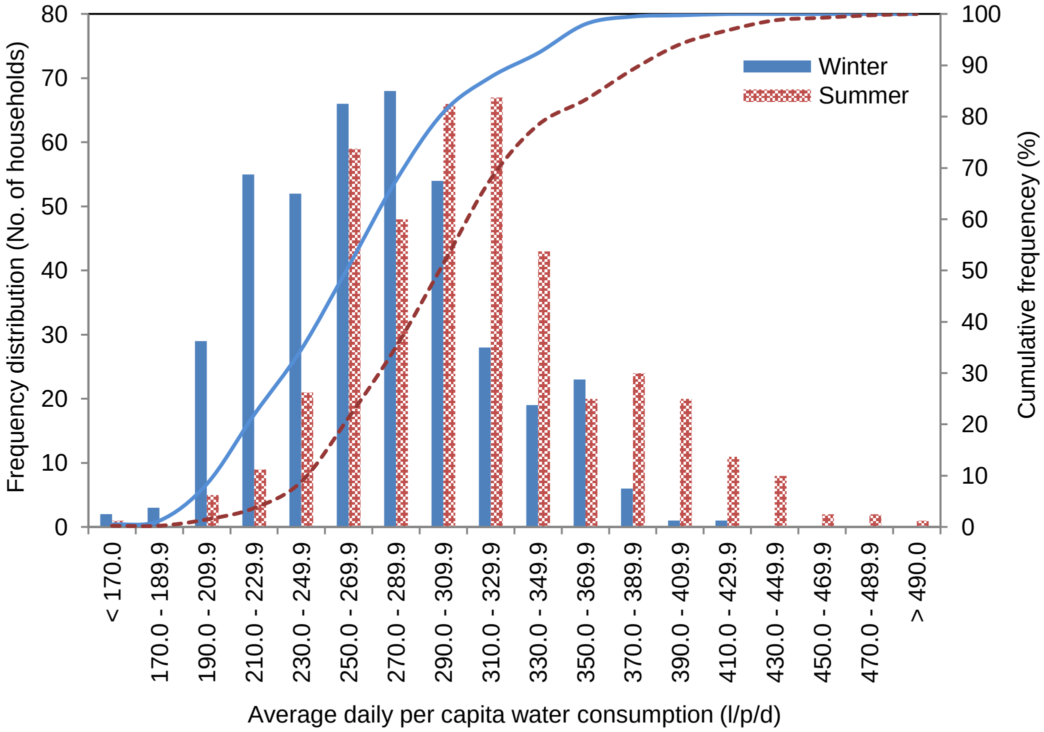
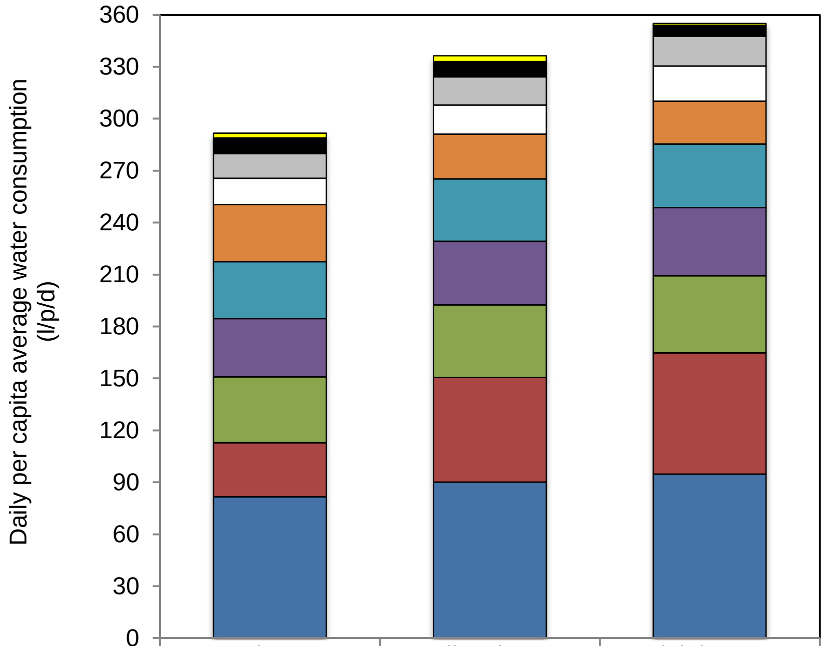


Figure 4.9 Seasonal variability of per capita average water consumption

4.6.2 Average per capita water end-uses in summer season

Figure 4.10 shows the average per capita water end-uses during summer season in low, medium and high income households. Apart from evaporative air-cooler use and toilet flushing, all water end-uses increase with the increase in per capita income. Similarly to the winter survey, the analysis of water consumption in summer season clearly shows that the highest water end-use is hand wash basin tap (Figure 4.10). Garden watering is the second highest water end-use during summer months while it is relatively low in winter season (Figure 4.4). Air-cooler water consumption accounts only 2-3% of average per capita consumption in all income households (Figure 4.10).



	Low income	Medium income	High income
Vehicle washing	2.76	3.23	1.04
Air cooler	9.05	8.99	6.28
House washing	14.29	16.25	17.14
Cooking & drinking	15.20	16.71	20.31
Toilet flushing	32.99	25.94	24.81
Dishwashing	32.98	36.07	36.69
Laundry	33.56	36.71	39.46
Shower	38.12	42.02	44.54
Garden watering	31.15	60.27	69.91
Taps	81.73	90.27	94.88

Note: All the data presented in this table are in liter per capita per day.

Figure 4.10 Average per capita water end-uses in summer season

4.6.3 Seasonal variability of water end-use

To examine the seasonal variability of water end-uses, a two-tailed t-test is used at 95% confidence interval as shown in Table 4.8. It can be seen from this table that the p value of toilet flushing and dishwashing is higher than 0.05. This means there is no statistically significant difference between the consumption in winter and summer season. This finding is in agreement with Rathnayaka et al.'s (2015) findings which showed that each of toilet flushing, dishwashing, bathing and laundry are less sensitive for seasonality. On the other hand, the other water end-uses (i.e., hand wash basin taps, shower, laundry, cooking, garden watering, house washing and vehicle washing) have statistically significant difference ($p<0.05$) between the two seasons (Table 4.8).

Table 4.8 Statistical comparison of water end-uses between winter and summer

Water end-use	Average water consumption (l/p/d)		t value	Significant (2-tailed) (p)
	Winter	Summer		
Hand wash basin tap	87.32	89.91	-2.00	0.046 *
Shower	36.81	42.00	-8.99	0.000 *
Dishwashing	36.41	35.58	1.15	0.251 **
Clothes washing	34.37	36.94	-7.61	0.000 *
Toilet flushing	26.15	27.15	-1.34	0.181 **
Garden watering	18.99	56.98	-26.23	0.000 *
Cooking and drinking	15.66	18.57	-26.91	0.000 *
House washing	13.94	16.11	-8.15	0.000 *
Vehicle washing	1.21	2.38	-6.97	0.000 *
Evaporative cooler	0	8.08	-12.53	0.000 *

* = significantly difference between winter and summer

** = not significantly difference between winter and summer

During summer months, indoor water use (274.3 l/p/d) including evaporative air-cooler consumption slightly increases compared to winter consumption (250.7 l/p/d) (Table 4.8). Whereas, outdoor use (garden watering and vehicle washing) shows a high seasonal variation from 20.2 l/p/d in winter to 59.4 l/p/d in summer. The seasonal variability of water end-uses in the surveyed households is shown in Figure C4.1 to Figure C4.10 (Appendix C4).

The summary of average values of water end-use parameters (frequency, duration of use and flow rate) is illustrated in Table 4.9. The table shows the comparison of these parameters between winter and summer season. Statistical analysis (mean, median, standard deviation, variance, minimum, maximum, skewness and confidence interval) for parameters presented in Table 4.9 are shown in Tables C3.1-C3.8 (Appendix C3). The key findings are explained in the following sections.

Table 4.9 Seasonal variability of mean values of water end-use parameters

End-use	Parameter/variable	Unit	Overall survey		Low income		Medium income		High income	
			Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Shower	Frequency of showering per capita per day	shw/p/d	0.49	0.97	0.34	0.92	0.47	0.97	0.61	1.00
	Duration of each shower	min/shw	8.64	4.84	8.87	4.41	8.72	4.72	8.38	5.27
	Flow rate	l/min	9.02	9.02	9.48	9.48	9.27	9.27	8.39	8.39
Hand wash basin tap	Frequency of using taps per capita per day	tpu/p/d	10.46	10.97	9.96	10.46	10.31	10.87	10.98	11.42
	Duration of tap use	sec/tpu	60.81	59.63	58.31	57.04	61.02	59.73	62.20	61.24
	Flow rate	l/min	8.14	8.14	8.13	8.13	8.24	8.24	8.02	8.02
Toilet flushing	Frequency of toilet use per capita per day	fl/p/d	4.65	4.78	5.39	5.39	4.66	4.76	4.14	4.41
	Water use in each flush	l/fl	5.51	5.51	6.01	6.01	5.36	5.36	5.38	5.38
Dish washing	Frequency of washing dishes per day	wsh/d	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
	Duration of running water in each wash	min/p/wsh	1.47	1.43	1.16	1.16	1.50	1.41	1.64	1.64
	Flow rate	l/min	8.36	8.36	9.54	9.54	8.39	8.39	7.54	7.54
Laundry	Frequency of laundry per day	wsh/d	1.48	1.58	0.83	0.88	1.46	1.58	1.93	2.05
	Volume of water per washing load	l/wsl	167.32	167.32	190.02	190.02	161.01	161.01	160.28	160.28
House washing	Frequency of house washing per day	wsh/d	0.69	0.79	0.51	0.66	0.69	0.80	0.80	0.92
	Duration of each wash	min/p/wsh	2.13	2.13	1.79	1.80	2.10	2.10	2.38	2.39
	Flow rate	l/min	9.80	9.8	12.20	12.19	9.88	9.88	8.12	8.12
Vehicle washing	Frequency of vehicles washing per day	wsh/d	0.07	0.14	0.06	0.13	0.10	0.21	0.04	0.08
	Duration of each wash	min/wsh	1.39	1.39	1.81	1.82	1.34	1.35	1.10	1.10
	Flow rate	l/min	12.82	12.82	12.79	12.79	12.75	12.75	13.08	13.07
Garden watering	Frequency of garden watering per day	wtr/d	0.13	0.38	0.07	0.19	0.14	0.43	0.14	0.40
	Duration of each watering	min/wtr	13.01	13.04	13.11	13.11	11.88	11.88	14.49	14.49
	Flow rate	l/min	11.67	11.67	11.64	11.63	11.94	11.93	11.34	11.34
Cooking	Volume of water consumed in cooking	l/p/d	13.66	14.57	11.20	12.18	12.85	13.71	16.33	17.32
Air-cooler	Water consumption of each air-cooler/hour	l/hr	0	3.88	0	2.83	0	4.20	0	5.06
	Per capita water consumption for air-cooler	l/p/d	0	8.08	0	9.05	0	8.99	0	6.28
Total daily per capita water consumption		l/p/d	271.39	333.26	241.22	291.83	272.18	336.46	290.36	356.63

Note: l=liter, p=person, d=day, min=minute, sec=second, bt=bath, shw=shower, tpu=tap use, fl=flushes, wsh=washes, wsl=washing load, wtr=watering

Hand wash basin tap use

In agreement with the winter survey results, the analysis of summer water consumption shows that hand wash basin tap is the most predominant water end-use in the surveyed households (Table 4.9). In terms of flow rate and duration of the use of hand wash basin tap, the difference is negligible between winter and summer season (Table 4.9). On the other hand, the frequency of use slightly increases from 10.46 in winter to 10.97 tpu/p/d during summer months. Suggesting, the increase in temperature increases the frequency of tap use for hand and face washing.

Further analysis shows that the number of surveyed households which consumes more than 100 l/p/d is increased from 111 in winter to 129 households in summer (Figure C4.2 in Appendix C4).

Shower

Rathnayaka et al. (2015) suggested that the shower water use is driven by behavioural and weather factors. The comparison of summer and winter surveys showed that the number of households consuming higher than 40 l/p/d for showering is increased from 37% in winter to 54% of households in summer season (Figure C4.1 in Appendix C4). This can be due to the higher temperature during summer months compared to winter. The increase of shower water use is attributed to the increased frequency of showering in summer season as shown in Table 4.9. The frequency of showering in summer increases to approximately double (0.97 shw/p/d).

However, the average duration of each shower decreases from 8.64 min in winter to 4.84 min in summer, with no changes in shower flow rate (Table 4.9). This finding is consistent with Rathnayaka et al.'s (2015) results which showed the relationship between average shower duration and seasonality.

Dishwashing

Table 4.8 shows that the daily per capita water consumption for dishwashing is not significantly different between winter and summer. The frequency of washing dishes, duration of running water in each washing session and the flow rate are similar in winter and summer season (Table 4.9). The frequency distribution of water use for dishwashing during summer is nearly identical with the winter use (Figure C4.3 in Appendix C4).

Laundry

The survey analysis shows that the volume of water use per washing load (167.3 l/wsl) is similar in both seasons as shown in Table 4.9. However, the frequency of laundry per day increased from 1.48 in winter to 1.58 wsh/d during summer months. This also concurs with the statistical analysis presented in Table 4.8. Hence, the daily per capita average water consumption for laundry is higher in summer than in winter (Table 4.8). Approximately, 90% of households tend to use more than 25 l/p/d for laundry in winter while their consumption increases to more than 30 l/p/d in summer period (Figure C4.4 in Appendix C4).

Toilet use

The analysis of water consumption in summer season shows that the frequency of toilet use per person per day increases only slightly to 4.78 fl/p/d, compared to the average value in winter (4.65 fl/p/d) (Table 4.9). The average amount of water use in each flush is the same in both seasons. Accordingly, the daily per capita water use for toilet is not significantly different between winter and summer period (Table 4.8).

House washing

In terms of water consumption for house washing, the flow rate and duration of each washing session do not vary throughout winter and summer (Table 4.9). However, the frequency of house washing increases from 0.69 in winter to 0.79 wsh/d during summer season (Table 4.9). This may be due to the impact of dry weather in summer season which causes more sand storms than that in the other seasons (Sissakian et al., 2013).

Cooking

The daily per capita average water consumption for cooking purposes increases from 13.66 in winter to 14.57 l/p/d during summer months (Table 4.9). This represents significant statistical difference (Table 4.8). Further analysis shows that the surveyed households which use more than 14 l/p/d for cooking is increased from 38% in winter to 50% of households in summer (Figure C4.7 in Appendix C4).

Vehicle washing

Similarly to house washing, dishwashing and hand wash basin tap, the flow rate and duration of vehicle washing remained fairly the same during winter and summer season (Table 4.9). However, the average per capita water consumption for vehicle washing is significantly greater during summer compared to winter (Table 4.8). For example, the number of households which use more than 3 l/p/d for vehicle washing tends to increase from 13% in winter to 43% of households in summer (Figure C4.9 in Appendix C4). This is due to the increased frequency of vehicle washing in summer (0.14 wsh/d) (Table 4.9).

The probable explanation for increased vehicle washing sessions is the increase of sand storms during summer season. In 2008, over 122 dust storms were recorded for summer season by Iraqi Ministry of Environment (Sissakian et al., 2013). Owing to shift in climate change patterns, the number of dust storms is expected to increase to approximately 300 per year during the next decade (Kobler, 2013). Hence, water consumption for vehicle washing is likely to increase.

Garden watering

Within water end-uses, the highest difference between winter and summer consumption is attributed to garden watering (Table 4.8). The number of surveyed households which consumes more than 40 l/p/d is only 1% during winter while it increases to 81% of households in summer (Figure C4.8 in Appendix C4). On the other hand, the flow rate and duration of each watering session do not change throughout winter and summer (Table 4.9). This finding is consistent with Rathnayaka et al. (2015) who showed that the daily temperature does not affect the flow rate and average duration of watering. Other factors that can affect the duration of watering include garden size, rainfall pattern and irrigation method.

<u>Evaporative air-cooler</u>

The extant studies assume that the evaporative air-cooler water use is weather dependent (Rathnayaka et al., 2015). The analysis of summer survey shows that the evaporative air-cooler water consumption accounts approximately 3% of daily per capita consumption (Table 4.8). Air-cooler water consumption decreases with the increase in per capita income; 9.05, 8.99 and 6.28 l/p/d in low, medium and high income households, respectively (Table 4.9). This is because the dependency on air-conditioners for space cooling increases with the increase in per capita income.

4.7 Conclusions

In this chapter, household water consumption at end-use level in the city of Duhok was analysed. The influence of household characteristics (demographic and socio-economic) on the water consumption was investigated. Using multiple linear regression (STEPWISE) and evolutionary polynomial regression (EPR) method, 24 statistical models were developed to estimate the daily per capita water consumption as a function of household characteristics. The developed models have been trained and validated. The STEPWISE and EPR regression models were compared. Sensitivity of the developed models to household characteristics was analysed. Finally, the best fit models were used to predict the future water demand for the city under the impact of four future scenarios. The key messages from the analysis in this chapter are:

- The per capita water consumption increases with the rise in household income and decreases with the increase in the household occupancy.
- Frequency of all water end-uses increases with the increase in per capita income except for toilet usage. Toilet use frequency in low income households is higher than that in medium and high income groups.
- The duration of hand wash basin tap in Duhok is much higher than the typical values in the developed world. This indicates an additional water use activities (e.g., ablution) via the hand wash basin tap.
- Flow rate from different water end-uses decreases with increase in the per capita income, suggesting that households in high income group are relatively new and fitted with water efficient appliances.

- Per capita consumption decreases with the increase in male adults, elders and children but increases with the increase in number of adult females in a household. Additionally, the change in the number of elders and children has identical effect on per capita consumption.
- Using the collected data, it is possible to predict per capita water consumption. The quality of prediction improves when the full data was disaggregated into low, medium and high income group households.
- The models based on EPR offer a marginal improvement in the predictions quality.
- The demographic characteristics provide more accurate predictions of per capita water consumption than the predictions resulting from the use of physical characteristics of the investigated households.
- Of the investigated scenarios, domestic water demand is expected to be highest in the Fortress World scenario. This is because of the expected growth rate of population and built-up area is high in this scenario.
- The frequency and per capita consumption of all water end-uses increase in summer, except for toilet flushing and dishwashing. The frequency of toilet flushing and dishwashing remains broadly unchanged during summer and winter.
- Seasonal variation does not seem to influence the flow rate of different appliances and end-uses.
- The duration of showering decreases in summer while the duration of other water end-uses does not vary throughout winter and summer.
- Within water end-uses, the highest difference between winter and summer consumption appears because of garden watering.

CHAPTER FIVE: ENERGY CONSUMPTION

5.1 Introduction

Residential energy use represents approximately 35% of global energy use (Daioglou et al., 2012) and can be much higher in some cities; for example, 75% in Burkina Faso (Hermann et al., 2012) and 80% in the city of Duhok, Iraq (General Directorate of Duhok Electricity, 2014). Therefore, residential energy use plays a key role in global energy-related environmental problems, such as climate change and resource scarcity (Daioglou et al., 2012).

Although, household energy consumption in developing countries is much lower than that in developed countries, it is expected to increase due to economic growth and rising per capita income (ESCAP, 2009). Human increase their energy use for different household tasks instead of doing them manually with neglecting economic and environmental implications, in order to gain time, convenience, comfort and mobility (Anker-Nilssen, 2003). Energy use at a household level is highly dependent upon the activities of the occupants and their associated use of electrical appliances (Richardson et al., 2010; Branco et al., 2004).

Weather plays an important role in the fluctuation of energy consumption throughout the year (Sailor, 2001). For example, household energy demand for space heating and cooling varies with the temperature and humidity. Therefore, the seasonal variability of energy consumption should be taken into account while estimating the annual demand.

This chapter aims to investigate the impact of household characteristics (socio-economic and physical) on energy consumption, using a survey conducted during winter season in Duhok. The survey aimed to capture energy consumption at end-use level at a household scale. The chapter also presents statistical regression models developed to estimate daily per capita energy consumption as a function of household characteristics using STEPWISE and EPR regression techniques. Finally, the household energy consumption survey is repeated during summer season. The results of summer and winter surveys are compared to explore the seasonal variability of energy consumption.

5.2 Influence of household characteristics on energy consumption

The influence of household characteristics on energy consumption is investigated using the data of the survey conducted during winter season in Duhok households. The results and main finding are summarised in the following sections (5.2.1 to 5.2.4).

5.2.1 Influence of household characteristics on the total average energy consumption

The influence of household characteristics on the total household energy consumption is investigated. The results found, in general, the relationship between the total average electricity consumption (kWh/hh/d) and the physical characteristics (e.g., household built-up area, number of rooms and number of floors) is stronger than that with the demographic characteristics (e.g., number of children, elders, adult males and adult females in the household) as shown in Figure 5.1. The correlation coefficients for the relationships in this figure are over 0.7. The relationships between demographic characteristics and household total average electricity consumption are shown in Appendix D1.

The average daily electricity consumption per one m^2 of household built-up area was approximately 0.34 kWh/m^2 and per one room in the household was around 24.8 kWh/room. Likewise, the daily household electricity consumption increases with the increase in number of floors in the household (R = 0.84).

Moreover, the increase in the household occupancy (i.e., number of people in the household) leads to increase in the total daily electricity consumption (R = 0.81). This finding is consistent with those of other researches, such as (Zhou and Teng, 2013) and (Genjo et al., 2005).

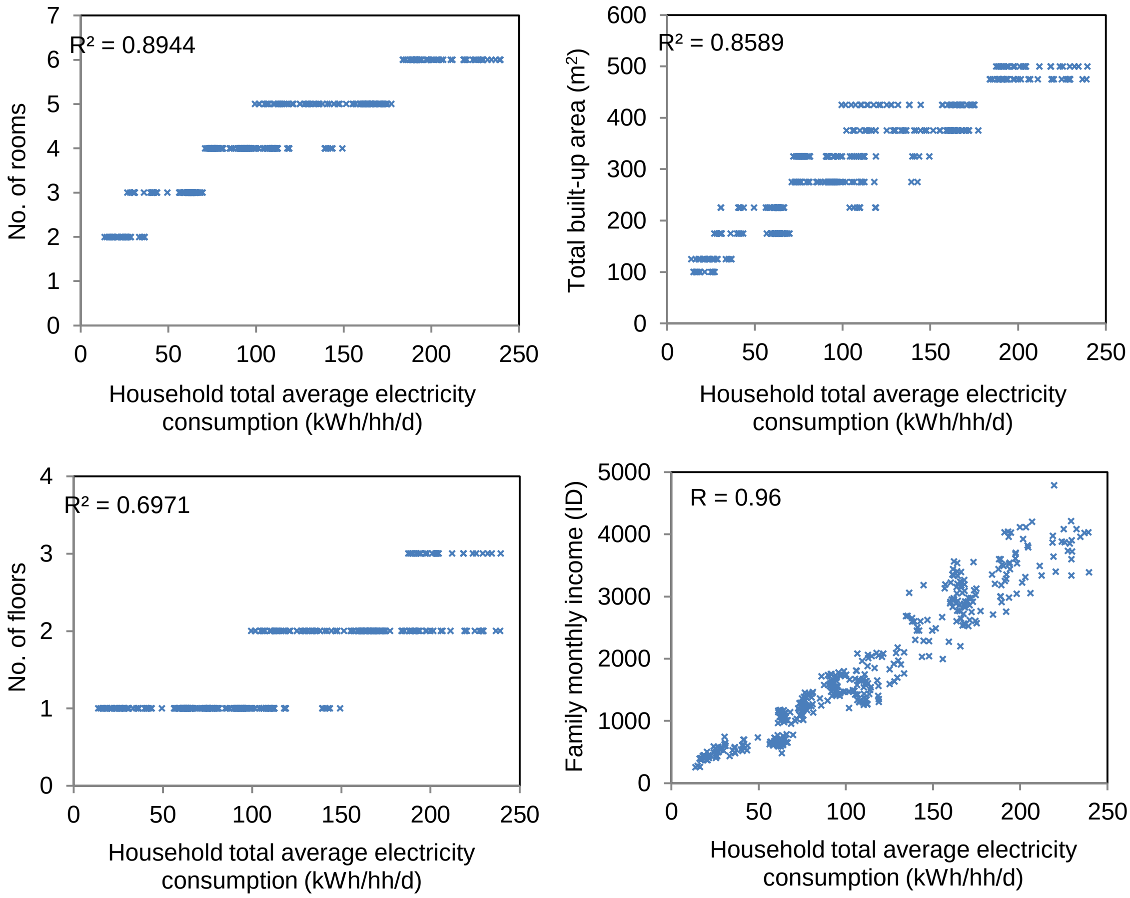


Figure 5.1 Household energy consumption-household characteristics relationship

5.2.2 Influence of household characteristics on per capita average energy consumption

The energy data analysis based on daily per capita consumption shows that per capita consumption in the houses (15.9 kWh/p/d) is much higher than that in the apartments (8.0 kWh/p/d). This decline in per capita electricity usage suggests the recently built multi-story apartments are highly insulated and also supplied with more energy efficient water heaters. The similar finding is reported by Bedir et al. (2013) that the apartments are less energy consumption than houses.

On the other hand, the average per capita consumption increases with the increase in number of rooms, number of floors and total built-up area of the household (Figure D2.6, Figure D2.7 and Figure D2.8 in Appendix D2). Additionally, per capita consumption increases with the increase in number of adults and elders in the household; however, it decreases with the increase in number of children. The relationships between household characteristics and daily per capita average energy consumption are shown in Appendix D2.

5.2.3 Influence of household characteristics on the average per capita energy end-uses

The analysis of demographic characteristics of the household shows there is a fairly strong relationship between number of adult females in the household and each energy end-use. All end-uses increase with the increase in number of adult females in the household (Table 5.1). However, the energy consumption of electronic and refrigeration appliances as well as kerosene use decrease with the increase in number of adult males in the household.

The increase in the number of children and elders in the household decreases the per capita LPG consumption for cooking and electricity use for water heating (Table 5.1). The increase in number of elders in the household leads to a decrease in per capita electricity use by washing appliances. Moreover, per capita electricity consumption for lighting and refrigeration appliances decreases with increasing number of children in the household (Table 5.1).

Table 5.1 Summary of relationship between household characteristics and average per capita energy end-uses

Energy end-uses	Household characteristics								
	No. of occupants	No. of children	No. of adult females	No. of adult males	No. of elders	No. of rooms	No. of floors	Total built-up area	Monthly per capita income
Space heating	0.47	0.06	0.58	0.33	0.15	0.79	0.68	0.78	0.92
Lighting	0.31	-0.03	0.47	0.22	0.12	0.65	0.47	0.64	0.81
Wet appliances	0.28	0.02	0.58	0.05	-0.03	0.57	0.35	0.56	0.67
Refrigeration appliances	-0.01	-0.25	0.62	-0.21	0.01	0.35	0.25	0.35	0.66
Electronic appliances	0.03	-0.14	0.39	-0.09	0.06	0.28	0.22	0.30	0.52
Cooking appliances	0.27	0.07	0.44	0.11	-0.09	0.57	0.43	0.58	0.74
Miscellaneous appliances	0.34	-0.12	0.72	0.23	0.06	0.62	0.48	0.60	0.70
Water heating	-0.11	-0.27	0.53	-0.28	-0.09	0.25	0.03	0.25	0.62
LPG	-0.03	-0.32	0.49	0.00	-0.03	0.41	0.39	0.42	0.73
Kerosene	-0.62	-0.53	0.16	-0.54	-0.22	-0.35	-0.46	-0.34	0.20

In terms of household physical characteristics, the analysis clearly shows that daily per capita energy consumption increases with the increase in number of rooms in the household (Figure 5.2) and also household built-up area (Figure 5.3). Similarly, Bedir et al. (2013) found that the number of rooms in

Dutch dwellings is positively correlated with electricity consumption. Nielsen (1993) showed that the increase in floor area in Denmark, increases household electricity consumption.

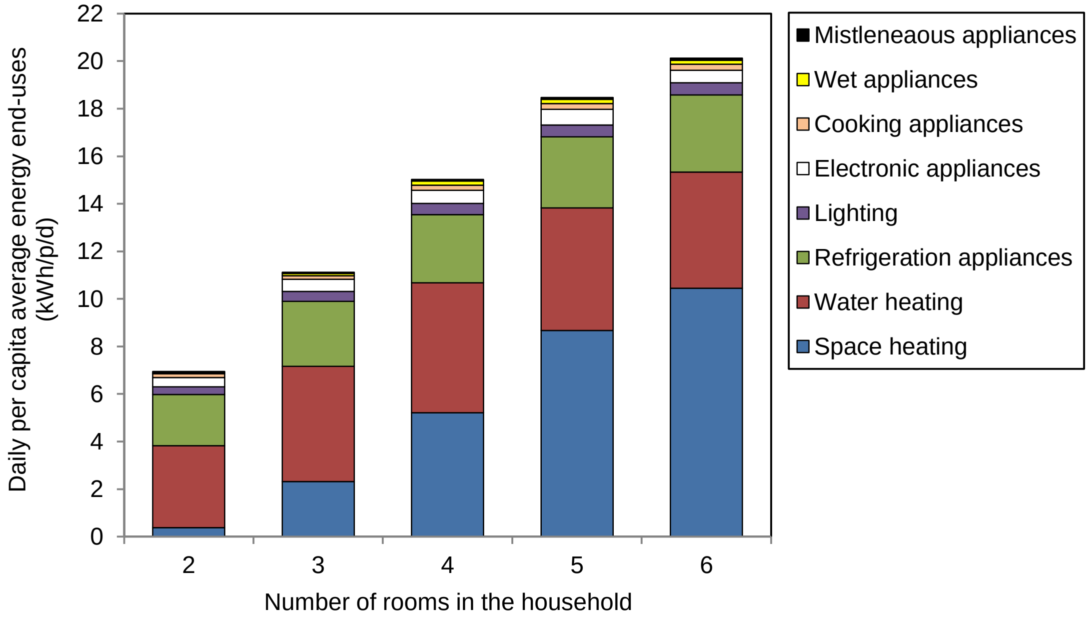


Figure 5.2 Relationship between energy end-uses and number of rooms in the household

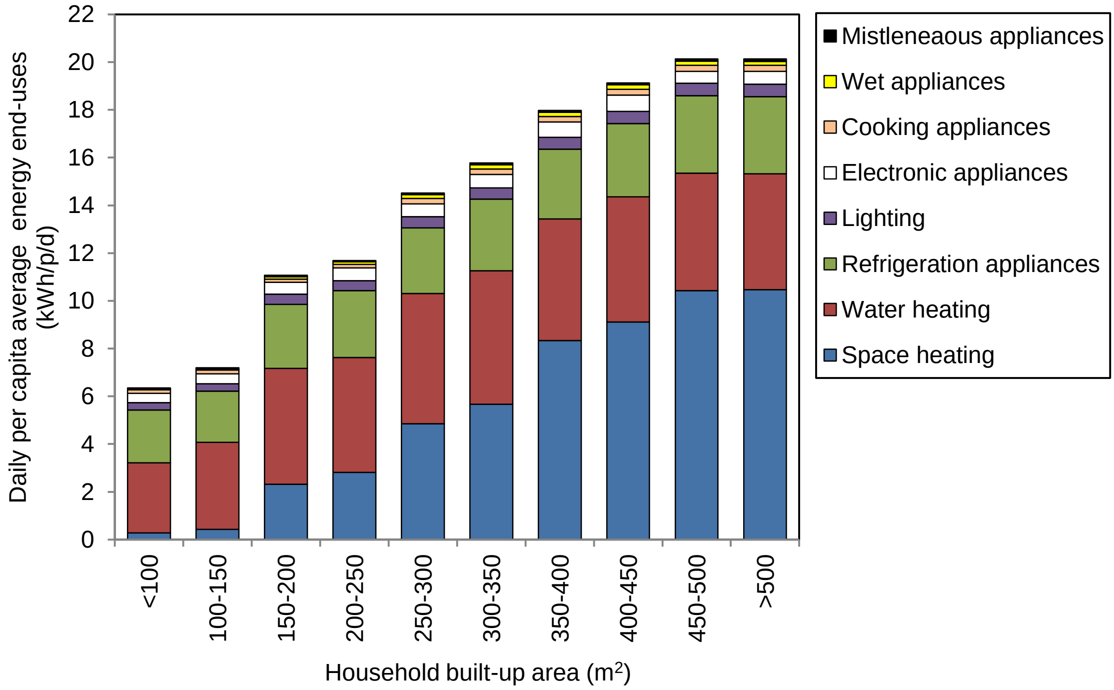


Figure 5.3 Relationship between energy end-uses and household built-up area

5.2.4 Influence of per capita income on the average energy consumption

The energy consumption in low, medium and high income group of the surveyed households is analysed, individually (Section 3.4.2). The analysis of this classification shows that the average per capita electricity consumption sharply increases with the increase in monthly per capita income (i.e., 8.1, 13.8 and 21.7 kWh/p/d in low, medium and high income group, respectively). This finding is in agreement with Wyatt's (2013) finding. He showed that the electricity consumption of the highest income group in the UK is higher than the lowest income.

The proportion of energy end-use for cooking, electronic, wet and miscellaneous appliances is approximately the same in all income groups. However, there is a significant difference in the proportion of other energy end-uses (i.e., space heating, water heating and refrigeration appliances) between the income groups (Figure 5.4). The space heating use accounts approximately 14% of the total electricity use in low income households and much higher in the high income group (51%). In contrast, the proportion of water heating in low income group (47%) is significantly higher than that in the high income households (25%). The proportion of refrigeration appliances energy consumption is also higher in low income group (27%) than that in the high income households (16%).

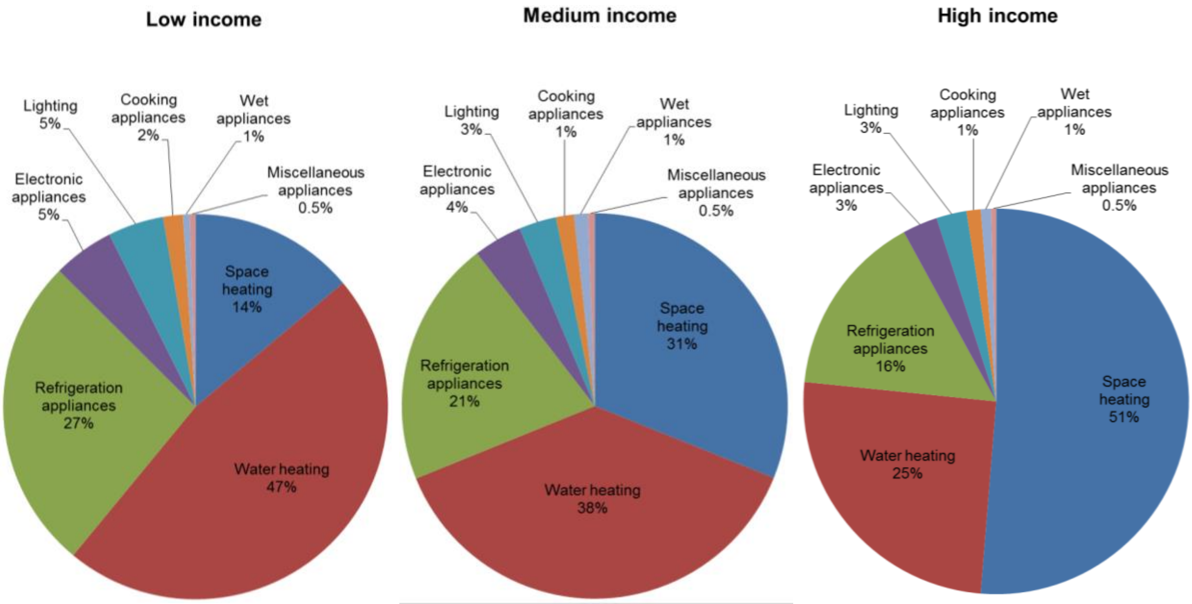
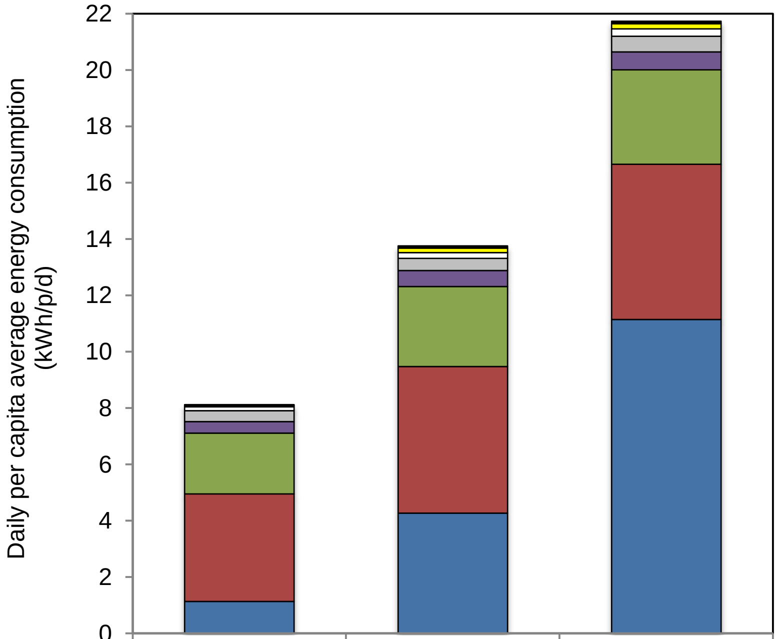


Figure 5.4 Summary of percentages of energy end-uses in all income groups

5.3 Average per capita energy end-uses

The per capita total energy consumption is disaggregated into a number of end-uses: space heating, water heating, lighting, cooking, refrigeration, electronic, wet and miscellaneous appliances. The average use of each of these end-uses per person per day in all income groups is presented in Figure 5.5. It can be seen in this figure that there is a considerable variation in daily per capita energy end-uses between the income groups. The highest energy end-use may be attributed to the space heating, water heating and refrigeration appliances (Figure 5.5). In terms of space heating use, daily electricity consumption per occupant in high income households is about 10 times higher than that in low income households. However, the electricity consumption for cooking, wet and miscellaneous appliances is relatively low (i.e., less than 0.3 kWh/p/d) and is not significantly different between the income groups.



	Low income	Medium income	High income
Miscellaneous appliances	0.040	0.078	0.092
Wet appliances	0.046	0.159	0.186
Cooking appliances	0.134	0.207	0.260
Lighting	0.381	0.431	0.551
Electronic appliances	0.417	0.562	0.640
Refrigeration appliances	2.152	2.846	3.356
Water heating	3.826	5.195	5.505
Space heating	1.129	4.275	11.148

Note: All the data presented in this table are in kWh per capita per day.

Figure 5.5 Impact of per capita income on the average energy end-uses

Kerosene use for space heating in both low and high income households is approximately 1.6 l/p/d, with a slightly higher consumption in medium income group (1.7 l/p/d). The low consumption in the high income households can be due to the heavy reliance on the electricity for space heating. This is in consistent with Arnold et al. (2006) and Kebede (2006) finding. They stated that households tend to shift their energy source from traditional to modern fuels with the increase in their income. Moreover, LPG use is relatively low in all income groups due to its use only for cooking purposes: 0.23, 0.25 and 0.31 l/p/d in low, medium and high income households, respectively.

5.4 Influence of per capita income on energy end-uses

The summary of average values of per capita energy end-use parameters for each appliance (e.g., number of appliances, the duration of use and wattage) is shown in Table 5.2. This table shows the comparison between these parameters in low, medium and high income households. Statistical analyses of these parameters for full survey, low, medium and high income groups are shown in Tables D3.1-D3.4 (Appendix D3). The key findings are explained in the following sections (5.4.1 to 5.4.8).

5.4.1 Space heating

The energy used for space heating varies and it depends on many factors. Swan et al. (2011) stated that it is influenced by climate change and house insulation factors. Liao and Chang (2002) indicated that the households with elder members consume higher energy for space heating than the households with only adult members. However, elders can be less energy users for water heating requirements than the adults because of their fewer water use activities. Richardson et al. (2010) listed the occupant's availability and their activity within a dwelling as another factor.

Space heating appliances (e.g., electrical heaters and air-conditioners) are one of the largest electricity end-uses in the surveyed households, although other sources of energy are used for space heating, such as kerosene and LPG. Throughout the survey, the daily per capita average electricity consumption for space heating was found to be 1.1, 4.3 and 11.2 kWh/p/d in low, medium and

Table 5.2 Summary of mean values of energy end-use parameters

End-use	Appliances	Parameters	Unit	Overall survey	Low income	Medium income	High income
Space heating	Electrical heater	Number of electrical heaters in use in a household	No.	0.87	0.79	0.86	0.94
		Duration of use of each electrical heater per capita per day	hr/p/d	0.98	1.36	0.97	0.78
		Wattage of each electrical heater	W	1101.72	1023.03	1017.88	1244.2
	Kerosene heater	Number of kerosene heaters in use in a household	No.	2.69	1.79	2.86	3.06
		Duration of use of each kerosene heater per capita per day	hr/p/d	2.44	3.59	2.25	1.92
		Volume of kerosene use by each heater per hour	l/htr/hr	0.28	0.27	0.28	0.28
		Volume of kerosene use by each heater per day	l/htr/d	4.13	4.27	4.01	4.18
	Gas heaters	Number of gas heaters in use in a household	No.	0.00	0.00	0.00	0.00
		Number of days each gas bottle is last for gas heater	d				
	Air conditioners	Number of air conditioners in use in a household	No.	1.36	0.01	1.23	2.43
		Duration of use of each air conditioner per capita per day	hr/p/d	1.17	0.56	1.01	1.37
		Wattage of each air conditioner	W	3118.2	2150.00	3034.09	3231.65
Lighting	Spot lights	Number of spot lights in use per day in a household	No.	9.04	5.10	7.97	13.01
		Duration of use of each spot light per capita per day	hr/p/d	1.48	1.92	1.45	1.24
	Tube lights	Number of tube lights in use per day in a household	No.	4.03	2.60	4.02	5.00
		Duration of use of each tube light per capita per day	hr/p/d	1.48	1.92	1.44	1.24
Wet appliances	Water pumps	Number of water pumps in use in a household	No.	0.50	0.28	0.73	0.35
		Duration of use of each water pump per capita per week	hr/p/w	0.76	0.62	0.76	0.82
		Wattage of each water pump	W	381.48	381.54	379.92	385.63
	Dishwasher	Number of dishwashing machines in use in a household	No.	0.00	0.00	0.00	0.00
		Duration of use of each dishwasher per capita per week	hr/p/w				
		Wattage of each dishwasher	W				
	Clothes washer	Number of clothes washing machines in use in a household	No.	0.94	0.75	1.00	1.00
		Energy consumption per washing cycle	kWh/wsl	0.51	0.23	0.61	0.53
Water heating	Electrical water heater	Total consumption of heated water per capita per day	l/p/d	85.85	65.80	89.35	94.69
		Total energy consumption for water heating per capita per day	kWh/p/d	4.99	3.83	5.19	5.51

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, W=Watt, wsl=clothes washing load, min=minute

Continue

Table 5.2 Summary of mean values of energy end-uses parameters

End-use	Appliances	Parameters	Unit	Overall survey	Low income	Medium income	High income
Refrigeration appliances	Chest-freezer	Number of chest-freezers in a household	No.	1.08	0.37	1.03	1.60
		Wattage of each chest-freezer	W	384.18	381.20	383.01	387.63
	Fridge-freezer	Number of fridge-freezers in a household	No.	1.44	1.00	1.39	1.81
		Wattage of each fridge-freezer	W	294.20	293.04	294.32	294.82
Electronic appliances	TV	Number of TVs in use in a household	No.	2.04	1.30	2.01	2.55
		Duration of use of each TV per capita per day	hr/p/d	1.51	2.09	1.43	1.24
		Wattage of each TV	W	175.10	125.11	191.05	187.99
	Radio	Number of radios in use in a household	No.	0.15	0.00	0.14	0.27
		Duration of use of each radio per capita per day	hr/p/d	0.40		0.39	0.40
		Wattage of each radio	W	92.46		94.40	91.18
	Computer	Number of computers in use in a household	No.	1.11	0.93	0.85	1.55
		Duration of use of each computer per capita per day	hr/p/d	0.43	0.61	0.46	0.28
		Wattage of each computer	W	134.03	131.47	135.00	134.64
	Video record	Number of video records in use in a household	No.	0.00	0.00	0.00	0.00
		Duration of use of each video record per capita per day	hr/p/d				
		Wattage of each video record	W				
	CD player	Number of CD players in use in a household	No.	0.18	0.00	0.02	0.50
		Duration of use of each CD player per capita per day	hr/p/d	0.11		0.10	0.11
		Wattage of each CD player	W	32.54		32.88	32.11
	Play station	Number of play stations in use in a household	No.	0.38	0.00	0.38	0.62
		Duration of use of each play station per capita per day	hr/p/d	0.16		0.14	0.18
		Wattage of each play station	W	168.50		169.10	168.02
Cooking appliances	Electrical hob	Number of electrical hobs in use in a household	No.	0.00	0.00	0.00	0.00
		Duration of use of each electrical hob per capita per day	hr/p/d				
		Wattage of each electrical hob	W				

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, W=Watt, wsl=clothes washing load, min=minute

Continue

Table 5.2 Summary of mean values of energy end-uses parameters

End-use	Appliances	Parameters	Unit	Overall survey	Low income	Medium income	High income
Cooking appliances	Electrical oven	Number of electrical ovens in use in a household	No.	0.94	0.75	1.00	1.00
		Duration of use of each electrical oven per capita per week	hr/p/w	0.49	0.39	0.44	0.60
		Wattage of each electrical oven	W	2827.34	2802.90	2841.48	2821.58
	Electrical kettle	Number of electrical kettles in use in a household	No.	0.59	0.45	0.65	0.62
		Duration of use of each electrical kettles per capita per day	min/p/d	0.88	0.91	1.00	0.72
		Wattage of each electrical kettle	W	2467.63	2465.85	2468.42	2467.44
	Microwave oven	Number of microwave ovens in use in a household	No.	0.00	0.00	0.00	0.00
		Duration of use of each microwave oven per capita per day	min/p/d				
		Wattage of each microwave oven	W				
	Toaster	Number of toasters in use in a household	No.	0.00	0.00	0.00	0.00
		Duration of use of each toaster per capita per day	min/p/d				
		Wattage of each toaster	W				
	Gas hob	Number of gas hobs in use in a household	No.	1.00	1.00	1.00	1.00
		Number of days each gas bottle is last for cooking	d	16.11	25.12	15.81	10.51
	Kerosene hob	Number of kerosene hobs in use in a household	No.	0.00	0.00	0.00	0.00
		The amount of kerosene use for cooking per day	l/p/d				
Miscellaneous appliances	Hair dryer	Number of hair dryers in use in a household	No.	1.42	1.00	1.44	1.65
		Duration of use of each hair dryer per capita per week	min/p/w	1.56	1.15	1.34	2.12
		Wattage of each hair dryer	W	1372.48	1335.87	1378.98	1388.49
	Vacuum cleaner	Number of vacuum cleaners in use in a household	No.	0.95	0.79	1.00	1.00
		Duration of use of each vacuum cleaner per capita per week	hr/p/w	0.18	0.10	0.17	0.22
		Wattage of each vacuum cleaner	W	1087.24	1093.15	1106.25	1060.07
	Sewing machine	Number of sewing machines in use in a household	No.	0.90	0.79	0.93	0.93
		Duration of use of each sewing machine per capita per week	hr/p/w	0.26	0.27	0.26	0.26
		Wattage of each sewing machine	W	100.05	99.78	99.72	100.62
	Iron	Number of irons in use in a household	No.	1.00	1.00	1.00	1.00
		Duration of use of each iron per capita per week	hr/p/w	0.21	0.11	0.22	0.24
		Wattage of each iron	W	1276.90	1290.22	1269.03	1278.06

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, W=Watt, wsl=clothes washing load, min=minute high income households, respectively. The difference in space heating consumption between the income groups is a result of high ownership level for air-conditioners in high-income households (2.4 air-conditioners/hh) compared to other income groups, as well as using the air-conditioners for a longer duration (10.9 hr/hh/d) than medium (6.6 hr/hh/d) and low income (5.0 hr/hh/d) houses.

In terms of using kerosene for space heating, the difference was not significant between medium (11.4 l/hh/d) and high-income (12.8 l/hh/d) families; although, the space that requires heating in high-income households is larger than that in the medium income households. Most of the space heating in high income group is achieved through air-conditioners powered by electricity. In low income households the kerosene consumption for space heating is about 7.6 l/hh/d. The amount of kerosene use by each heater is relatively the same in all income groups (i.e., ranged between 0.27 and 0.28 l/htr/hr) with duration of use approximately 15 hr/htr/d. There were no gas heaters recorded in all income groups.

5.4.2 Water heating

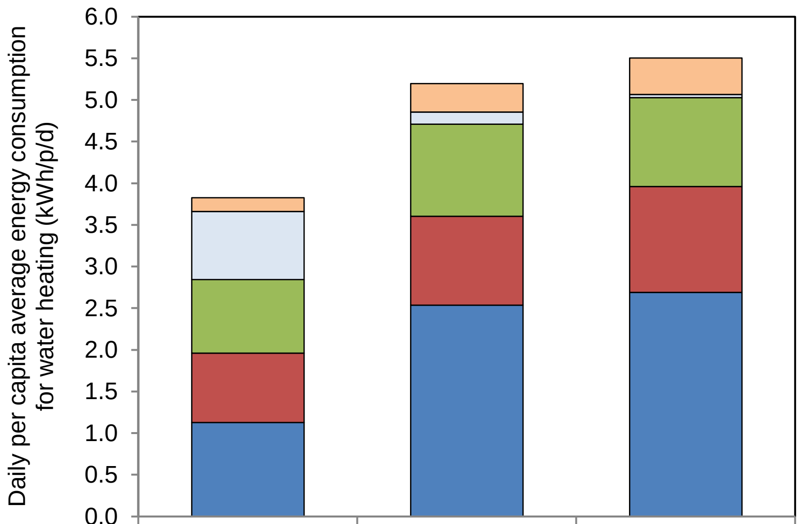
The average temperature of water supplied in Duhok is approximately 12 ºC during the cold season (Duhok Directorate of Seismology and Meteorology, 2015). The water temperature at the outlet of heater (T_{out}) has been measured in four households in Duhok. The temperature ranged between 60 and 67 ºC. The average value of 62 ºC has been used in Equation 3.7. Therefore, in order to achieve the preferred tap water temperature (40 ºC), it is assumed that 50% of the water used for indoor water end-uses (i.e., showering, hand wash basin tap usage, dishwashing, laundry and cooking) requires heating (Figure 3.10).

Per capita average hot water consumption for each end-use is calculated based on the proportions in given Figure 3.10 and the results of water consumption survey Figure 4.4. The results of per capita average hot water consumption for each end-use for all surveyed households, low, medium and high-income groups are shown in Table 5.3. The proportion of hot water consumption accounts approximately 27% of the total per capita consumption in low income households and slightly higher (33%) in medium and high income groups.

Using the values in Table 5.3 with Equation 3.7, per capita average electricity consumption for water heating is calculated (Figure 5.6). The results show that the difference in the quantity of electricity consumption is significant between the income groups: 3.8, 5.2 and 5.5 kWh/p/d in low, medium and high income households, respectively. This is due to increase the quantity of water consumption with the increase in per capita income (Figure 4.4). The highest energy consumption for water heating is attributed to the tap usage (Figure 5.6). This is mainly because of the fact that the highest proportion of water consumption is via taps (Figure 4.3).

Table 5.3 Average values of daily per capita average hot water consumption

	Per capita hot water consumption (l/p/d)				
	Showering	Hand wash basin taps	Dishwashing	Laundry	Cooking
All surveyed households	18.63	39.06	17.91	4.49	5.76
Low income households	14.37	19.36	15.20	14.04	2.84
Medium income households	18.34	43.64	18.99	2.53	5.86
High income households	21.84	46.29	18.35	0.65	7.57



	Low income	Medium income	High income
Cooking	0.165	0.340	0.440
Laundry	0.816	0.147	0.038
Dishwashing	0.883	1.104	1.067
Showering	0.835	1.066	1.269
Taps	1.125	2.537	2.691

Note: All the data presented in this table are in kWh per capita per day.

Figure 5.6 Summary of per capita energy consumption for water heating for each end-use in all income groups

On the other hand, the energy consumption for water heating for laundry decreases with the increase in per capita income (Figure 5.6). This is due to the high ownership level for clothes washer with internal water heater in medium (85% of households) and high (100% of households) income groups while water is heated separately in the most of low income households (91%).

5.4.3 Refrigeration appliances

The third highest electricity usage (Figure 5.4) in the surveyed households is attributed to refrigeration appliances (chest-freezer and fridge-freezer), accounting for approximately 2.2, 2.9 and 3.4 kWh/p/d in low, medium and high-income households, respectively (Figure 5.5).

In all income groups the duration of daily use of refrigeration appliances is same (24 hr/d) and also there is no significant difference in the appliances' wattage between the income groups. The average wattage is 381, 383 and 388 for chest-freezer and 293, 294 and 295 for fridge-freezer in low, medium and high income groups, respectively (Table 5.2). However, the household ownership for double refrigeration appliances is prominent from the survey, especially in the high income households, which increase the energy consumption of refrigeration appliances.

5.4.4 Lighting

The daily energy consumption for artificial lighting depends on the daylight hours and seasons (Yao and Steemers, 2005). It might be higher during the winter season due to the short daylight hours. In the north of Iraq the average daylight hours is around 10.5 hr in winter season and considerably longer (13.5 hr) in summer season (Time and Date, 2015). Daily duration of using lights in Duhok survey is reported as per household. These values were then converted to per capita consumption using the occupancy data as presented in Table 5.2. The survey analysis shows that the average daily duration of using the lights was around 8.8 hr/hh/d in low income households with a slightly longer duration in medium income (9.5 hr/hh/d) and high income (9.9 hr/hh/d) households. However, the duration of using lights may decrease during summer time.

In the surveyed households, the common types of lighting bulbs are spot and tube lights (fluorescent lights). The average number of recorded spot light bulbs is approximately double compared to the number of tube lights in all income groups (Table 5.2). The total number of lighting bulbs in the household is increased with the increase in per capita income (Table 5.2). This is due to the increase of household built-up area with the increase in per capita income (Table B2.1 in Appendix B2) and consequently requires more lighting bulbs. Therefore, the average lighting consumption in high-income group (4.6 kWh/hh/d) is higher than that in the medium (3.0 kWh/hh/d) and low-income (1.9 kWh/hh/d) households.

5.4.5 Electronic appliances

Electronic appliances include a variety of devices, such as TV, computer, radio, CD player, video record and video game. The contribution of electronic appliances to overall per capita electricity consumption is less than 5% in all income groups (Figure 5.4). Survey data analysis shows that the highest proportion of electricity consumption within electronic appliances is attributed to the TV, accounting approximately 85% of the total consumption by electronic appliances in all income groups. This is due to using TV for long duration in all income groups (approximately 9.5 hr/hh/d) as well as the high wattage compared to the other electronic appliances (Table 5.2). In terms of TV ownership, a multiple owning (i.e., more than two) is relatively high in medium and high income households compared to the low income group (1.3 TVs/hh) as shown in Table 5.2. Therefore, the TV electricity consumption in high and medium income groups is more than double than that in the low income households (i.e., only 1.66 kWh/hh/d).

Computer is the second highest electricity user within electronic appliances group while the electricity consumption increases with the increase in per capita income due to the high ownership level (Table 5.2).

5.4.6 Wet appliances

The appliances that use water (e.g., washing machine, dishwasher and water pump) are classified as wet appliances. The total electricity consumption by all of these appliances is only approximately 1% of the total daily per capita consumption in all income groups (Figure 5.4). However, the per capita consumption increases with the increased income, accounting approximately, 0.4, 1.1 and 1.3 kWh/p/w in low, medium and high income households, respectively.

The daily per capita electricity consumption for washing machine depends upon the average number of washing cycles per household per week and also the machine’s electricity consumption per washing cycle (kWh/wsl). The higher per capita electricity consumption via washing machine in medium and high income groups (approximately 0.9 kWh/p/w) may attribute to the machine's electricity consumption per washing cycle. The average electricity consumption per washing cycle is over 0.5 kWh/wsl in medium and high income groups, while it is less than 0.25 kWh/wsl in low-income households (Table 5.2). In low income households, the significant majority (91% of households) of the washing machines were found to be without internal water heaters. However, the most households in medium (85% of households) and high (100% of households) income group are using washing machine with internal water heater, consequently that increase the appliance energy consumption.

Water pump is another wet appliance has been recorded in the survey, which is used for pumping water to the household storage tanks during a water supply period for later consumption. The public water supply in Duhok is not continuous. Water is only supplied 3 to 4 times a week and the duration of each supply session varies between 4 to 6 hours (Duhok Directorate of Water and Sewerage, 2014). Water pump is the second largest electricity consumer within wet appliances group, accounting approximately 20% of the total wet appliances electricity consumption in all income groups. The average ownership level of a water pump in medium income group (70%) is higher than that in low and high income households (30%) (Table 5.2). Therefore, per capita electricity consumption for water pumping is higher in medium income group (i.e., 0.21 kWh/p/w).

Dishwasher ownership is very low in all income groups in Duhok with it being almost zero in both low and medium income households and only 21% in high-income households. However, they are rarely used.

5.4.7 Cooking appliances

Of all recorded electrical cooking appliances in the surveyed households, electric oven and kettle are the most commonly used, consuming less than 2% of the total daily per capita electricity consumption in all income groups (Figure 5.4). However, the ownership level and duration of use increase with the increase in per capita income (Table 5.2). Consequently, the per capita electricity consumption in medium and high income households is approximately 0.25 kWh/p/d, whilst in the low-income group it is half of this consumption (Figure 5.5). Electricity consumption for cooking is relatively low in all income groups. LPG is the main source of energy for cooking. The survey data suggest that kerosene oil use for cooking is not in practice anymore.

In terms of LPG consumption for cooking purposes, the analysis shows that each LPG cylinder lasts for approximately 25.0, 15.8 and 10.5 d in low, medium and high income households, respectively (Table 5.2). The typical LPG cylinder size for households is 26.2 l (Kurdistan Ministry of Natural Resources, 2015). The daily per capita LPG consumption for cooking is calculated using these figures (i.e., no. of days), the gas cylinder size and the number of occupants in a household. The calculated results found that the average daily per capita LPG consumption for cooking is approximately 0.23, 0.26 and 0.32 l/p/d in low, medium and high income households, respectively.

5.4.8 Miscellaneous appliances

Miscellaneous electrical appliances (e.g., iron, vacuum cleaner, hair dryer and sewing machine) can be the lowest energy end-use in the household because of their less frequent use and for short durations. It accounts only 0.5% of the total daily per capita energy consumption (Figure 5.4). The average weekly per capita electric consumption for miscellaneous appliances was found to be between 0.3 kWh/p/w in low income and 0.6 kWh/p/w in medium and high income groups, depending on the usage pattern and ownership level of appliances (Table 5.2).

The half of electricity consumption via miscellaneous appliances is attributed to the iron, which has a relatively high wattage (i.e., ranged between 1050 and 1500 W), compared to the other miscellaneous appliances (Table 5.2). Vacuum cleaner can be the second largest energy user in all income groups (35% of the total electric consumption from miscellaneous appliances); however, its energy consumption in medium and high income households (0.2 kWh/p/w) is higher than that in low income group (0.1 kWh/p/w). The lowest energy consumption is attributed to the hair dryer and sewing machine, accounting only around 0.05 and 0.02 kWh/p/w, respectively in all income groups.

5.5 Statistical modelling of daily per capita energy usage with household characteristics

70% of the collected energy consumption data (i.e., calibration set) from the 407 surveyed households were used to develop statistical models to estimate daily per capita energy consumption as a function of household characteristics. The household characteristics were divided into demographic and physical. Multiple linear regression (STEPWISE) and Evolutionary polynomial regression modelling techniques were used to develop the statistical models in order to identify the computationally efficient models. The procedure of the regression modelling techniques is explained in Section 3.4.4.1 and 3.4.4.2.

5.5.1 Models based on multiple linear regression (STEPWISE)

The STEPWISE multiple linear regression analysis is applied using IBM SPSS Statistics 22 software to find the best subset model for daily per capita energy use estimation. The STEPWISE regression approach is explained in Section 3.4.4.1. The relationships between daily per capita energy consumption and the household characteristics are investigated. The correlation coefficient values of these relationships are shown in Table 5.4. As can be seen from the table, per capita energy consumption is highly correlated with the number of rooms, the total built-up area and income of the household. Based on the strength of relationship (correlation coefficient value), the independent variable (i.e., household characteristic) is included or excluded from the regression model.

Using STEPWISE approach with the calibration set of data of whole surveyed household, three regression models were developed as a function of demographic, physical and whole characteristics (i.e., Model 1, 2 and 3 in Table 5.5). The procedure is repeated to develop three models for each income group using the calibration set of low, medium and high income households' data. The developed models are shown in Table 5.5 and they are subjected to further statistical tests as shown in Table 5.6. The results of ANOVA (F-test) and t-test in this table indicate that all the 12 regression models are statistically significant ($\rho<0.05$).

Table 5.4 Correlation coefficients between household characteristics and per capita energy consumption

		Correlation coefficient value (R)								
		Demographic characteristics				Physical characteristics				
		No. of children	No. of adult females	No. of adult males	No. of elders	No. of rooms	No. of floors	Total built-up area	Garden area	Income
Per capita energy consumption (kWh/p/d)	All surveyed households	-0.04	0.65	0.16	0.10	0.71	0.56	0.71	0.56	0.94
	Low income households	-0.52	0.09	0.20	0.35	0.56	0.00	0.58	0.38	0.49
	Medium income households	-0.71	0.09	0.50	0.31	0.86	0.70	0.77	0.45	0.67
	High income households	-0.54	0.06	0.63	0.17	0.72	0.59	0.64	0.41	0.64

Note: kWh/p/d=kWh per capita per day

Table 5.5 Models and coefficients of determination (R^2) using multiple linear regression method (STEPWISE)

	Model	R^2	
		Calibration set	Validation set
All surveyed households	Model based on demographic characteristics of the household $\mathrm{TE_w} = 3.63 + 3.8 \times \mathrm{AF_w} + 1.34 \times \mathrm{AM_w}$ ……… (1)	0.50	0.49
	Model based on physical characteristics of the household $\mathrm{TE_w} = 0.68 + 1.16 \times \mathrm{RO_w} - 0.66 \times \mathrm{F_w} + 0.04 \times \mathrm{I_w}$ ……… (2)	0.82	0.84
	Model based on all (demographic and physical) characteristics of the household $\mathrm{TE_w} = 0.4 + 0.45 \times \mathrm{AF_w} + 0.46 \times \mathrm{E_w} + 1.09 \times \mathrm{RO_w} - 0.71 \times \mathrm{F_w} + 0.04 \times \mathrm{I_w}$ ……… (3)	0.87	0.86
Low income households	Model based on demographic characteristics of the household $\mathrm{TE_l} = 8.62 + 0.18 \times \mathrm{C_l} - 0.32 \times \mathrm{AF_l} - 0.30 \times \mathrm{AM_l} + 0.36 \times \mathrm{E_l}$ ……… (4)	0.59	0.59
	Model based on physical characteristics of the household $\mathrm{TE_l} = 7.82 - 0.67 \times \mathrm{RO_l} + 0.02 \times \mathrm{HH_l} - 0.03 \times \mathrm{G_l}$ ……… (5)	0.69	0.75
	Model based on all (demographic and physical) characteristics of the household $\mathrm{TE_l} = 7.96 - 0.56 \times \mathrm{AF_l} + 0.005 \times \mathrm{HH_l}$ ……… (6)	0.79	0.73
Medium income households	Model based on demographic characteristics of the household $\mathrm{TE_m} = 16.01 - 0.36 \times \mathrm{C_m} - 0.54 \times \mathrm{AM_m} - 0.58 \times \mathrm{E_m}$ ……… (7)	0.77	0.70
	Model based on physical characteristics of the household $\mathrm{TE_m} = 22.03 - 2.24 \times \mathrm{RO_m} + 0.85 \times \mathrm{F_m}$ ……… (8)	0.84	0.86
	Model based on all (demographic and physical) characteristics of the household $\mathrm{TE_m} = 19.46 - 0.3 \times \mathrm{C_m} - 0.43 \times \mathrm{AM_m} - 0.49 \times \mathrm{E_m} - 0.66 \times \mathrm{RO_m} - 0.005 \times \mathrm{I_m}$ ……… (9)	0.89	0.76
High income households	Model based on demographic characteristics of the household $\mathrm{TE_h} = 27.08 - 0.66 \times \mathrm{C_h} - 1.01 \times \mathrm{AM_h} - 0.53 \times \mathrm{E_h}$ ……… (10)	0.52	0.53
	Model based on physical characteristics of the household $\mathrm{TE_h} = 36.39 - 4.48 \times \mathrm{F_h} - 0.03 \times \mathrm{HH_h} + 0.10 \times \mathrm{G_h} + 0.007 \times \mathrm{I_h}$ ……… (11)	0.83	0.80
	Model based on all (demographic and physical) characteristics of the household $\mathrm{TE_h} = 35.05 - 0.49 \times \mathrm{C_h} - 0.66 \times \mathrm{AM_h} - 3.86 \times \mathrm{F_h} - 0.014 \times \mathrm{HH_h} + 0.085 \times \mathrm{G_h}$ ……… (12)	0.87	0.78

where:
TE = daily per capita energy consumption (kWh/p/d),
C = number of children in the household,
AF = number of adult females in the household,
AM = number of adult males in the household,
E = number of elders in the household,
RO = number of rooms in the household,
F = number of floors in the household,
HH = total household built-up area (m^2),
G = total garden area (m^2),
I = per capita monthly income (Thousand ID),
w = whole sample,
l = low income households,
m = medium income households, and
h = high income households.

Table 5.6 Performance of the twelve models developed using STEPWISE regression method

		Constant	No. of children	No. of adult females	No. of adult males	No. of elders	No. of rooms	No. of floors	Total built-up area	Garden area	Income
Model 1	t-statistic (p-value)	5.26 (0.000)		18.74 (0.000)	7.00 (0.000)						
	ANOVA	F(2,404)= 193.55, p<0.005									
Model 2	t-statistic (p-value)	2.21 (0.027)					8.45 (0.000)	-2.75 (0.006)			43.57 (0.000)
	ANOVA	F(3,403)= 1551.31, p<0.005									
Model 3	t-statistic (p-value)	1.30 (0.194)		4.49 (0.000)		2.71 (0.007)	8.13 (0.000)	-3.03 (0.003)			36.84 (0.000)
	ANOVA	F(5,401)=992.67, p<0.005									
Model 4	t-statistic (p-value)	27.86 (0.000)		-2.02 (0.046)							
	ANOVA	F(1,90)=4.08, p<0.005									
Model 5	t-statistic (p-value)										
	ANOVA										
Model 6	t-statistic (p-value)	17.88 (0.000)		-2.39 (0.019)					1.99 (0.050)		
	ANOVA	F(2,89)=4.09, p<0.005									
Model 7	t-statistic (p-value)	155.21 (0.000)	-13.24 (0.000)		-10.67 (0.000)	-4.851 (0.000)					
	ANOVA	F(3,172)=187.21, p<0.005									
Model 8	t-statistic (p-value)	53.05 (0.000)					-15.28 (0.000)	4.06 (0.000)			
	ANOVA	F(2,173)=230.80, p<0.005									
Model 9	t-statistic (p-value)	26.58 (0.000)	-7.31 (0.000)		-6.59 (0.000)	-4.00 (0.000)	-4.39 (0.000)				-2.67 (0.008)
	ANOVA	F(5,170)=132.23, p<0.005									
Model 10	t-statistic (p-value)	76.00 (0.000)	-8.21 (0.000)		-9.02 (0.000)	-2.41 (0.017)					
	ANOVA	F(3,135)=67.39, p<0.005									
Model 11	t-statistic (p-value)	13.39 (0.000)						-7.56 (0.000)	-6.43 (0.000)	7.49 (0.000)	2.12 (0.036)
	ANOVA	F(4,134)=54.13, p<0.005									
Model 12	t-statistic (p-value)	23.09 (0.000)	-5.84 (0.000)		-5.41 (0.000)			-7.50 (0.000)	-3.11 (0.002)	7.13 (0.000)	
	ANOVA	F(5,133)=66.59, p<0.005									

Note: ANOVA=analysis of variance

The estimated energy from the developed models was plotted against the surveyed per capita energy consumption values as shown in Figure 5.7. It is apparent from this figure that the trend-lines of validation and calibration set are relatively identical in all cases. Additionally, the figure shows that the R^2 value for the models based on physical characteristics is higher than for those based on demographic characteristics. The R^2 value improves further when the models developed as a function of all household characteristics (demographic and physical).

5.5.2 Models based on evolutionary polynomial regression (EPR)

Evolutionary polynomial regression technique (Section 3.4.4.2) was used to develop mathematical model expressions for daily per capita energy consumption estimation. Using 70% of the whole surveyed households (calibration set) with EPR technique, three nonlinear regression models were developed as a function of demographic, physical and all characteristics (Model 1, 2 and 3, respectively in Table 5.7). Three mathematical models were also developed for each income group (low, medium and high) using their calibration set of data as shown in Table 5.7. The models presented in this table have achieved the highest coefficient of determination (R^2). The estimated per capita energy consumption from the developed models was plotted against the surveyed values as shown in Figure 5.8. The results of all models presented in this figure show that the trend-lines of calibration and validation set of data are relatively identical. The figure also shows that the R^2 value increases when the models were developed as a function of physical characteristics. In addition, the R^2 value improves further when all household characteristics (demographic and physical) are included in the model.

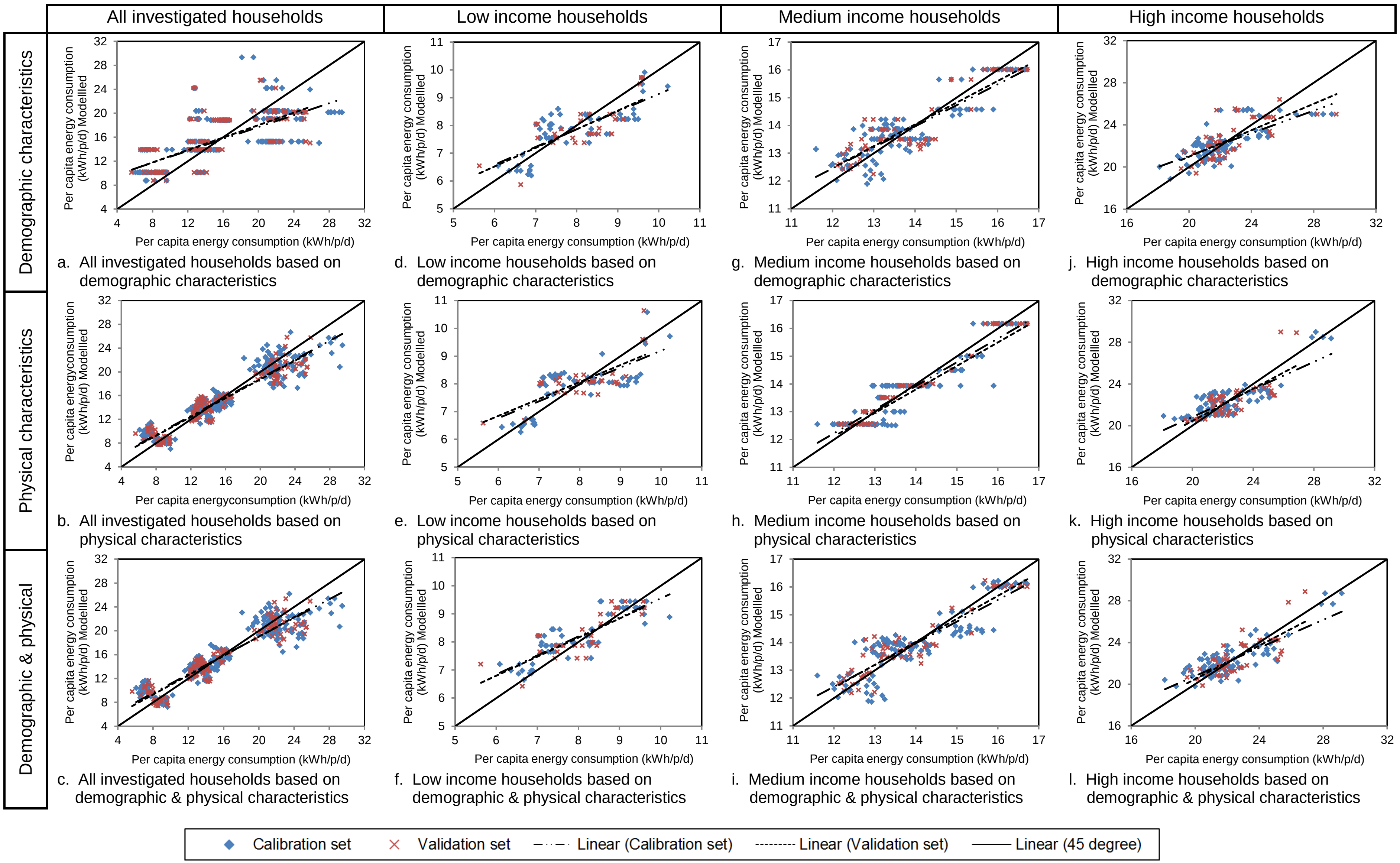


Figure 5.7 Relationship between actual and predicted daily per capita energy consumption using STEPWISE method

Table 5.7 Models and coefficients of determination (R^2) using evolutionary polynomial regression method (EPR)

	Model	R^2	
		Calibration set	Validation set
All surveyed households	Model based on demographic characteristics of the household $TE_w = 17.31 - 29.44 \times AM_w^{0.5} + 16.25 \times AM_w^{1.5} - 8.96 \times AF_w^{0.5} \times AM_w^{1.5} + 9.50 \times AF_w \times AM_w^{0.5}$ ……(1)	0.59	0.62
	Model based on physical characteristics of the household $TE_w = 18.33 - 1.68 \times I_w^{0.5} + 0.0051 \times I_w^{1.5} + 0.00063 \times RO_w^{1.5} \times I_w^{1.5} - 3.3285 \times 10^{-5} \times RO_w^{1.5} \times I_w^2$ ……(2)	0.82	0.81
	Model based on all (demographic and physical) characteristics of the household $TE_w = 0.76 + 0.035 \times I_w + 0.115 \times RO_w \times I_w^{0.5} - 1.21 \times 10^{-7} \times AF_w^{0.5} \times AM_w \times HH_w^{0.5} \times I_w^2 - 1.33 \times 10^{-5} \times C_w^{0.5} \times I_w^2$ ……(3)	0.88	0.91
Low income households	Model based on demographic characteristics of the household $TE_l = 8.12 - 1.20 \times C_l^{0.5} \times AM_l + 0.75 \times C_l \times AM_l + 1.035 \times C_l \times AF_l^2 \times E_l - 0.30 \times C_l^2 \times AF_l^2 \times E_l^{1.5}$ ……(4)	0.59	0.57
	Model based on physical characteristics of the household $TE_l = 7.13 + 4.89 \times 10^{-8} \times RO_l \times HH_l^2 \times I_l^{1.5} - 1.314 \times 10^{-9} \times RO_l^2 \times HH_l^2 \times I_l^2$ ……(5)	0.72	0.69
	Model based on all (demographic and physical) characteristics of the household $TE_l = 8.13 - 0.018 \times C_l^{0.5} \times I_l + 0.12 \times C_l^{0.5} \times AF_l^2 \times E_l^{0.5} \times G_l^{0.5} + 0.001 \times C_l \times I_l^{1.5}$ ……(6)	0.91	0.91
Medium income households	Model based on demographic characteristics of the household $TE_m = 16.1 - 0.62 \times E_m^{0.5} - 0.166 \times AM_m^2 - 0.81 \times C_m + 0.072 \times C_m^{1.5} \times AM_m$ ……(7)	0.80	0.79
	Model based on physical characteristics of the household $TE_m = -27.26 + 6.37 \times I_m^{0.5} + 0.0003 \times I_m^2 - 0.018 \times RO_m^{0.5} \times I_m^{1.5} + 0.0003 \times RO_m \times I_m^2$ ……(8)	0.85	0.80
	Model based on all (demographic and physical) characteristics of the household $TE_m = 16.13 - 0.03 \times AM_m \times I_m^{0.5} - 0.29 \times AF_m \times E_m^{0.5} - 0.007 \times C_m^{0.5} \times RO_m^{1.5} \times I_m^{0.5}$ ……(9)	0.89	0.82
High income households	Model based on demographic characteristics of the household $TE_h = 32.0 - 4.28 \times AM_h^{0.5} - 0.105 \times AF_h^2 \times E_h^{0.5} - 4.85 \times C_h^{0.5} + 1.87 \times C_h^{0.5} \times AM_h^{0.5}$ ……(10)	0.68	0.66
	Model based on physical characteristics of the household $TE_h = 44.65 + 1.19 \times G_h^{0.5} - 0.0009 \times HH_h^{1.5} - 17.46 \times F_h^{0.5} + 0.0016 \times F_h^2 \times I_h$ ……(11)	0.86	0.82
	Model based on all (demographic and physical) characteristics of the household $TE_h = 46.51 - 20.21 \times F_h^{0.5} + 0.71 \times F_h \times G_h^{0.5} - 0.049 \times AM_h^{0.5} \times G_h - 0.38 \times C_h \times AF_h^{0.5}$ ……(12)	0.89	0.85

where:
TE = daily per capita energy consumption (kWh/p/d),
C = number of children in the household,
AF = number of adult females in the household,
AM = number of adult males in the household,
E = number of elders in the household,
RO = number of rooms in the household,
F = number of floors in the household,
HH = total household built-up area (m^2),
G = total garden area (m^2),
I = per capita monthly income (Thousand ID),
w = whole sample,
l = low income households,
m = medium income households, and
h = high income households.

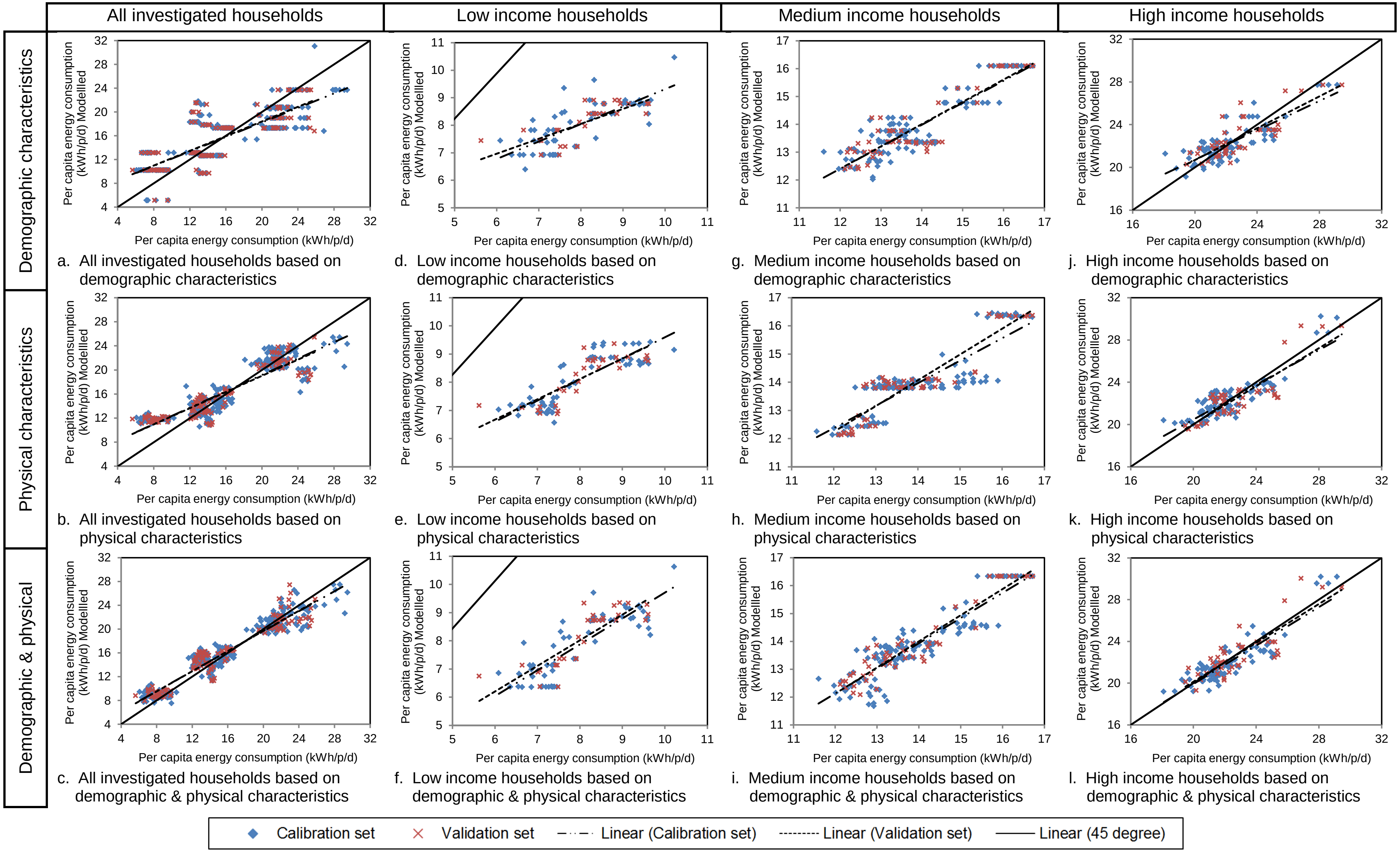


Figure 5.8 Relationship between actual and predicted daily per capita energy consumption using EPR method

5.5.3 Comparison of models

The developed STEPWISE and EPR regression models are compared using their R^2 values as shown in Table 5.8. From the comparison, it can be concluded that the R^2 value improves in the case of EPR based models. Additionally, the R^2 values improve for the energy prediction models based on disaggregated data into income groups. The energy prediction models based on physical characteristics show better predictions than those based on demographic characteristics. Furthermore, the table shows that the highest R^2 values were for the models which developed as a function of all household characteristics (i.e., demographic and physical).

Table 5.8 Coefficients of determination (R^2) of the final regression models

	Per capita energy consumption modelled with household demographic characteristics		Per capita energy consumption modelled with household physical characteristics		Per capita energy consumption modelled with demographic and physical characteristics	
	STEPWISE	EPR	STEPWISE	EPR	STEPWISE	EPR
All surveyed households	0.5	0.59	0.82	0.82	0.87	0.88
Low income households	0.59	0.59	0.69	0.72	0.79	0.91
Medium income households	0.77	0.80	0.84	0.85	0.89	0.89
High income households	0.52	0.68	0.83	0.86	0.87	0.89

5.6 Seasonal variability of energy consumption (summer survey):

In order to observe the influence of seasonal variability on the energy consumption at a household, the energy survey explained in Section 3.3.1 was repeated during summer season. In the summer survey all energy end-uses are similar to that in winter survey, except space heating (i.e., electrical heater, kerosene heater and air-conditioner) which is replaced with space cooling (i.e., fan, evaporative air-cooler and air-conditioner) (Appendix A). Information are collected on the ownership level, duration of use and wattage of all appliances in each energy end-use.

5.6.1 Average per capita energy consumption in summer season

Palmer et al. (2013) indicated that there is a variation in electricity consumption between winter and summer months. Similarly, the analysis of summer survey in the city of Duhok shows that the daily per capita average electricity consumption decreases to 11.83 kWh/p/d, compared to that during winter (15.21 kWh/p/d). These results are consistent with those reported by General Directorate of Duhok Electricity (Table 3.5), which clearly showed that the electricity demand for the city during summer period (May to October) is less than that in winter months.

Further comparison of electricity consumption between winter and summer season is shown in Figure 5.9. It can be seen form this figure that the number of households which consume more than 12.0 kWh/p/d decreases from 71 in winter to 55% of households during summer months. The possible explanation for this decrease is as a result of consuming less energy for water heating in summer period compared to winter (Figure D4.2 in Appendix D4).

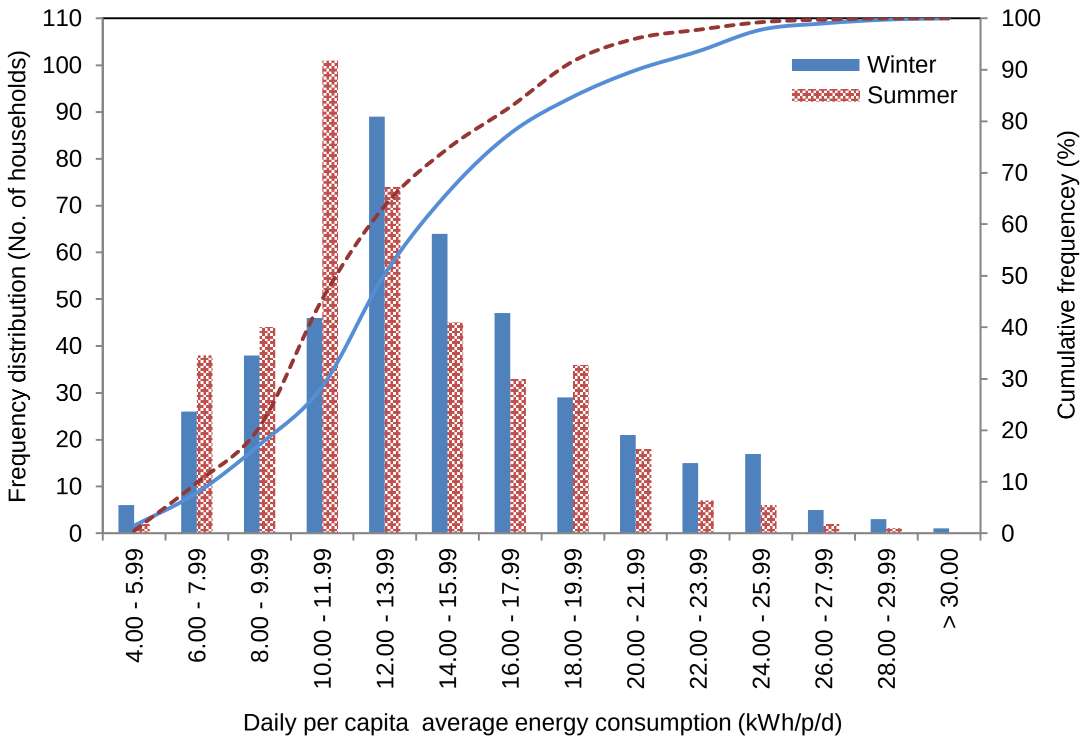
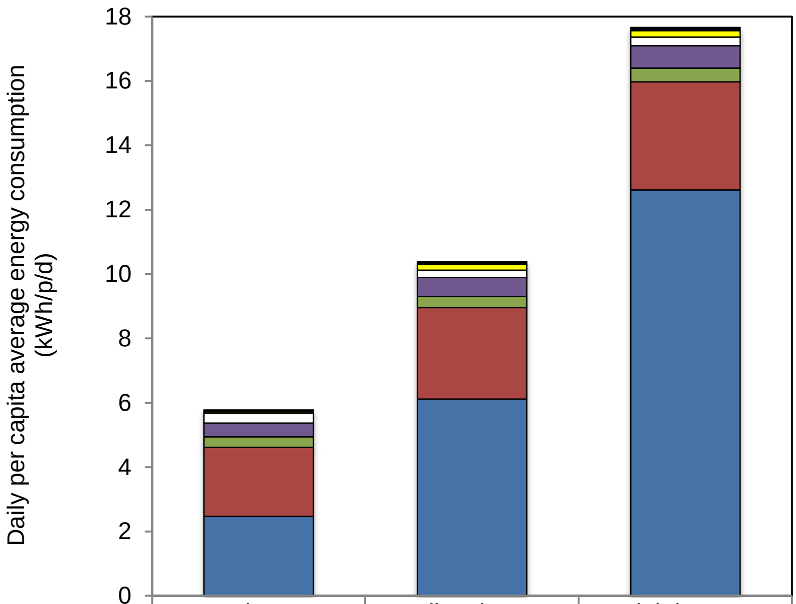


Figure 5.9 Seasonal variability of per capita average energy consumption

5.6.2 Average per capita energy end-uses in summer season

Daily per capita average energy of each end-use for low, medium and high income households during summer period is shown in Figure 5.10. It can be concluded from this figure that all energy end-uses in summer period increase with the increase in per capita income. Space cooling is the most predominant energy end-use in the household. Additionally, the energy consumption for water heating is nil due to the high temperature during summer period.



	Low income	Medium income	High income
■ Miscellaneous appliances	0.064	0.085	0.094
□ Wet appliances	0.053	0.182	0.198
□ Cooking appliances	0.298	0.229	0.277
■ Electronic appliances	0.422	0.585	0.690
■ Lighting	0.328	0.348	0.431
■ Refrigeration appliances	2.152	2.846	3.356
■ Space cooling	2.463	6.110	12.611

Note: All the data presented in this table are in kWh per capita per day.

Figure 5.10 Average per capita energy end-uses in summer season

5.6.3 Seasonal variability of energy end-use

The seasonal variability of energy end-uses is examined using a two-tailed t-test at 95% confidence interval as shown in Table 5.9. This statistical test allows accounting for variability in energy use of the same sample set of households between winter and summer season (Section 3.4.3). From the presented results in Table 5.9, it can be seen that the p value for only refrigeration appliances end-use is greater than 0.05. This means there is no statistically significant difference between winter and summer consumption. The average electricity consumption of refrigeration appliances remains fairly unchanged throughout winter and summer season.

However, all the other energy end-uses are statistically significant difference ($p<0.05$) between the both seasons as shown in Table 5.9. The table also shows that the consumption of all energy end-uses in summer is higher than that in winter, except for water heating and lighting. This is as a result of the difference in temperature and daylight changes between winter and summer season (Palmer et al., 2013).

The summary of average values of energy end-use parameters for each appliance (number of appliances in use, duration of use and wattage) is illustrated in Table 5.10. The table shows the comparison of these parameters between winter and summer season. Statistical analysis (mean, median, standard deviation, variance, minimum, maximum, skewness and confidence interval) for parameters presented in Table 5.10 are shown in Tables D3.1-D3.8 (Appendix D3). The key findings are explained in the following sections.

Table 5.9 Statistical comparison of energy end-uses between winter and summer

Energy end-use	Unit	Average energy use (kWh/p/d)		t value	Significant (2-tailed) (p)
		Winter	Summer		
Space heating and cooling	kWh/p/d	5.912	7.506	-23.730	0.000 *
Water heating	kWh/p/d	4.991	0.000	90.198	0.000 *
Refrigeration appliances	kWh/p/d	2.863	2.863	0.00	0.999 **
Electronic appliances	kWh/p/d	0.557	0.585	-15.413	0.000 *
Lighting	kWh/p/d	0.461	0.372	35.793	0.000 *
Cooking appliances	kWh/p/d	0.208	0.261	-9.107	0.000 *
Wet appliances	kWh/p/d	0.143	0.159	-24.928	0.000 *
Miscellaneous appliances	kWh/p/d	0.074	0.083	-12.637	0.000 *
Per capita LPG consumption	l/p/d	0.270	0.279	-15.767	0.000 *

* = significantly difference between winter and summer

** = not significantly difference between winter and summer

Table 5.10 Seasonal variability of mean values of energy end-use parameters

End -use	Appliances	Parameters/variable	Unit	Overall survey		Low income		Medium income		High income	
				Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Space heating in winter & cooling in summer	Electrical heater	Number of electrical heaters in use in a household	No.	0.87		0.79		0.86		0.94	
		Duration of use of each electrical heater per capita per day	hr/p/d	0.98		1.36		0.97		0.78	
		Wattage of each electrical heater	W	1101.72		1023.03		1017.88		1244.2	
	Kerosene heater	Number of kerosene heaters in use in a household	No.	2.69		1.79		2.86		3.06	
		Duration of use of each kerosene heater per capita per day	hr/p/d	2.44		3.59		2.25		1.92	
		Volume of kerosene use by each heater per hour	l/htr/hr	0.28		0.27		0.28		0.28	
		Volume of kerosene use by each heater per day	l/htr/d	4.13		4.27		4.01		4.18	
	Air conditioners	Number of air conditioners in use in a household	No.	1.36	1.36	0.01	0.01	1.23	1.23	2.43	2.43
		Duration of use of each air conditioner per capita per day	hr/p/d	1.17	1.42	0.56	1.78	1.01	1.34	1.37	1.51
		Wattage of each air conditioner	W	3118.2	3118.20	2150.00	2150.00	3034.09	3034.09	3231.65	3231.65
	Fan	Number of fans in use in a household	No.		3.60		3.68		3.49		3.68
		Duration of use of each fan per capita per day	hr/p/d		2.66		3.71		2.58		2.08
		Wattage of each fan	W		104.78		106.28		104.94		103.60
	Air-cooler	Number of air-coolers in use in a household	No.		0.83		0.80		0.99		0.65
		Duration of use of each air-cooler per capita per day	hr/p/d		2.51		4.02		2.16		1.90
		Wattage of each air-cooler	W		303.39		309.73		301.33		301.98
Wet appliances	Water pumps	Number of water pumps in use in a household	No.	0.50	0.50	0.28	0.28	0.73	0.73	0.35	0.35
		Duration of use of each water pump per capita per week	hr/p/w	0.76	1.06	0.62	1.00	0.76	1.08	0.82	1.06
		Wattage of each water pump	W	381.48	381.48	381.54	381.54	379.92	379.92	385.63	385.63
	Clothes washer	Number of clothes washing machines in use in a household	No.	0.94	0.94	0.75	0.75	1.00	1.00	1.00	1.00
		Energy consumption per washing cycle	kWh/wsl	0.51	0.51	0.23	0.23	0.61	0.61	0.53	0.53
Lighting	Spot lights	Number of spot lights in use per day in a household	No.	9.04	9.04	5.10	5.10	7.97	7.97	13.01	13.01
		Duration of use of each spot light per capita per day	hr/p/d	1.48	1.22	1.92	1.71	1.45	1.15	1.24	0.97
	Tube lights	Number of tube lights in use per day in a household	No.	4.03	4.03	2.60	2.60	4.02	4.02	5.00	5.00
		Duration of use of each tube light per capita per day	hr/p/d	1.48	1.22	1.92	1.70	1.44	1.15	1.24	0.98

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, W=Watt, wsl=clothes washing load, min=minute

Continue

Table 5.10 Seasonal variability of mean values of energy end-use parameters

End -use	Appliances	Parameters/variable	Unit	Overall survey		Low income		Medium income		High income	
				Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Refrigeration appliances	Chest-freezer	Number of chest-freezers in a household	No.	1.08	1.08	0.37	0.37	1.03	1.03	1.60	1.60
		Wattage of each chest-freezer	W	384.18	384.38	381.20	378.24	383.01	383.01	387.63	387.63
	Fridge-freezer	No. of fridge-freezers in a household	No.	1.44	1.44	1.00	1.00	1.39	1.39	1.81	1.81
		Wattage of each fridge-freezer	W	294.20	294.20	293.04	293.04	294.32	294.32	294.82	294.82
Electronic appliances	TV	Number of TVs in use in a household	No.	2.04	2.04	1.30	1.30	2.01	2.01	2.55	2.55
		Duration of use of each TV per capita per day	hr/p/d	1.51	1.53	2.09	2.12	1.43	1.45	1.24	1.24
		Wattage of each TV	W	175.10	175.10	125.11	125.11	191.05	191.05	187.99	187.99
	Radio	Number of radios in use in a household	No.	0.15	0.15	0.00	0.00	0.14	0.14	0.27	0.27
		Duration of use of each radio per capita per day	hr/p/d	0.40	0.40			0.39	0.39	0.40	0.40
		Wattage of each radio	W	92.46	92.46			94.40	94.40	91.18	91.18
	Computer	Number of computers in use in a household	No.	1.11	1.11	0.93	0.93	0.85	0.85	1.55	1.55
		Duration of use of each computer per capita per day	hr/p/d	0.43	0.49	0.61	0.65	0.46	0.49	0.28	0.39
		Wattage of each computer	W	134.03	134.38	131.47	131.22	135.00	136.00	134.64	134.64
	CD player	Number of CD players in use in a household	No.	0.18	0.18	0.00	0.00	0.02	0.02	0.50	0.50
		Duration of use of each CD player per capita per day	hr/p/d	0.11	0.11			0.10	0.10	0.11	0.11
		Wattage of each CD player	W	32.54	32.15			32.88	33.25	32.11	32.09
	Play station	Number of play stations in use in a household	No.	0.38	0.38	0.00	0.00	0.38	0.38	0.62	0.62
		Duration of use of each play station per capita per day	hr/p/d	0.16	0.39			0.14	0.37	0.18	0.40
		Wattage of each play station	W	168.50	168.50			169.10	169.10	168.02	168.02
Cooking appliances	Electrical oven	Number of electrical ovens in use in a household	No.	0.94	0.94	0.75	0.75	1.00	1.00	1.00	1.00
		Duration of use of each electrical oven per capita per week	hr/p/w	0.49	0.62	0.39	0.92	0.44	0.49	0.60	0.63
		Wattage of each electrical oven	W	2827.34	2827.34	2802.90	2802.90	2841.48	2841.48	2821.58	2821.58
	Electrical kettle	Number of electrical kettles in use in a household	No.	0.59	0.59	0.45	0.45	0.65	0.65	0.62	0.62
		Duration of use of each electrical kettles per capita per day	min/p/d	0.88	1.10	0.91	1.26	1.00	1.17	0.72	0.93
		Wattage of each electrical kettle	W	2467.63	2467.63	2465.85	2465.85	2468.42	2468.42	2467.44	2467.44
	Gas hob	Number of gas hobs in use in a household	No.	1.00	1	1.00	1	1.00	1	1.00	1
		Number of days each gas bottle is last for cooking	d	16.11	15.64	25.12	24.59	15.81	15.40	10.51	10.04

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, W=Watt, wsl=clothes washing load, min=minute

Continue

Table 5.10 Seasonal variability of mean values of energy end-use parameters

End-use	Appliances	Parameters/variable	Unit	Overall survey		Low income		Medium income		High income	
				Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Water heating	Electrical water heater	Total consumption of heated water per capita per day	l/p/d	85.85	0.00	65.80	0.00	89.35	0.00	94.69	0.00
		Total energy consumption for water heating per capita per day	kWh/p/d	4.99	0.00	3.83	0.00	5.19	0.00	5.51	0.00
Miscellaneous appliances	Hair dryer	Number of hair dryers in use in a household	No.	1.42	1.42	1.00	1.00	1.44	1.44	1.65	1.65
		Duration of use of each hair dryer per capita per week	min/p/w	1.56	1.56	1.15	1.15	1.34	1.34	2.12	2.12
		Wattage of each hair dryer	W	1372.48	1372.48	1335.87	1335.87	1378.98	1378.98	1388.49	1388.49
	Vacuum cleaner	Number of vacuum cleaners in use in a household	No.	0.95	0.95	0.79	0.79	1.00	1.00	1.00	1.00
		Duration of use of each vacuum cleaner per capita per week	hr/p/w	0.18	0.23	0.10	0.29	0.17	0.20	0.22	0.23
		Wattage of each vacuum cleaner	W	1087.24	1087.24	1093.15	1093.15	1106.25	1106.25	1060.07	1060.07
	Sewing machine	Number of sewing machines in use in a household	No.	0.90	0.90	0.79	0.79	0.93	0.93	0.93	0.93
		Duration of use of each sewing machine per capita per week	hr/p/w	0.26	0.26	0.27	0.27	0.26	0.26	0.26	0.26
		Wattage of each sewing machine	W	100.05	100.05	99.78	99.78	99.72	99.72	100.62	100.62
	Iron	Number of irons in use in a household	No.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Duration of use of each iron per capita per week	hr/p/w	0.21	0.21	0.11	0.11	0.22	0.24	0.24	0.25
		Wattage of each iron	W	1276.90	1276.90	1290.22	1290.22	1269.03	1269.03	1278.06	1278.06

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, W=Watt, wsl=clothes washing load, min=minute

Space heating and cooling

The seasonal variability of domestic energy use for space heating and cooling is mainly affected by weather conditions (Lam et al., 2008). Within energy end-uses in Duhok survey, the highest consumption is attributed to space heating in winter and space cooling during summer months, as presented in Table 5.9. However, the data in this table clearly shows that the energy consumption for space cooling is higher than that for space heating. This is due to use some other sources of energy (e.g., kerosene fuel) which reduces the reliance on electricity for space heating during winter months.

Further analysis of comparison between space heating and cooling electricity consumption is shown in Figure D4.1 (Appendix D4). This figure illustrates that 60% of surveyed households consumes more than 4.2 kWh/p/d for space heating in winter season. However, their consumption increases to more than 5.8 kWh/p/d for space cooling during summer months.

The number of electrical appliances (fan, air-conditioner and evaporative air-cooler) in use for space cooling during summer season is more than that in use for space heating during winter (air-conditioner and electrical heater). The duration of use of electrical appliances for space heating and cooling is another reason for increase the electricity consumption in summer. For example, per capita average duration of use of air-conditioner for cooling (1.42 hr/p/d) is longer than that for space heating (1.17 hr/p/d) (Table 5.10). On the other hand, the average number and wattage of air-conditioner does not vary throughout winter and summer season.

Water heating

The largest variation between energy consumption in winter and summer season is attributed to water heating (Table 5.9). The statistical analysis of energy survey in summer season shows that there is no use for water heater. This is due to the high temperature during summer months which warm the stored water in overhead tanks for daily uses. This finding agrees with the recorded figures in Bahrain which showed that the electricity use for water heating does not exist in summer (Akbari et al., 1996).

Refrigeration appliances

The comparison of electricity consumption between winter and summer shows that the parameters of refrigeration appliances (i.e., number, duration of use and wattage) remain without change throughout both seasons (Table 5.10). Therefore, the daily per capita average energy consumption for refrigeration appliances in winter (2.863 kWh/p/d) is equivalent to that in summer (Table 5.9). Similarly, Akbari et al. (1996) found that the refrigeration appliances energy consumption does not vary in winter and summer. However, the frequent opening refrigerator door might increase the energy consumption (Harrington, 2000).

Electronic appliances

The analysis of energy consumption in summer season shows that the average per capita electricity consumption for electronic appliances (0.585 kWh/p/d) is slightly higher than that in winter (0.557 kWh/p/d) (Table 5.9). For example, the number of households which consumes more than 0.6 kWh/p/d for electronic appliances tends to increase from 37% in winter to 47% of households during summer season (Figure D4.4 in Appendix D4).

The increase of energy consumption for electronic appliances is as a result of using them for longer duration in summer, particularly, TV, computer and play station (Table 5.10). This might be because of the availability of family members at home for longer durations during summer holidays. On the other hand, the other parameters (number of appliances and wattage) of electronic appliances remain unchanged throughout both seasons.

Lighting

The energy use for lighting varies seasonally due to its dependence on daylight hours (Bennich et al., 2011). Therefore, the electricity consumption for lighting in winter is higher than that during summer months in England (Palmer et al., 2013). Similarly, the results of energy consumption surveys in Duhok show that the electricity consumption for lighting decreases from 0.461 kWh/p/d in winter to 0.372 kWh/p/d in summer (Table 5.9). This is due to the short duration of using lights during summer months.

The daily per capita average duration of use of lighting appliances in Table 5.10 is converted to per household consumption using the occupancy data. Hence, the average duration of using lights per household is relatively short in summer (7.6 hr/hh/d) compared to winter (9.5 hr/hh/d). This is because of the long daylight hours in summer (Time and Date, 2015). The number of spot and bulb lights in the household remains broadly unchanged in both seasons (Table 5.10).

Cooking appliances

In 2012, Owen stated that the electricity consumption for cooking purposes is seasonally varies. In agreement with Owen's finding, the analysis of energy survey in Duhok shows that the average electricity consumption for cooking slightly increases from 0.208 kWh/p/d in winter to 0.261 kWh/p/d in summer (Table 5.9). Further analysis shows that the consumption of 93% of households is higher than 0.10 kWh/p/d in winter while their consumption increases to more than 0.15 kWh/p/d in summer (Figure D4.6 in Appendix D4). This is as a result of use of electric oven and kettle for a longer duration in summer than in winter (Table 5.10). The average number of electrical appliances and wattage is similar in both seasonal surveys (Table 5.10).

In terms of LPG use for cooking, the variation of per capita consumption is negligible between winter and summer season (Table 5.9). The average number of days each gas bottle lasts for cooking is approximately 16.1 and 15.6 d/gas bottle in winter and summer, respectively (Table 5.10).

Wet appliances

The comparison between winter and summer shows that the number and wattage of all wet appliances (water pump and clothes washer) remain without change throughout both seasons (Table 5.10). However, the frequency of laundry per day increases during summer months as presented in Table 4.9. Additionally, the surveyed households tend to use water pump for longer duration in summer, compared to winter (Table 5.10). The increase in duration of use of water pump is as a result of increased per capita water demand during summer months (Table 4.8). Consequently, per capita electricity consumption for wet appliances increases from 0.143 kWh/p/d in winter to 0.159 kWh/p/d in summer (Table 5.9).

Miscellaneous appliances

Similarly to energy consumption during winter, the lowest consumption within energy end-uses is attributed to miscellaneous appliances in summer season. However, the average duration of use of vacuum cleaner slightly increases from 0.18 in winter to 0.23 hr/p/w in summer (Table 5.10). The possible explanation for this is the dust storms which constantly blow during June and July (summer season) with fewer storms within the other months (Sissakian et al., 2013). Thereby, the energy consumption for miscellaneous appliances increases slightly from 0.074 in winter to 0.083 kWh/p/d in summer season (Table 5.9).

On the other hand, the statistical parameters (number of appliances, duration of use and wattage) of other miscellaneous appliances (hair dryer, iron and sewing machine) remain unchanged during both seasonal surveys (Table 5.10).

5.7 Conclusions

The key messages from the analysis of the energy consumption surveys in Duhok are:

- The daily per capita average energy (i.e., electricity, LPG and kerosene) consumption increases with the increase in per capita income.
- Daily per capita average electricity consumption in the apartments is much lower than that in the stand alone houses. This can be because of the recently built multi-story apartments are highly insulated and also fitted with energy efficient water heaters.
- Per capita electricity consumption increases with the increase in number of adults and elders in the households, while it decreases with the increase in number of children.
- All energy end-uses increase with the increase in number of adult females in the household.
- The increase in the number of adult males in a household appears to decrease per capita energy consumption in electronic and refrigeration appliances.

- Daily per capita electricity consumption for water heating and LPG for cooking decrease with the increase in number of children and elders in a household.
- Electricity is used as the main energy source for space heating in the high income group. On the other hand, in the low income households, kerosene remains a significant energy source for space heating.
- The ownership level of all household appliances (e.g., electrical heaters, air-conditioners, washing machine, freezer, oven, etc.) increases with the increase in per capita income.
- The duration of use for energy consuming appliances increases with the increase in household income.
- Using the survey data, it is possible to predict daily per capita energy consumption. The quality of prediction improves when the full data was disaggregated into low, medium and high income group households.
- The physical characteristics provide more accurate predictions of per capita energy consumption than the predictions resulting from the use of demographic characteristics of the investigated households.
- The average number of each electrical appliance in the household and wattage remains broadly unchanged throughout winter and summer season.
- The duration of use of most electrical appliances is longer during summer than in winter. However, the duration of using lights decreases in summer season due to the long daylight hours.
- The energy consumption of refrigeration appliances does not vary throughout winter and summer, with a decrease in lighting consumption during summer. However, the consumption of other energy end-uses is higher in summer than in winter.
- Apart from kettle use, the energy consumption for water heating is nonexistent during summer season.
- Due to use kerosene fuel as another source of energy for space heating in winter, the electricity consumption for space heating is less than that for space cooling.

CHAPTER SIX: FOOD CONSUMPTION

6.1 Introduction

Food is a basic daily need to provide energy for body functions and physical activities. Per capita needs daily approximately 900 g of wheat to obtain 10 MJ as a sufficient nutritional energy (Leenes, 2006). However, various types of food are required to maintain health as only what diet lacks many essential nutrients.

The demand for food keeps increasing as a result of population growth especially in developing countries, changes in agriculture and the food industry and a shift from local self-sufficiency towards a global commodity market (Tilman et al., 2002). This puts pressure on the use of natural resources (i.e., agricultural land, fresh water, and energy) and results in environmental impacts. The impacts include pollution (e.g., pesticide and herbicide emissions) and contribution to climate change through emissions of methane, dinitrogen oxide, and carbon dioxide (Leenes, 2006). These negative impacts make food production unsustainable from an environmental perspective. However, people need a sufficient amount of food every day.

Food availability, access and utilization are complex issues; comprise a wide range of interrelated economic, social and political factors which challenge the vulnerable households and regions of the world (Okutu, 2012). FAO (2008) stressed that food access is strongly related to household socio-economic characteristics. However, household level studies for food consumption pattern are few and it needs more attention (Codjoe et al., 2016). Food consumption patterns depend on several factors, such as personal preference, habit, availability, economy, convenience, social relations, ethnic heritage, religion, tradition, culture, and nutritional requirements (Codjoe and Owusu, 2011; Okutu, 2012; Musaiger, 1982; Van Phuong et al., 2015).

This chapter discusses the analysis of Duhok household survey conducted during winter season for various types of food (i.e., cereal grains, meat, dairy, roots and tubers, vegetables and fruits, oilseeds and pulses, oils and fats and sugar). The survey was aimed to provide information on each food commodity: frequency of cooking, quantity of food consumption, duration of cooking session and water used for preparation (Appendix A). The chapter also investigates the impact of household characteristics (demographic and socio-economic) on food consumption. Additionally, the food survey was repeated during summer season and compared with the winter survey to examine the impact of seasonal variability on food consumption. The main findings are summarised in the following sections.

6.2 Influence of household characteristics on food consumption

The influence of household characteristics on food consumption is presented in the following sections (Section 6.2.1 to 6.2.4).

6.2.1 Influence of household characteristics on the total average food consumption

The influence of household characteristics on the total household food consumption is investigated. The results found that the relationship between the total average food consumption (kg/hh/d) and the household occupancy (number of people in the household) is high (R=0.97) (Figure E1.1 in Appendix E1). The rate of increase in food consumption is much higher with the increase in male adults in comparison to the increase in the number of adult females, elders and children (Figure E1.2 to Figure E1.5 in Appendix E1). Moreover, the relationship between the total average food consumption and monthly household income (R=0.83) is stronger than that with monthly per capita income (R=0.42) (Figure E1.10 and Figure E1.11 in Appendix E1). The relationships between household characteristics and total food consumption are shown in Appendix E1.

6.2.2 Influence of household characteristics on per capita average food consumption

The influence of demographic characteristics on daily per capita food consumption (g/p/d) is investigated. The results show that the average quantity of per capita food consumption increases with the increase in number of adults, elders and children in the household. However, the increase in number of adult males may lead to a higher increase in per capita food consumption, compared to the increase in number of adult females, children and elders in the household. The strongest relationship with average per capita food consumption is attributed to the monthly household income (R=0.92) (Figure E2.11 in Appendix E2) and household occupancy (R=0.88) (Figure E2.1 in Appendix E2).

In terms of gender impact, the results show that the daily per capita average food consumption for adult male (1650 g/p/d) is slightly higher than that for adult female (1600 g/p/d).

6.2.3 Influence of per capita income on the average food consumption

Using per capita figures (last column in Table 3.9) which are identified by CSO and KRSO survey in 2012, the food surveyed households are divided into three income groups: low, medium and high (Section 3.4.2). The analysis of this classification shows that the daily per capita total consumption of all food commodities increases with the increase in monthly income; from 1140 g/p/d in low income to 1450 g/p/d in medium income and 1920 g/p/d in high income households. For all surveyed households, the daily per capita average food consumption (1540 g/p/d) was relatively close to the reported value in COSIT et al. survey in Iraq (1580 g/p/d) in 2010.

The significant quantity of food consumption is attributed to vegetables and fruits as well as cereal grains in all income groups, while oils and fats are the lowest consumption (less than 3%) as shown in Figure 6.1. The proportion of consumed quantity of vegetables, fruits and meat increases with the increase in per capita income (Figure 6.1). However, the proportion of cereal grains consumption decreased from 32% in low income to 22% in high income group. This means that the reliance on meat, vegetables and fruits in the diet increases with the increase in per capita monthly income.

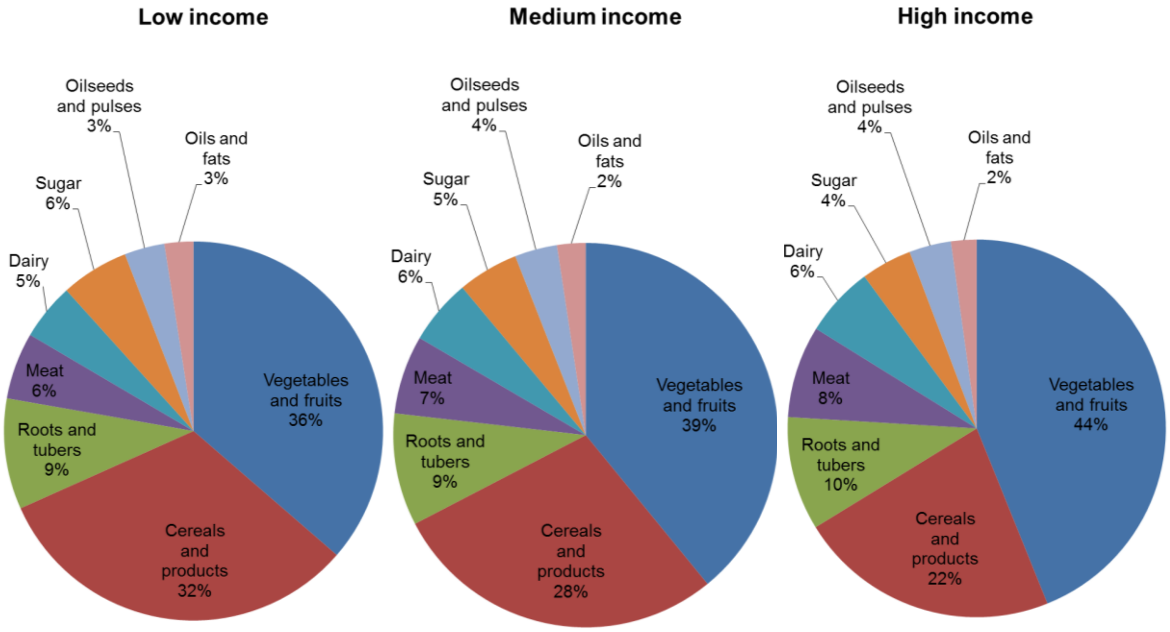


Figure 6.1 Contribution of each type of food into the total per capita consumption in different income groups

6.2.4 Influence of per capita income on the average calorie intake

The quantity of daily per capita food consumption is converted into calories using the conversion factors given by Kurdistan Ministry of Agriculture (Amendola and Vecchi, 2010). The conversion factors are based on FAO (2004) and have been adapted to take into account the specifications of available food commodities in Iraq. The results found that the daily per capita average calorie intake (i.e., dietary energy consumption) is approximately 2800 kcal/p/d, excluding some food commodities (e.g., beverages, nut, chocolate and jam). The calorie intake from the excluded commodities can be insignificant (i.e., only 77 kcal/p/d) as reported in COSIT et al. survey of household food consumption in Iraq (2010). Considering the excluded commodities into account, the daily per capita average calorie intake can be about 2877 kcal/p/d.

The daily per capita average calorie intake for all surveyed households (2877 kcal/p/d) is broadly similar to the recorded value for Duhok governorate (2910 kcal/p/d) in COSIT et al. survey in 2010. However, it is higher than the average value in the developing countries (2681 kcal/p/d) (WHO and FAO, 2003). Further, the average calorie intake increases with the increase in per capita income: 2300, 2710 and 3200 kcal/p/d in low, medium and high income groups, respectively.

The proportion of calorie intake from each type of food is compared between the income groups (Figure 6.2). The main finding is the proportion of calorie provided from all types of food increases with the increase in per capita income, excluding cereal grains (55, 53 and 47% in low, medium and high income groups, respectively). The significant increase in the proportion of calorie intake is attributed to the meat, which increases from 4% in low income to 7% in the high income group (Figure 6.2).

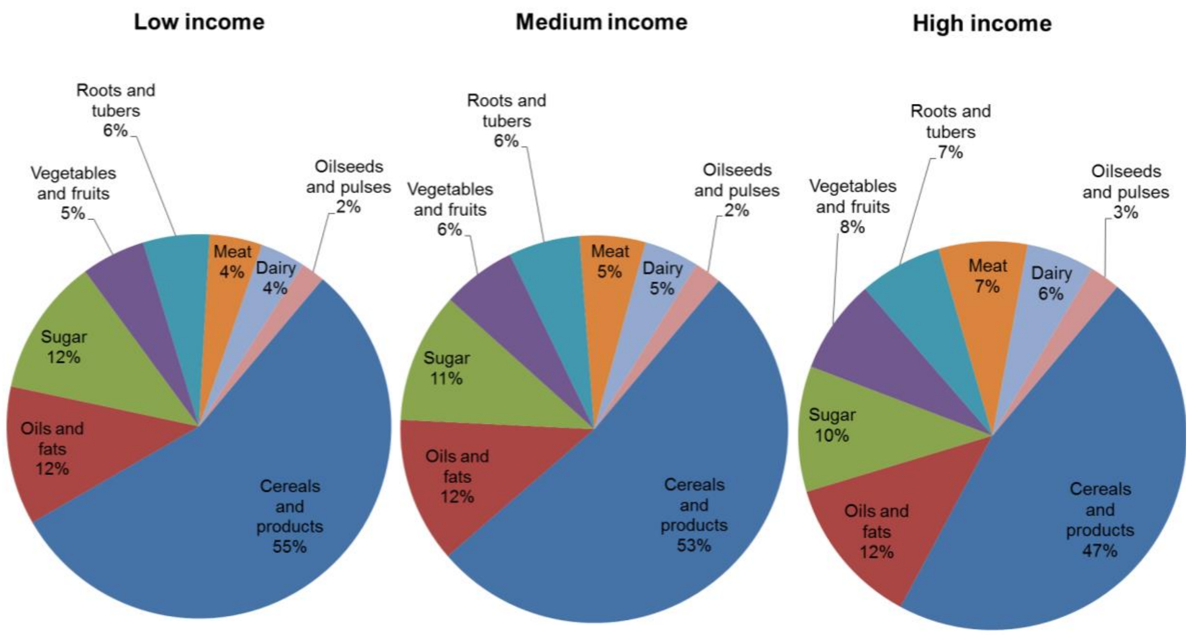
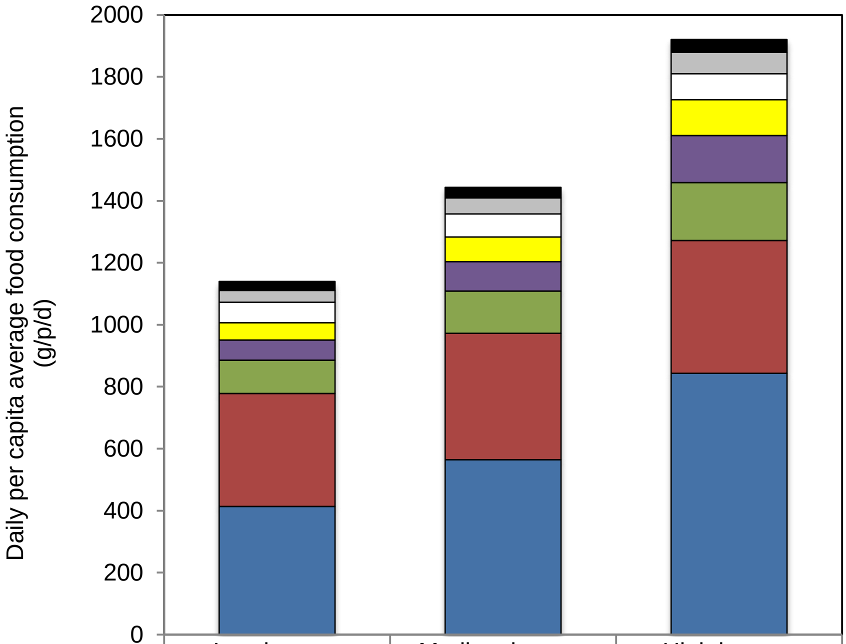


Figure 6.2 Contribution of each type of food into the daily per capita total calorie intake in different income groups

6.3 Average per capita consumption for different foods

The quantity of daily per capita food consumption is disaggregated into varies types: cereal grains, vegetables and fruits, meat, oils and fats, oilseeds and pulses, roots and tubers, sugar and dairy. The daily per capita average consumption of each food type in low, medium and high income group is illustrated in Figure 6.3. It can be seen that the consumption of each type of food increases with the increase in per capita income, with the highest consumption is attributed to vegetables and fruits and cereal grains in all income groups.



	Low income	Medium income	High income
Oils and fats	28	35	42
Oilseeds and pulses	39	52	69
Sugar	66	74	84
Dairy	55	79	116
Meat	65	95	152
Roots and tubers	108	136	187
Cereals and products	364	408	429
Vegetables and fruits	414	564	844

Note: All the data presented in this table are in gram per capita per day.

Figure 6.3 Impact of per capita income on daily food consumption

The daily per capita average consumption of each type of food for the whole surveyed households is compared with COSIT et al. survey (2010) to examine the consumption trend. Per capita consumption for vegetables and fruits shows an upward trend from 533 to 626 g/p/d, with a slightly increase in cereal grains (from 391 to 406 g/p/d) and animal protein (i.e., meat and dairy) (from 169 to 200 g/p/d). However, per capita consumption of oils and fats (36 g/p/d) and sugar (75 g/p/d) remains more or less unchanged.

6.4 Water use for food preparation

For each food commodity, the number of cooking sessions per week and household water consumption per session are surveyed (Appendix A). The collected data for each commodity are converted to a daily number of cooking sessions and per capita water consumption per session (Table 6.1). The resulted figures can be used with Equation 3.11 to calculate the daily per

Table 6.1 Summary of mean values of food commodity parameters

Food type	Commodity	Parameters	Unit	Overall survey	Low income	Medium income	High income
Cereal grains	Wheat	Daily per capita wheat flour consumption	g/p/d	257.95	235.65	261.67	268.00
		Water consumption per capita per cooking session	l/p/cs	1.68	2.13	1.63	1.45
		Number of cooking sessions per day	cs/d	0.14	0.14	0.14	0.14
		LPG consumption per capita per cooking session	ml/p/cs	24.97	31.67	23.01	23.03
	Rice	Daily per capita rice consumption	g/p/d	86.03	76.62	86.20	92.04
		Water consumption per capita per cooking session	l/p/cs	2.58	3.00	2.52	2.36
		Number of cooking sessions per day	cs/d	1.15	0.98	1.10	1.33
		LPG consumption per capita per cooking session	ml/p/cs	14.95	20.42	14.14	12.35
	Burgul and jareesh	Daily per capita burgul and jareesh consumption	g/p/d	5.67	5.47	5.47	6.06
		Water consumption per capita per cooking session	l/p/cs	1.51	1.75	1.47	1.39
		Number of cooking sessions per day	cs/d	0.13	0.10	0.10	0.19
		LPG consumption per capita per cooking session	ml/p/cs	14.95	20.42	14.14	12.35
	Macaroni and vermicelli	Daily per capita macaroni and vermicelli consumption	g/p/d	7.54	6.14	7.60	8.40
		Water consumption per capita per cooking session	l/p/cs	1.05	1.26	1.03	0.94
		Number of cooking sessions per day	cs/d	0.18	0.10	0.13	0.29
		LPG consumption per capita per cooking session	ml/p/cs	8.75	11.20	8.34	7.66
	Buns, cake and biscuits	Daily per capita buns, cake and biscuits consumption	g/p/d	48.99	41.23	48.57	54.65
		Water consumption per capita per cooking session	l/p/cs	0.58	0.82	0.56	0.46
		Number of cooking sessions per day	cs/d	1.02	0.61	0.99	1.33
		LPG consumption per capita per cooking session	ml/p/cs	18.44	25.09	17.31	15.46
Meat	Sheep and goat	Daily per capita sheep and goat meat consumption	g/p/d	35.03	23.04	31.52	47.41
		Water consumption per capita per cooking session	l/p/cs	2.58	3.00	2.52	2.36
		Number of cooking sessions per day	cs/d	1.01	0.61	0.97	1.33
		LPG consumption per capita per cooking session	ml/p/cs	89.71	122.72	84.80	74.09
	Bovine	Daily per capita bovine meat consumption	g/p/d	4.50	0.00	2.14	10.46
		Water consumption per capita per cooking session	l/p/cs	1.37	0.00	1.29	2.36
		Number of cooking sessions per day	cs/d	0.08	0.00	0.04	0.19
		LPG consumption per capita per cooking session	ml/p/cs	43.72	0.00	42.58	74.09

Note: g =grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table 6.1 Summary of mean values of food commodity parameters

Food type	Commodity	Parameters	Unit	Overall survey	Low income	Medium income	High income
Meat	Chicken and turkey	Daily per capita chicken and turkey consumption	g/p/d	52.30	32.51	47.63	71.32
		Water consumption per capita per cooking session	l/p/cs	2.58	3.00	2.52	2.36
		Number of cooking sessions per day	cs/d	0.89	0.52	0.86	1.18
		LPG consumption per capita per cooking session	ml/p/cs	52.55	67.28	49.96	46.09
	Fish and seafood	Daily per capita fish and seafood consumption	g/p/d	16.03	9.77	14.29	22.37
		Water consumption per capita per cooking session	l/p/cs	2.98	3.20	2.97	2.85
		Number of cooking sessions per day	cs/d	0.13	0.09	0.10	0.19
		LPG consumption per capita per cooking session	ml/p/cs	16.85	19.53	16.64	15.35
Dairy	Yogurt	Daily per capita yogurt consumption	g/p/d	43.90	28.54	40.13	58.86
		Number of cooking sessions per day	cs/d	0.02	0.01	0.04	0.01
		LPG consumption per capita per cooking session	ml/p/cs	9.36	2.04	17.97	3.29
	Cheese	Daily per capita cheese consumption	g/p/d	9.17	5.82	8.64	12.07
	Egg	Daily per capita egg consumption	egg/p/d	0.49	0.33	0.45	0.65
		Water consumption per capita per cooking session	l/p/cs	0.58	0.82	0.56	0.46
		Number of cooking sessions per day	cs/d	0.91	0.61	0.86	1.18
		LPG consumption per capita per cooking session	ml/p/cs	8.37	11.20	8.05	6.89
	Milk	Daily per capita milk consumption	g/p/d	29.22	18.53	26.82	39.32
		Number of cooking sessions per day	cs/d	0.24	0.10	0.24	0.34
		LPG consumption per capita per cooking session	ml/p/cs	11.75	15.41	11.22	10.00
	Butter	Daily per capita butter consumption	g/p/d	3.81	2.34	3.76	4.86
Roots and tubers	Potato	Daily per capita potato consumption	g/p/d	88.85	66.74	82.90	111.02
		Water consumption per capita per cooking session	l/p/cs	1.05	1.26	1.03	0.94
		Number of cooking sessions per day	cs/d	0.72	0.52	0.70	0.89
		LPG consumption per capita per cooking session	ml/p/cs	26.27	33.66	24.97	23.03
	Onion	Daily per capita onion consumption	g/p/d	56.44	41.09	52.30	71.84
	Carrots	Daily per capita carrot consumption	g/p/d	0.71	0.00	0.39	1.57
		Water consumption per capita per cooking session	l/p/cs	0.06	0.00	0.03	0.13
		Number of cooking sessions per day	cs/d	0.02	0.00	0.01	0.04
		LPG consumption per capita per cooking session	ml/p/cs	1.43	0.00	0.83	3.14

Note: g =grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table 6.1 Summary of mean values of food commodity parameters

Food type	Commodity	Parameters	Unit	Overall survey	Low income	Medium income	High income
Roots & tubers	Garlic	Daily per capita garlic consumption	g/p/d	1.27	0.02	0.93	2.52
	Radish	Daily per capita radish consumption	g/p/d	0.00	0.00	0.00	0.00
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00
Vegetables and fruits	Tomato	Daily per capita tomato consumption	g/p/d	221.53	155.73	202.97	288.57
		Water consumption per capita per cooking session	l/p/cs	0.72	0.83	0.70	0.66
		Number of cooking sessions per day	cs/d	1.08	0.96	1.07	1.18
	Cucumber	Daily per capita cucumber consumption	g/p/d	82.09	55.46	74.32	109.55
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00
	Aubergine	Daily per capita aubergine consumption	g/p/d	56.84	38.11	51.90	75.48
		Water consumption per capita per cooking session	l/p/cs	0.64	0.71	0.64	0.60
		Number of cooking sessions per day	cs/d	0.42	0.36	0.40	0.48
		LPG consumption per capita per cooking session	ml/p/cs	29.04	41.57	26.97	23.36
	Courgette	Daily per capita courgette consumption	g/p/d	29.76	20.04	27.55	38.99
		Water consumption per capita per cooking session	l/p/cs	0.64	0.71	0.64	0.60
		Number of cooking sessions per day	cs/d	0.19	0.11	0.13	0.33
		LPG consumption per capita per cooking session	ml/p/cs	30.37	47.48	26.97	23.36
	Okra	Daily per capita okra consumption	g/p/d	14.34	8.13	12.76	20.44
		Water consumption per capita per cooking session	l/p/cs	0.61	0.58	0.64	0.60
		Number of cooking sessions per day	cs/d	0.14	0.08	0.13	0.19
		LPG consumption per capita per cooking session	ml/p/cs	27.16	33.23	26.97	23.36
	Lettuce	Daily per capita lettuce consumption	g/p/d	7.33	3.59	6.43	10.94
		Water consumption per capita per cooking session	l/p/cs	0.47	0.42	0.44	0.54
		Number of cooking sessions per day	cs/d	0.13	0.06	0.11	0.19
	Sweet pepper	Daily per capita sweet pepper consumption	g/p/d	7.42	3.55	6.55	11.06
		Water consumption per capita per cooking session	l/p/cs	0.16	0.18	0.16	0.17
		Number of cooking sessions per day	cs/d	0.13	0.06	0.12	0.18
	Celery	Daily per capita celery consumption	g/p/d	7.16	3.51	6.21	10.78
		Water consumption per capita per cooking session	l/p/cs	0.26	0.18	0.26	0.31
		Number of cooking sessions per day	cs/d	0.12	0.05	0.11	0.19

Note: g =grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table 6.1 Summary of mean values of food commodity parameters

Food type	Commodity	Parameters	Unit	Overall survey	Low income	Medium income	High income
Vegetables and fruits	Water melon	Daily per capita water melon consumption	g/p/d	86.49	58.84	78.41	115.01
	Orange	Daily per capita orange consumption	g/p/d	28.86	18.74	25.26	40.12
	Apple	Daily per capita apple consumption	g/p/d	28.53	18.61	25.16	39.35
		Water consumption per capita per cooking session	l/p/cs	0.33	0.34	0.34	0.31
		Number of cooking sessions per day	cs/d	0.43	0.22	0.37	0.63
	Melon	Daily per capita melon consumption	g/p/d	19.62	11.72	17.82	27.14
	Grape	Daily per capita grape consumption	g/p/d	11.67	6.13	8.63	19.18
		Water consumption per capita per cooking session	l/p/cs	0.24	0.18	0.21	0.30
		Number of cooking sessions per day	cs/d	0.27	0.06	0.21	0.47
	Pumpkin	Daily per capita pumpkin consumption	g/p/d	11.75	6.39	8.87	18.94
		Water consumption per capita per cooking session	l/p/cs	0.24	0.19	0.21	0.30
		Number of cooking sessions per day	cs/d	0.08	0.06	0.07	0.10
		LPG consumption per capita per cooking session	ml/p/cs	23.14	23.76	20.27	26.36
	Banana	Daily per capita banana consumption	g/p/d	12.56	6.64	11.18	18.21
Oilseeds and pulses	Bean	Daily per capita bean consumption	g/p/d	18.19	13.14	16.93	23.14
		Water consumption per capita per cooking session	l/p/cs	1.49	1.69	1.47	1.39
		Number of cooking sessions per day	cs/d	0.24	0.11	0.24	0.33
		LPG consumption per capita per cooking session	ml/p/cs	49.10	62.36	48.28	41.37
	Chickpea	Daily per capita chickpea consumption	g/p/d	18.22	12.76	17.20	23.12
		Water consumption per capita per cooking session	l/p/cs	1.49	1.69	1.47	1.39
		Number of cooking sessions per day	cs/d	0.24	0.11	0.24	0.33
		LPG consumption per capita per cooking session	ml/p/cs	49.10	62.36	48.28	41.37
	Lentils	Daily per capita lentils consumption	g/p/d	18.12	13.15	17.16	22.63
		Water consumption per capita per cooking session	l/p/cs	1.93	2.08	1.91	1.85
		Number of cooking sessions per day	cs/d	0.24	0.11	0.24	0.33
		LPG consumption per capita per cooking session	ml/p/cs	49.10	62.36	48.28	41.37
Oils & fats	Vegetable oil	Daily per capita vegetable oil consumption	g/p/d	35.67	28.36	34.86	41.53
	Animal fats	Daily per capita animal fats consumption	g/p/d	0.19	0.00	0.00	0.56
	Sugar	Daily per capita sugar consumption	g/p/d	75.36	66.10	73.73	83.55

Note: g =grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres capita water consumption for food preparation. The daily per capita water consumption for cooking each type of food in different income groups is calculated as shown in Figure 6.4.

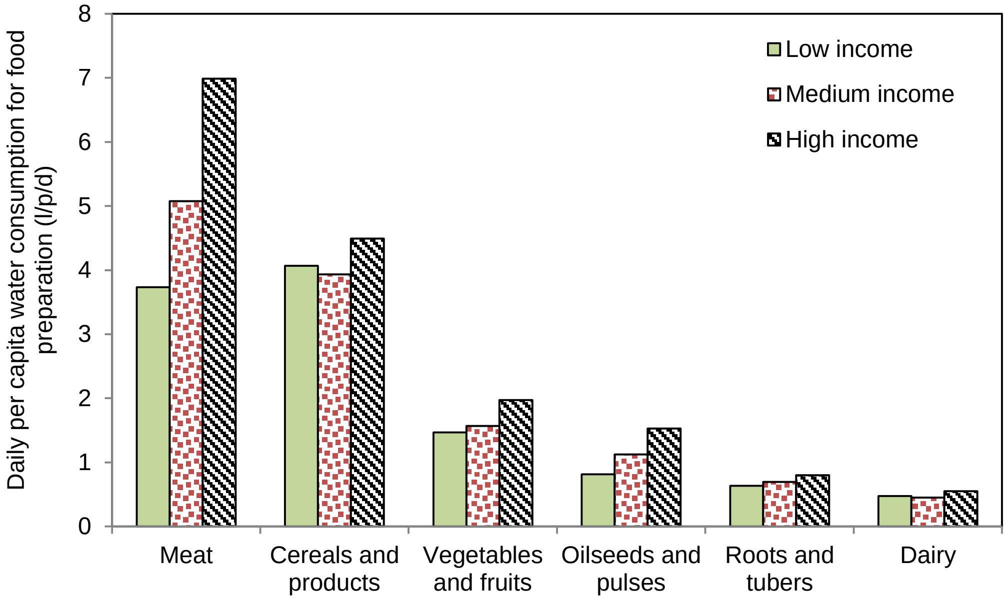


Figure 6.4 Summary of water consumption for food preparation in different income households

6.5 Energy use for food preparation

The analysis of energy consumption survey shows that the LPG is the most common fuel for cooking purposes in households in Duhok, with less reliance on the electricity for food preparation. LPG is supplied to the households in pressurized cylinders. The capacity of each cylinder is 26.2 l (Kurdistan Ministry of Natural Resources, 2015).

For each surveyed food commodity in Table 3.12, the quantity of LPG consumption per cooking session is calculated using Equation 3.15. The results of per capita LPG consumption in the cooking session of each food commodity are shown in Table 6.1, for different income groups. Using these figures and the number of cooking sessions per day, the quantity of LPG consumption for cooking each food commodity was calculated and are shown in Figure 6.5. This figure shows that meat cooking requires considerable amount of LPG. The meat consumption is forecasted to grow considerably (Musaiger and Miladi, 1997), and this will have further implications for energy use.

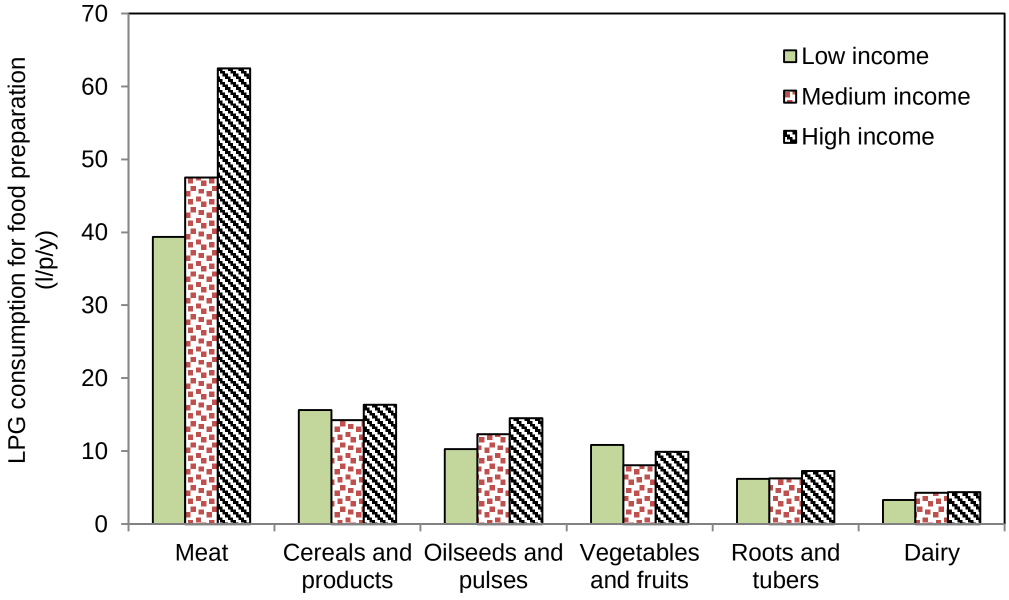


Figure 6.5 Summary of LPG consumption for food preparation in different income households

6.6 Influence of per capita income on the consumption of food types

The summary of per capita average values of each food commodity parameters (e.g., frequency of cooking and the quantity of food consumption) are illustrated in Table 6.1. This table shows the comparison between these parameters in low, medium and high income households. Statistical analysis (mean, median, standard deviation, variance, minimum, maximum, skewness, kurtosis and confidence interval) for parameters presented in Table 6.1 are shown in Tables E3.1-E3.4 (Appendix E3). The key findings are explained in Section 6.6.1 to 6.6.8.

6.6.1 Cereals and products

The analysis of surveyed households for food consumption shows that there is a high consumption of cereal grains (e.g., wheat and rice) and products made with the cereals (e.g., burgul, jareesh, macaroni, vermicelli and bun). Around half of the calorie intake is provided from cereals and products in low, medium and high income groups (Figure 6.2), accounting to approximately 1270, 1420 and 1500 kcal/p/d, respectively.

Within cereals and products made with cereals group, the major consumed crop is wheat, accounting approximately to 63% of daily per capita cereal grains consumption in all income households (Figure 6.6). Additionally, per capita cereal grains consumption increases slightly with the increase in per capita income, for being approximately 235, 260 and 270 g/p/d of wheat and also 77, 86 and 92 g/p/d of rice in low, medium and high income households, respectively (Table 6.1).

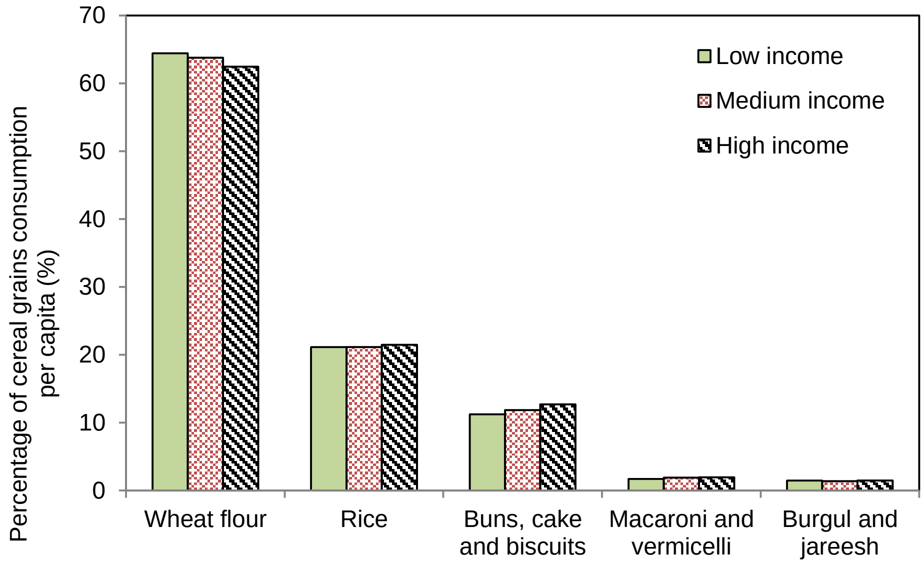


Figure 6.6 Percentage of consumption of each commodity within cereals grains group in different income households

Compared to the reported per capita wheat consumption in COSIT et al. survey (230 g/p/d) in 2010, the daily average consumption has increased slightly to 260 g/p/d (Table 6.1). Similarly, per capita rice consumption has also increased from 83 to 86 g/p/d.

The per capita consumption of other cereal products is relatively low compared to the wheat and rice consumption. For example, the daily per capita macaroni and vermicelli consumption is approximately 8 g/p/d as well as burgul and jareesh combined is only 6 g/p/d (Table 6.1).

Water consumption:

In terms of average daily per capita water consumption for cereal grains preparation, it is approximately 4.0 l/p/d in each of low and medium income households, with slightly higher water consumption (4.5 l/p/d) in the high income group (Figure 6.4). The highest water consumption is attributed to the rice preparation (approximately 70% of the total water consumption for cereal grains preparation) (Table 6.1).

Energy consumption:

The annual per capita average LPG consumption to prepare cereal grains and products is ranged between 15 and 16 l/p/y in all income groups (Figure 6.5). The highest proportion (40%) of energy consumption for cereal grains preparation is attributed to the rice.

6.6.2 Meat

The survey analysis of meat consumption in Table 6.1 shows a shift in Duhok diet towards more animal protein (i.e., meat and dairy) (200 g/p/d), compared to the recorded value in COSIT et al. survey (169 g/p/d) in 2010. The comparison with daily per capita average meat consumption (e.g., mutton, poultry and fish) in 1989 in Iraq (71.8 g/p/d (Aoyama, 1999)) shows an increase to 108 g/p/d as shown in Table 6.1. This is consistent with developing countries' trends whereby meat consumption increases with the population, urban and income growth (Delgado, 2003). The daily per capita average meat consumption in Duhok (108 g/p/d) is slightly higher than the average consumption in some Middle East countries, such as UAE, Egypt and Kuwait, with 96.4, 94.7 and 92.4 g/p/d, respectively in these countries (Musaiger, 2011).

Table 6.1 shows that per capita poultry meat consumption is slightly higher than mutton meat consumption in all income households. On the other hand, the daily per capita average meat consumption increases with the increase in per capita income: approximately 30, 45 and 70 g/p/d of poultry meat and 25, 30 and 50 g/p/d of mutton meat in low, medium and high income households, respectively (Table 6.1).

In terms of bovine meat consumption, it was nonexistent in low income households but significantly higher in high income group (10 g/p/d). The reason for this may be due to the high price for beef in Iraq, compared to the other types of meat (Scotti, 2011).

Fish and seafood consumption is relatively low compared to poultry and mutton meat, with being approximately 10 g/p/d in low income and much higher in the high income households (22 g/p/d) as shown in Table 6.1. The average fish and seafood consumption of whole surveyed households (16 g/p/d) is broadly similar to the reported value in COSIT et al. survey (15.9 g/p/d) in 2010.

Water consumption:

Similarly to LPG consumption, water usage for meat preparation is the highest within food types in medium and high income groups (Figure 6.4). However, it is slightly less than the water consumption for cereal grains preparation in low income households.

Energy consumption:

As shown in Figure 6.5, the annual per capita average LPG consumption for meat preparation is higher than that for other types of food in all income groups, with being significantly higher in high income households (63 l/p/y) compared to medium (48 l/p/y) and low (40 l/p/y) income groups. The detailed analysis found that approximately 32% of LPG consumption for meat preparation is attributed to poultry meat and 60% of LPG is used to cook mutton, in all income households.

6.6.3 Dairy products

The analysis of surveyed dairy products (i.e., yogurt, milk, cheese and butter) in Table 6.1 shows that the daily per capita average consumption in high income group (125 g/p/d) is higher than that in medium (87 g/p/d) and low (60 g/p/d) income households. Within dairy products group, the highest consumed commodity is yogurt (29, 40 and 59 g/p/d in low, medium and high income households, respectively), with less consumption for milk (19, 27 and 39 ml/p/d in low, medium and high income groups, respectively) (Table 6.1). The average number of consumed eggs per capita per week is 2.3, 3.2 and 4.6 eggs/p/w in low, medium and high income groups, respectively.

Water and energy consumption:

The analyses of water and energy consumption for food preparation show that both are the lowest for dairy products, accounting approximately 0.5 l/p/d of water (Figure 6.4) and 4.1 l/p/y of LPG (Figure 6.5) in all income households. This can be due to the fact that most of dairy products are bought from markets.

6.6.4 Vegetables and fruits

The daily consumption of fresh fruits and vegetables is the highest, compared to the all other types of food in all income groups (Figure 6.3). The daily per capita average consumption increases with the increase in per capita income from approximately 410 g/p/d in low income to 840 g/p/d in high income households (Figure 6.3). The low consumption of vegetables and fruits in low income group may be attributed to their high prices. The overall per capita consumption of vegetables and fruits provides less than 8% of the total calorie intake in all income groups (Figure 6.2).

Within the surveyed types of vegetables and fruits, the highest consumption is attributed to tomato, accounting approximately 35% of the total consumed quantity of vegetables and fruits in all income households (Figure 6.7). Cucumber and water melon are the second highest consumed vegetables and fruits, with approximately 13% for each one in all income groups. Apart from aubergine, the consumption of each of the rest of surveyed vegetables and fruits (i.e., courgette, okra, lettuce, pepper, celery, orange, apple, grape, melon, pumpkin and banana) is less than 5% of per capita consumption of vegetables and fruits in all income households (Figure 6.7).

Water and energy consumption:

The daily per capita average water consumption for vegetables and fruits preparation (i.e., washing and cooking) is approximately 1.5 l/p/d in low and medium income groups, with a slightly higher water consumption in high income households (2.0 l/p/d) (Figure 6.4). In terms of LPG usage for vegetables and fruits preparation, the annual per capita average consumption is approximately 10 l/p/y (i.e. less than 9% of the total LPG consumption) in all income groups as shown in Figure 6.5.

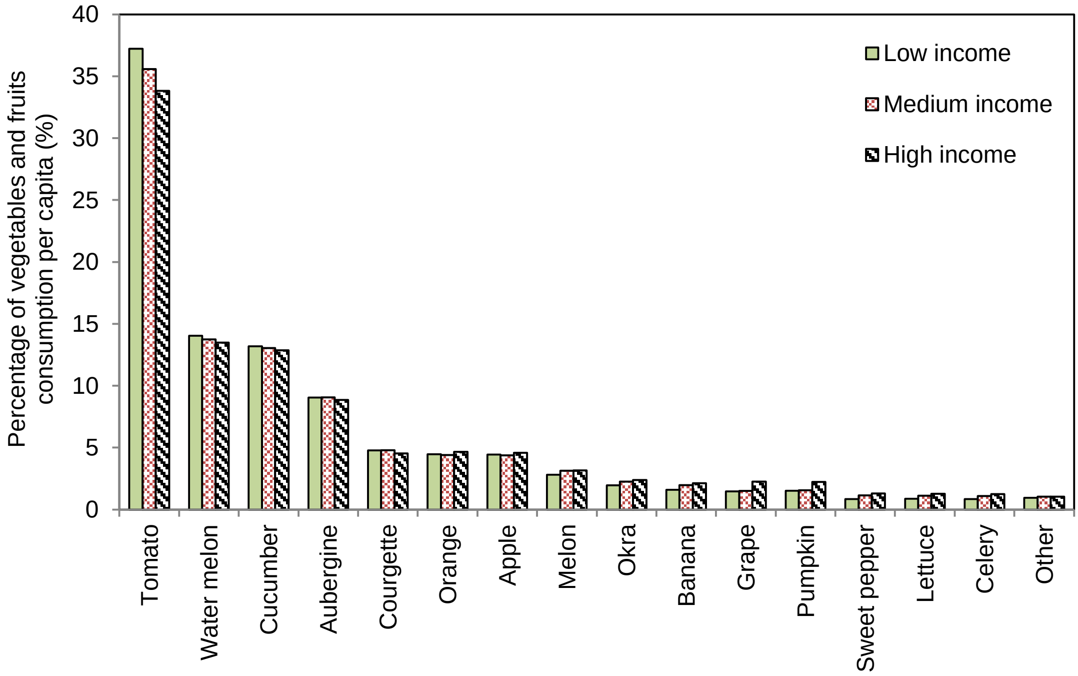


Figure 6.7 Percentage of consumption of each type of vegetables and fruits in different income households

6.6.5 Oilseeds and pulses

The proportion of daily calorie intake from oilseeds (e.g., sesame and sunflower) and pulses (e.g., chickpea, lentils and bean) is the lowest within food types, accounting less than 3% of the calorie intake in all income groups (Figure 6.2). The daily per capita consumption of bean, chickpea and lentils is approximately similar within each income group. For each type of oilseeds and pulses, the daily per capita average consumption is approximately 13 g/p/d in low income group and increases to 17 and 23 g/p/d in medium and high income households, respectively (Table 6.1).

Water and energy consumption:

The survey analysis clearly shows that the per capita average water and LPG consumption for oilseeds and pulses preparation increase with the increase in per capita income. The per capita average consumption is approximately 0.8, 1.1 and 1.5 l/p/d of water (Figure 6.4) and 10.3, 12.3 and 14.5 l/p/y of LPG (Figure 6.5) in low, medium and high income groups, respectively.

6.6.6 Roots and tubers

Roots and tubers include all types of vegetables which grow and develop underground, such as, potato, onion, carrots, garlic and radish. It supplies approximately 6% of the daily total calorie intake in all income groups (Figure 6.2). The analysis of daily per capita average consumption of roots and tubers (147 g/p/d) shows an upward trend, compared to the reported value in 2010 (79 g/p/d) (COSIT et al., 2010).

Potato is one of the highly consumed plants in the world (Pimentel, 2009), which is also heavily consumed in Duhok; accounting approximately 60% of the total per capita consumption of roots and tubers in all income groups (Figure 6.8). Onion consumption (38%) was found to be less than potato consumption.

<u>*Water and energy consumption:*</u>

For roots and tubers preparation, the highest consumption of water and energy is attributed to potato, accounting to approximately 0.7 l/p/d of water (Figure 6.4) and 6.5 l/p/y of LPG (Figure 6.5) in all income households.

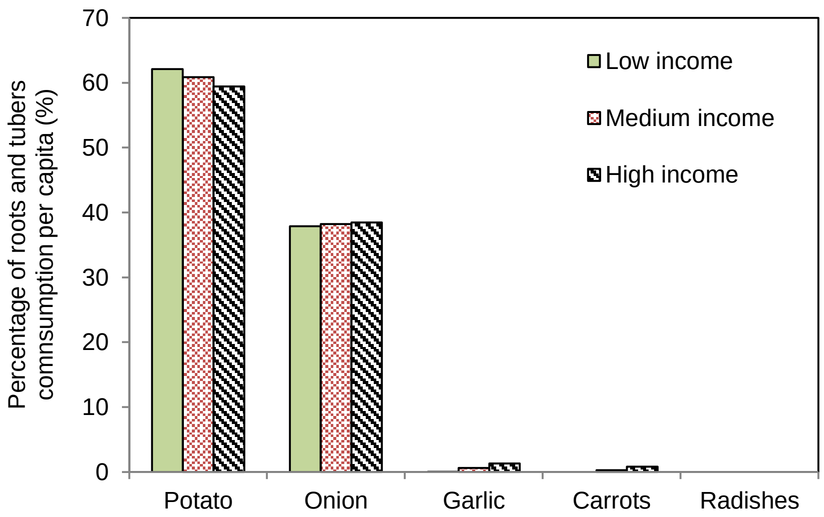


Figure 6.8 Percentage of consumption of each type of roots and tubers in different income households

6.6.7 Sugar

Sugar consumption can be either as a sweetener with beverages (e.g., tea) or in the form of sugar-containing food (e.g., biscuits and confectionery). The analysis of dietary calorie intake for the surveyed households shows that around 11% of the total energy is provided from sugar (Figure 6.2). This is slightly higher than the recommended rate by WHO (less than 10%) (Te Morenga et al., 2013). However, the annual per capita average consumption from the Iraqi survey (28 kg/p/y) is lower than the reported value in the USA (29 kg/p/y), the UK (36 kg/p/y) and Australia (37 kg/p/y) (Barclay and Brand-Miller, 2011).

On the other hand, the comparison between the income groups shows that the daily per capita average sugar consumption in high income households (84 g/p/d) is higher than that in medium (74 g/p/d) and low (66 g/p/d) income groups (Table 6.1). The daily per capita average sugar consumption for the whole surveyed households (75 g/p/d) (Table 6.1) is broadly similar to the reported value (73 g/p/d) in COSIT et al. survey (2010).

6.6.8 Oils and fats

The analysis of oils and fats (e.g., vegetable oil and animal fat) consumption shows that daily per capita average consumption is ranged between 28 g/p/d in low income and 42 g/p/d in high income households (Table 6.1). This is very low compared to the reported values in some Middle East countries, such as Iran, Jordan and Syria with 62.8, 89.7 and 104.2 g/p/d, respectively (Musaiger, 2011). However, oils and fats can be the second highest dietary energy supplier within food types, providing approximately 12% (i.e., 350 kcal/p/d) of the daily calorie intake (Figure 6.2).

6.7 Seasonal variability of food consumption (summer survey)

Although, per capita food consumption may not remain constant throughout the year (Rossato et al., 2015), most studies addressed the consumption during a particular period of the year only (Costa, et al., 2013). This may influence the correct estimation of demand for different food. The seasonal variability in food consumption might be more pronounced in developing countries where the price of most food commodities varies seasonally (Leonard and Thomas, 1989). Therefore, the food survey explained in Section 3.3.1 was repeated during summer season in June 2015 to investigate the impact of seasonal variability on per capita food consumption.

The information of summer survey are collected from the same sample of households which were selected for winter survey. This eliminates the additional variation that could arise due to conducting survey at households with different characteristics and behaviour. The full summer survey is shown in Appendix A. Information were collected on the frequency of cooking and consumed quantity of each type of food. As well as, the duration and water used for the cooking session of each food commodity.

6.7.1 Average per capita food consumption in summer season

The statistical analysis of per capita consumption for all surveyed food commodities in summer season is presented in Table E3.5 (Appendix E3). The summation of these figures shows that the average amount of daily per capita food consumption is marginally increased from 1540 in winter to 1555 g/p/d in summer. Further analysis of frequency distribution and cumulative frequency of per capita food consumption for all surveyed households during winter and summer is shown in Figure 6.9. From this figure, it can be concluded that the number of households which consumes more than 1400 g/p/d of food is slightly increased from 66 in winter to 71% of households in summer.

However, the daily per capita average calorie intake decreased from 2860 in winter to 2840 kcal/p/d during summer season. In agreement with Ma et al. (2006), the seasonal difference of daily calorie intake is slightly fluctuated between winter and summer season. This may indicate there is no much variation in Duhok’s diet over the seasons.

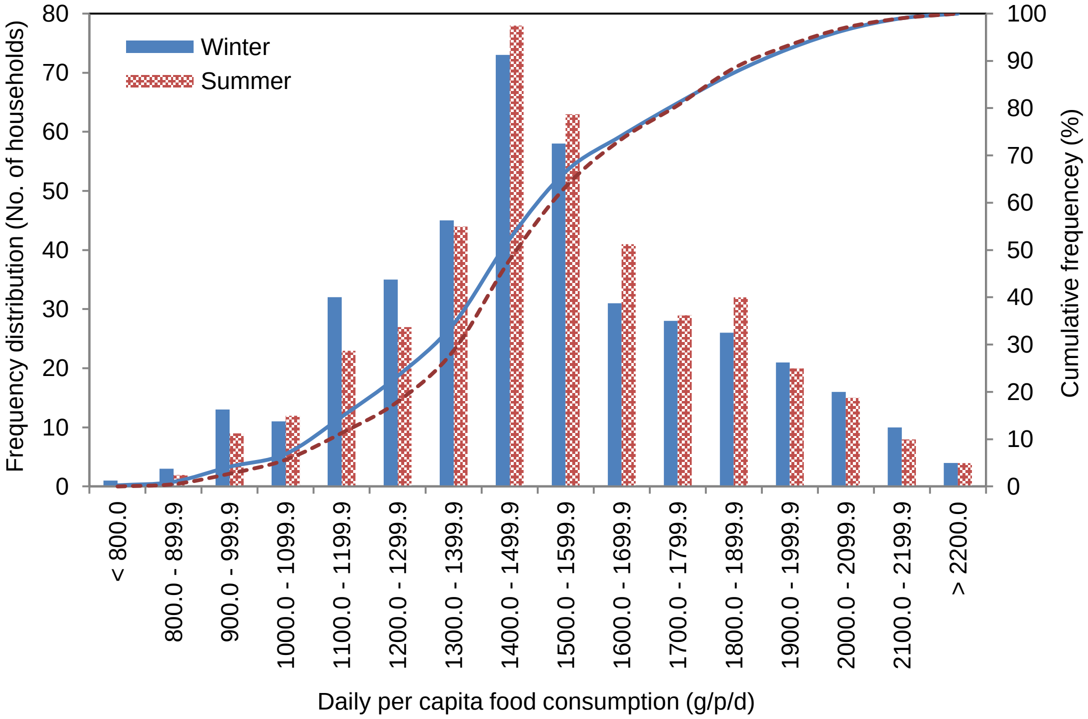
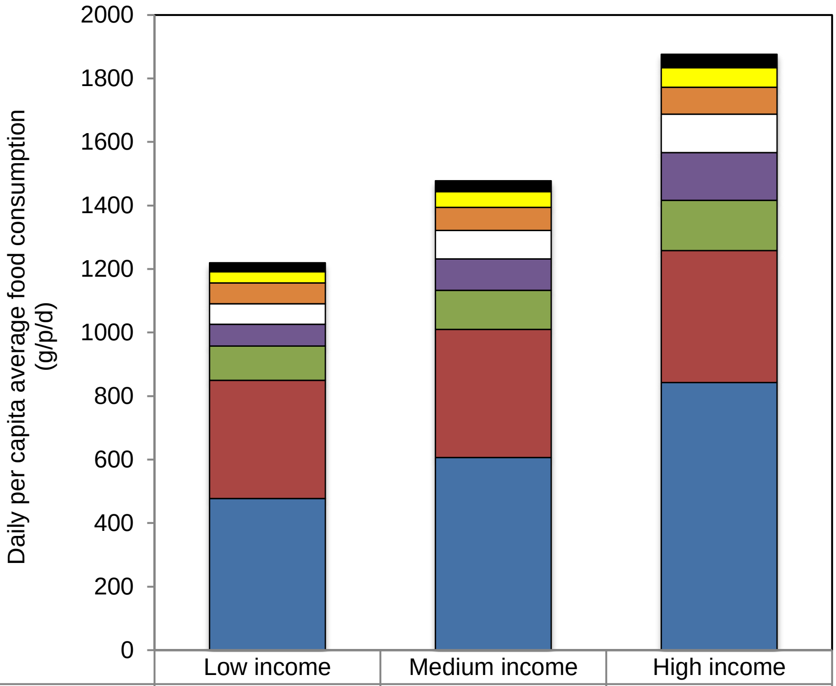


Figure 6.9 seasonal variability of per capita average food consumption

6.7.2 Average per capita consumption for each type of food in summer

Using the collected data of summer survey, the average per capita consumption for each type of food is analysed in low, medium and high income households (Section 3.4.2). Figure 6.10 illustrates the results of analysis of daily per capita average consumption for each type of food during summer season in low, medium and high income households. In agreement with the winter survey, this figure shows that the amount of per capita consumption for each type of food increases with the increased income. In addition, the highest consumption is attributed to vegetables and fruits in both seasons.



	Low income	Medium income	High income
Oil and fats	28.2	34.3	42.1
Oilseeds and pulses	35.9	48.9	61.5
Sugar	65.5	73.5	84.5
Dairy	64.4	89.6	121.3
Meat	68.9	98.3	150.4
Roots and tubers	108.0	122.9	157.6
Cereals and products	371.3	403.8	415.4
Vegitables and fruits	478.2	606.9	843.4

Note: All the data presented in this table are in gram per capita per day.

Figure 6.10 Average per capita consumption of each type of food in summer

6.7.3 Seasonal variability of each type of food

Two-tailed t-test (Section 3.4.3) is used at 95% confidence interval to examine the seasonal variability of each type of food as presented in Table 6.2. The results in this table show that the p value for meat, sugar and oils and fats is higher than 0.05. This means there is no significant difference between the consumption in winter and summer season.

However, the difference of per capita consumption for other types of food (i.e., cereal grains, dairy products, roots and tubers, vegetables and fruits and oilseeds and pulses) was statistically significant ($p<0.05$) between winter and summer season. Per capita consumption for only vegetables and fruits and dairy products is higher in summer, compared to winter.

Table 6.2 Statistical comparison of types of food between winter and summer

Food end-use	Average food consumption (g/p/d)		t value	Significant (2-tailed) (p)
	Winter	Summer		
Cereal grains and products	406.27	400.43	8.11	0 *
Meat	107.73	109.45	-1.52	0.056 **
Dairy products	86.38	94.75	-19.27	0 *
Roots and tubers	147.18	131.38	16.76	0 *
Vegetables and fruits	625.81	658.57	-14.17	0 *
Oilseeds and pulses	54.66	50.3	12.91	0 *
Oils and fats	35.67	35.57	0.84	0.399 **
Sugar and products	75.36	75.42	-0.24	0.808 **

* = significant difference between winter and summer
** = not significant difference between winter and summer

Cereal grains and products

In agreement with food consumption survey in winter, cereal grains and products made with cereals are heavily consuming during summer season (Table 6.2). However, there is a slightly decrease in per capita consumption for cereal grains in summer compared to winter. The detailed analysis shows that the decrease in wheat consumption is from 257.9 g/p/d in winter to 251.9 g/p/d in summer (Table 6.3). Per capita consumption for the rest of cereal grains and their products does not change throughout winter and summer season.

Further analysis of comparison between cereal grains consumption in winter and summer is shown in Figure E5.1 (Appendix E5). From this figure, it can be seen that the number of surveyed households which consumes less than 420 g/p/d increased from 66 in winter to 75% of households during summer.

Meat

The intake of proteins does not vary seasonally (De Castro, 1991; Ma et al., 2006). Similarly, the analysis of surveyed food shows that the per capita meat consumption does not vary throughout winter and summer seasons (Table 6.2). Only fish and sea food consumption slightly increases from 16 in winter to 19.5 g/p/d in summer (Table 6.3).

Table 6.3 Seasonal variability of mean values of food commodity parameters

Type	Commodity	Parameters/variable	Unit	Overall survey		Low income		Medium income		High income	
				Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Cereal grains	Wheat	Daily per capita wheat flour consumption	g/p/d	257.95	251.95	235.65	241.30	261.67	255.73	268.00	254.21
		Water consumption per capita per cooking session	l/p/cs	1.68	1.68	2.13	2.13	1.63	1.63	1.45	1.45
		No. of cooking sessions per day	cs/d	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
		LPG consumption per capita per cooking session	ml/p/cs	24.97	25.14	31.67	30.45	23.01	23.37	23.03	23.87
	Rice	Daily per capita rice consumption	g/p/d	86.03	86.21	76.62	76.61	86.20	86.39	92.04	92.33
		Water consumption per capita per cooking session	l/p/cs	2.58	2.58	3.00	3.00	2.52	2.52	2.36	2.36
		No. of cooking sessions per day	cs/d	1.15	1.16	0.98	1.02	1.10	1.10	1.33	1.33
		LPG consumption per capita per cooking session	ml/p/cs	14.95	15.02	20.42	19.63	14.14	14.34	12.35	12.82
	Burgul and jareesh	Daily per capita burgul and jareesh consumption	g/p/d	5.67	5.66	5.47	5.42	5.47	5.47	6.06	6.06
		Water consumption per capita per cooking session	l/p/cs	1.51	1.51	1.75	1.75	1.47	1.47	1.39	1.39
		No. of cooking sessions per day	cs/d	0.13	0.13	0.10	0.10	0.10	0.10	0.19	0.19
		LPG consumption per capita per cooking session	ml/p/cs	14.95	15.02	20.42	19.63	14.14	14.34	12.35	12.82
	Macaroni and vermicelli	Daily per capita macaroni and vermicelli consumption	g/p/d	7.54	7.58	6.14	6.17	7.60	7.62	8.40	8.47
		Water consumption per capita per cooking session	l/p/cs	1.05	1.05	1.26	1.26	1.03	1.03	0.94	0.94
		No. of cooking sessions per day	cs/d	0.18	0.18	0.10	0.10	0.13	0.13	0.29	0.29
		LPG consumption per capita per cooking session	ml/p/cs	8.75	8.82	11.20	10.80	8.34	8.48	7.66	7.96
	Buns, cake and biscuits	Daily per capita buns, cake and biscuits consumption	g/p/d	48.99	49.00	41.23	41.96	48.57	48.49	54.65	54.32
		Water consumption per capita per cooking session	l/p/cs	0.58	0.58	0.82	0.82	0.56	0.56	0.46	0.46
		No. of cooking sessions per day	cs/d	1.02	1.02	0.61	0.61	0.99	0.99	1.33	1.33
		LPG consumption per capita per cooking session	ml/p/cs	18.44	18.53	25.09	24.08	17.31	17.58	15.46	16.05
Meat	Sheep and goat	Daily per capita sheep and goat meat consumption	g/p/d	35.03	34.86	23.04	23.15	31.52	31.60	47.41	46.72
		Water consumption per capita per cooking session	l/p/cs	2.58	2.58	3.00	3.00	2.52	2.52	2.36	2.36
		No. of cooking sessions per day	cs/d	1.01	1.01	0.61	0.61	0.97	0.97	1.33	1.33
		LPG consumption per capita per cooking session	ml/p/cs	89.71	90.15	122.72	117.85	84.80	86.17	74.09	76.85
	Bovine	Daily per capita bovine meat consumption	g/p/d	4.50	4.31	0.00	0.00	2.14	2.30	10.46	9.71
		Water consumption per capita per cooking session	l/p/cs	1.37	0.86	0.00	0.00	1.29	0.32	2.36	2.11
		No. of cooking sessions per day	cs/d	0.08	0.07	0.00	0.00	0.04	0.02	0.19	0.18
		LPG consumption per capita per cooking session	ml/p/cs	43.72	27.63	0.00	0.00	42.58	9.91	74.09	68.34

Note: g =grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table 6.3 Seasonal variability of mean values of food commodity parameters

Type	Commodity	Parameters/variable	Unit	Overall survey		Low income		Medium income		High income	
				Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Meat	Chicken and turkey	Daily per capita chicken and turkey consumption	g/p/d	52.30	51.00	32.51	34.41	47.63	46.78	71.32	67.31
		Water consumption per capita per cooking session	l/p/cs	2.58	2.84	3.00	3.03	2.52	2.81	2.36	2.77
		No. of cooking sessions per day	cs/d	0.89	0.86	0.52	0.52	0.86	0.86	1.18	1.09
		LPG consumption per capita per cooking session	ml/p/cs	52.55	52.93	67.28	64.82	49.96	50.79	46.09	47.76
	Fish and seafood	Daily per capita fish and seafood consumption	g/p/d	16.03	19.46	9.77	11.68	14.29	17.81	22.37	26.69
		Water consumption per capita per cooking session	l/p/cs	2.98	3.39	3.20	3.52	2.97	3.43	2.85	3.26
		No. of cooking sessions per day	cs/d	0.13	0.10	0.09	0.09	0.10	0.10	0.19	0.11
		LPG consumption per capita per cooking session	ml/p/cs	16.85	16.92	19.53	18.39	16.64	16.93	15.35	15.94
Dairy	Yogurt	Daily per capita yogurt consumption	g/p/d	43.90	52.11	28.54	38.42	40.13	50.26	58.86	63.50
		No. of cooking sessions per day	cs/d	0.02	0.02	0.01	0.01	0.04	0.04	0.01	0.01
		LPG consumption per capita per cooking session	ml/p/cs	9.36	9.29	2.04	2.03	17.97	17.84	3.29	3.27
	Cheese	Daily per capita cheese consumption	g/p/d	9.17	9.26	5.82	5.79	8.64	8.69	12.07	12.28
	Egg	Daily per capita egg consumption	egg/p/	0.49	0.49	0.33	0.32	0.45	0.46	0.65	0.64
		Water consumption per capita per cooking session	l/p/cs	0.58	0.58	0.82	0.82	0.56	0.56	0.46	0.46
		No. of cooking sessions per day	cs/d	0.91	0.91	0.61	0.61	0.86	0.86	1.18	1.18
		LPG consumption per capita per cooking session	ml/p/cs	8.37	8.43	11.20	10.80	8.05	8.20	6.89	7.16
	Milk	Daily per capita milk consumption	g/p/d	29.22	29.24	18.53	17.82	26.82	26.78	39.32	39.93
		No. of cooking sessions per day	cs/d	0.24	0.24	0.10	0.10	0.24	0.24	0.34	0.34
		LPG consumption per capita per cooking session	ml/p/cs	11.75	11.76	15.41	14.48	11.22	11.43	10.00	10.38
	Butter	Daily per capita butter consumption	g/p/d	3.81	3.83	2.34	2.52	3.76	3.69	4.86	4.86
Root and tubers	Potato	Daily per capita potato consumption	g/p/d	88.85	72.10	66.74	66.91	82.90	67.96	111.02	80.77
		Water consumption per capita per cooking session	l/p/cs	1.05	1.05	1.26	1.26	1.03	1.03	0.94	0.94
		No. of cooking sessions per day	cs/d	0.72	0.68	0.52	0.52	0.70	0.67	0.89	0.80
		LPG consumption per capita per cooking session	ml/p/cs	26.27	26.46	33.66	32.43	24.97	25.39	23.03	23.87
	Onion	Daily per capita onion consumption	g/p/d	56.44	56.61	41.09	40.98	52.30	52.51	71.84	72.16
	Carrots	Daily per capita carrot consumption	g/p/d	0.71	1.37	0.00	0.04	0.39	1.49	1.57	2.11
		Water consumption per capita per cooking session	l/p/cs	0.06	0.14	0.00	0.004	0.03	0.15	0.13	0.22
		No. of cooking sessions per day	cs/d	0.02	0.08	0.00	0.003	0.01	0.12	0.04	0.08
		LPG consumption per capita per cooking session	ml/p/cs	1.43	2.98	0.00	0.09	0.83	3.31	3.14	4.47

Note: g =grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table 6.3 Seasonal variability of mean values of food commodity parameters

Type	Commodity	Parameters/variable	Unit	Overall survey		Low income		Medium income		High income	
				Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Roots & tubers	Garlic	Daily per capita garlic consumption	g/p/d	1.27	1.26	0.02	0.02	0.93	0.95	2.52	2.46
	Radish	Daily per capita radish consumption	g/p/d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vegetables and fruits	Tomato	Daily per capita tomato consumption	g/p/d	221.53	224.46	155.73	170.57	202.97	202.68	288.57	287.71
		Water consumption per capita per cooking session	l/p/cs	0.72	0.72	0.83	0.83	0.70	0.70	0.66	0.66
		No. of cooking sessions per day	cs/d	1.08	1.19	0.96	1.20	1.07	1.18	1.18	1.19
	Cucumber	Daily per capita cucumber consumption	g/p/d	82.09	83.75	55.46	62.30	74.32	78.25	109.55	104.91
	Aubergine	Daily per capita aubergine consumption	g/p/d	56.84	57.80	38.11	45.43	51.90	54.27	75.48	70.45
		Water consumption per capita per cooking session	l/p/cs	0.64	0.64	0.71	0.71	0.64	0.64	0.60	0.60
		No. of cooking sessions per day	cs/d	0.42	0.59	0.36	0.60	0.40	0.56	0.48	0.63
		LPG consumption per capita per cooking session	ml/p/cs	29.04	29.08	41.57	39.78	26.97	27.34	23.36	24.20
	Courgette	Daily per capita courgette consumption	g/p/d	29.76	29.80	20.04	19.95	27.55	27.72	38.99	38.96
		Water consumption per capita per cooking session	l/p/cs	0.64	0.64	0.71	0.71	0.64	0.64	0.60	0.60
		No. of cooking sessions per day	cs/d	0.19	0.19	0.11	0.11	0.13	0.13	0.33	0.33
		LPG consumption per capita per cooking session	ml/p/cs	30.37	30.41	47.48	45.68	26.97	27.34	23.36	24.20
	Okra	Daily per capita okra consumption	g/p/d	14.34	16.69	8.13	11.36	12.76	15.01	20.44	22.35
		Water consumption per capita per cooking session	l/p/cs	0.61	0.64	0.58	0.69	0.64	0.64	0.60	0.60
		No. of cooking sessions per day	cs/d	0.14	0.32	0.08	0.29	0.13	0.32	0.19	0.34
		LPG consumption per capita per cooking session	ml/p/cs	27.16	29.64	33.23	42.28	26.97	27.34	23.36	24.20
	Lettuce	Daily per capita lettuce consumption	g/p/d	7.33	7.29	3.59	3.68	6.43	6.29	10.94	10.94
		Water consumption per capita per cooking session	l/p/cs	0.47	0.47	0.42	0.43	0.44	0.44	0.54	0.54
		No. of cooking sessions per day	cs/d	0.13	0.13	0.06	0.06	0.11	0.11	0.19	0.18
	Sweet pepper	Daily per capita sweet pepper consumption	g/p/d	7.42	7.31	3.55	3.79	6.55	6.41	11.06	10.77
		Water consumption per capita per cooking session	l/p/cs	0.16	0.16	0.18	0.18	0.16	0.15	0.17	0.17
		No. of cooking sessions per day	cs/d	0.13	0.13	0.06	0.06	0.12	0.11	0.18	0.18
	Celery	Daily per capita celery consumption	g/p/d	7.16	8.52	3.51	4.10	6.21	8.52	10.78	11.45
		Water consumption per capita per cooking session	l/p/cs	0.26	0.46	0.18	0.32	0.26	0.49	0.31	0.51
		No. of cooking sessions per day	cs/d	0.12	0.29	0.05	0.18	0.11	0.32	0.19	0.34

Note: g =grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table 6.3 Seasonal variability of mean values of food commodity parameters

Type	Commodity	Parameters/variable	Unit	Overall survey		Low income		Medium income		High income	
				Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Vegetables and fruits	Water melon	Daily per capita water melon consumption	g/p/d	86.49	88.29	58.84	59.29	78.41	81.69	115.01	115.83
	Orange	Daily per capita orange consumption	g/p/d	28.86	26.20	18.74	18.62	25.26	24.50	40.12	33.37
	Apple	Daily per capita apple consumption	g/p/d	28.53	36.13	18.61	28.46	25.16	35.65	39.35	41.82
		Water consumption per capita per cooking session	l/p/cs	0.33	0.50	0.34	0.54	0.34	0.48	0.31	0.50
		No. of cooking sessions per day	cs/d	0.43	0.58	0.22	0.36	0.37	0.54	0.63	0.78
	Melon	Daily per capita melon consumption	g/p/d	19.62	29.37	11.72	24.53	17.82	26.20	27.14	36.58
	Grape	Daily per capita grape consumption	g/p/d	11.67	21.41	6.13	14.91	8.63	21.02	19.18	26.19
		Water consumption per capita per cooking session	l/p/cs	0.24	0.66	0.18	0.65	0.21	0.65	0.30	0.68
		No. of cooking sessions per day	cs/d	0.27	0.46	0.06	0.35	0.21	0.37	0.47	0.63
	Pumpkin	Daily per capita pumpkin consumption	g/p/d	11.75	11.80	6.39	6.17	8.87	8.96	18.94	19.11
		Water consumption per capita per cooking session	l/p/cs	0.24	0.24	0.19	0.19	0.21	0.21	0.30	0.31
		No. of cooking sessions per day	cs/d	0.08	0.08	0.06	0.06	0.07	0.07	0.10	0.10
		LPG consumption per capita per cooking session	ml/p/cs	23.14	23.67	23.76	22.52	20.27	20.83	26.36	28.04
	Banana	Daily per capita banana consumption	g/p/d	12.56	10.18	6.64	6.03	11.18	9.82	18.21	13.40
Oilseeds and pulses	Bean	Daily per capita bean consumption	g/p/d	18.19	17.39	13.14	12.92	16.93	16.55	23.14	21.41
		Water consumption per capita per cooking session	l/p/cs	1.49	1.49	1.69	1.69	1.47	1.47	1.39	1.39
		No. of cooking sessions per day	cs/d	0.24	0.24	0.11	0.11	0.24	0.24	0.33	0.33
		LPG consumption per capita per cooking session	ml/p/cs	49.10	49.55	62.36	60.29	48.28	49.14	41.37	42.96
	Chickpea	Daily per capita chickpea consumption	g/p/d	18.22	17.03	12.76	11.91	17.20	16.98	23.12	20.49
		Water consumption per capita per cooking session	l/p/cs	1.49	1.49	1.69	1.69	1.47	1.47	1.39	1.39
		No. of cooking sessions per day	cs/d	0.24	0.24	0.11	0.11	0.24	0.24	0.33	0.33
		LPG consumption per capita per cooking session	ml/p/cs	49.10	49.55	62.36	60.29	48.28	49.14	41.37	42.96
	Lentils	Daily per capita lentils consumption	g/p/d	18.12	15.64	13.15	11.03	17.16	15.07	22.63	19.41
		Water consumption per capita per cooking session	l/p/cs	1.93	1.73	2.08	1.22	1.91	1.91	1.85	1.85
		No. of cooking sessions per day	cs/d	0.24	0.23	0.11	0.06	0.24	0.24	0.33	0.33
		LPG consumption per capita per cooking session	ml/p/cs	49.10	43.93	62.36	35.45	48.28	49.14	41.37	42.96
Oils & fats	Vegetable oil	Daily per capita vegetable oil consumption	g/p/d	35.67	35.56	28.36	28.42	34.86	34.52	41.53	41.60
	Animal fats	Daily per capita animal fats consumption	g/p/d	0.19	0.19	0.00	0.00	0.00	0.00	0.56	0.56
	Sugar	Daily per capita sugar consumption	g/p/d	75.36	75.41	66.10	65.46	73.73	73.49	83.55	84.42

Note: g =grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Dairy

Daily per capita consumption of dairy products remains without change throughout winter and summer, except for yogurt, which increases from 43.9 in winter to 52.1 g/p/d in summer (Table 6.3). Consequently, the daily per capita total consumption for dairy products increases from 86.4 g/p/d in winter to 94.8 g/p/d in summer (Table 6.2).

Vegetables and fruits

Within all surveyed types of food, the highest difference between per capita consumption in winter and summer season is attributed to vegetable and fruits (Table 6.2). Approximately, 48% of households tend to consume more than 600 g/p/d of vegetables and fruits in winter while their consumption increases to more than 650 g/p/d in summer (Figure E5.2 in Appendix E5). Hence, the daily per capita consumption for vegetables and fruits in summer is higher than that in winter (Table 6.3). This is consistent with Rossato et al. (2015), who found that the consumption of fruits is higher and cereal grains is lower during summer. This may be due to the variation in prices and produced amount of vegetables and fruits throughout the year.

Oilseeds and pulses

Per capita consumption of each type of oilseeds and pulses slightly decreases in summer, compared to that in winter (Table 6.3). The observed difference of per capita consumption for oilseed and pulses is approximately 4.4 g/p/d between winter and summer season (Table 6.2).

Roots and tubers

The number of surveyed households which consumes more than 140 g/p/d of roots and tubers is decreased from 240 in winter to 180 households in summer (Figure E5.4 in Appendix E5). Therefore, the daily per capita consumption for roots and tubers in summer (131 g/p/d) is lower than winter (147 g/p/d) (Table 6.2). The decrease in per capita consumption is attributed to only potato as presented in Table 6.3.

Sugar

The seasonal comparison of food consumption shows that the daily per capita sugar consumption is similar in winter and summer season (Table 6.2). The frequency distribution of per capita sugar consumption during summer is nearly identical with the winter consumption (Figure E5.6 in Appendix E5).

Oils and fats

Similarly, to meat and sugar, the daily per capita consumption for oils and fats remains unchanged throughout winter and summer season (Table 6.2).

6.7.4 Seasonal variability of water use for food preparation

For each food commodity, the average quantity of water consumption per cooking session does not vary throughout winter and summer (Table 6.3). In addition, the average number of cooking sessions of most food commodities remains without change throughout both seasons, except for some vegetables and fruits. The number of preparation sessions of aubergine, okra, celery, apple and grape increases during summer season. Therefore, the highest difference in water used for food preparation between winter and summer is attributed to vegetables and fruits (Figure 6.11).

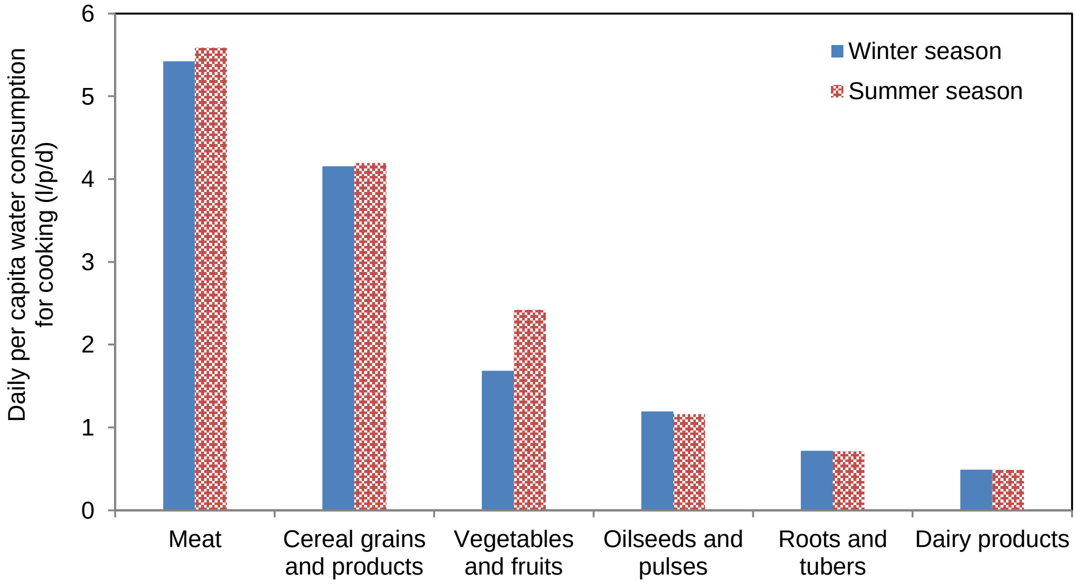


Figure 6.11 Comparison of water consumption for food preparation between winter and summer

6.7.5 Seasonal variability of LPG use for food preparation

The quantity of LPG consumption for cooking each type of food does not change throughout winter and summer season, except for vegetables and fruits (Figure 6.12). This is due to increased number of cooking sessions of aubergine and okra in summer. The average number of cooking sessions of other food commodities remains fairly the same in both seasons. Within all types of food, meat preparation recorded the highest consumption of LPG compared to other types of food.

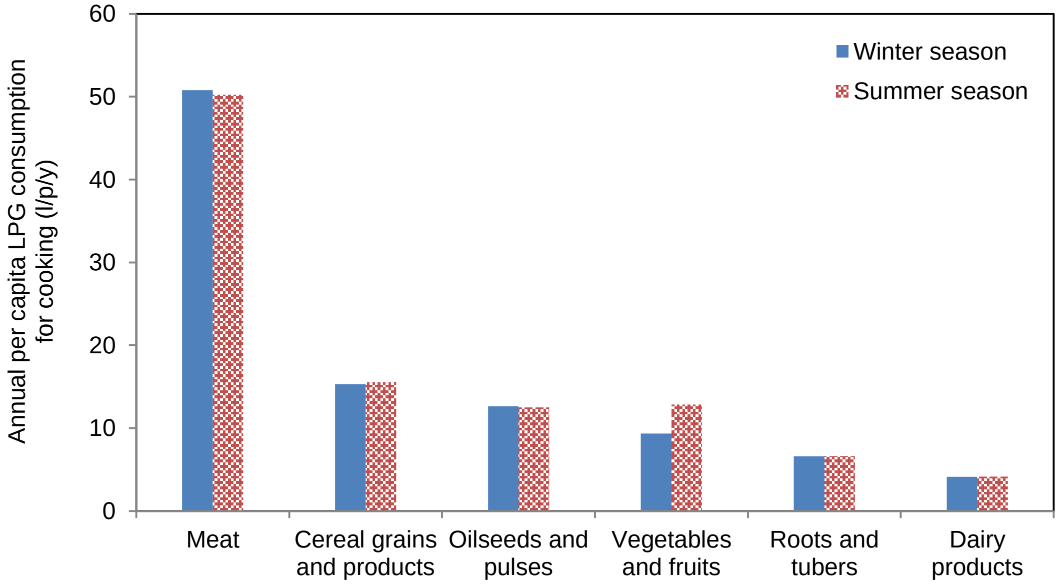


Figure 6.12 Comparison of LPG consumption for food preparation between winter and summer

6.8 Conclusions

The key messages from the analysis of the food consumption survey are:

- The total average household food consumption (kg/hh/d) increases with the increase in household occupancy and income.
- The rate of increase in per capita food consumption is much higher with the increase in male adults, compared to the increase in the number of adult females, elders and children in the household.
- The average daily calorie intake for adult males is higher than that for adult females, children and elders.

- Approximately half of the daily calorie intake is provided from cereal grains and products. However, the proportion of calorie intake from cereal grains decreases with the increase in per capita income.
- The consumption of vegetables, fruits and meat increases with the increase in per capita income.
- Daily per capita meat consumption in Iraq is high compared to the average consumption in the developing countries.
- Per capita poultry meat consumption is higher than each of mutton, bovine and fish meat consumption.
- Although the meat consumption is much lower than many other types of food (e.g. vegetables, fruits and cereal grains), it requires the highest quantity of water and LPG consumption for its preparation.
- Vegetables and fruits consumption is the highest among all food groups. However, the water and energy required to prepare them at home is the least.
- Daily per capita average consumption for meat, sugar and oils and fats remains constant throughout winter and summer season.
- The average consumption of some types of food (cereal grains, roots and tubers, oilseeds and pulses) decreases during summer. However, the daily per capita consumption for dairy products, vegetables and fruits is higher in summer than in winter.
- Apart from vegetables and fruits, the average quantity of LPG consumption for food preparation does not vary throughout winter and summer.
- Seasonal variation does not influence the average quantity of water use for food preparation, except for vegetables and fruits.

CHAPTER SEVEN: SENSITIVITY & UNCERTAINTY ANALYSIS

7.1 Introduction

This chapter presents the sensitivity analysis of the WEF model output results to the input parameters. The validity of the WEF model is tested in this chapter using Monte Carlo simulation uncertainty assessment technique and comparison of the model simulation results with the measured historical data.

7.2 Sensitivity analysis

Sensitivity analysis is an integral part of model development. It measures the model validation and provides insight of model performance via analytical examination of input parameters (Hamby, 1994). In another meaning, it allows identifying the parameters that have the greatest impact on the model results. This is important to improve the efficiency of model results. In addition, sensitivity analysis can provide guidance for the robustness of model outputs when making decisions (Phillips et al., 2000).

To analyse the sensitivity of the WEF model output to the input parameters, one factor at a time has been used. This sensitivity analysis method is presented in Section 3.7. The range of variation of each input parameter has been calculated as upper and lower value using Equation 3.30 and Equation 3.31, respectively. The required statistics for these equations are mean ($\bar{X}$) and standard deviation (σ) of each input parameter. The values of $\bar{X}$ and σ for the model input parameters related to WEF are presented in Appendix C3, Appendix D3 and Appendix E3, respectively.

The change in model output is quantified by using the upper/lower value of each input parameter individually while holding all other input parameters at their base-case values (i.e., without change). The resulted difference in model output due to the change in input parameter is the sensitivity of the model output to the input parameter under consideration. The sensitivity analysis results of the WEF model are presented in Section 7.2.1 to 7.2.3.

7.2.1 Household water demand estimation

Using the household scale WEF model, the sensitivity of water demand estimation to water end-use parameters (frequency, duration of use and flow rate) has been analysed. The values of statistics (i.e., $\bar{X}$ and σ) required for each input parameter are presented in Tables C3.1-C3.8 (Appendix C3). These statistics have been used to calculate upper and lower value for the input parameter under consideration. Then, the sensitivity of household water demand is quantified using the upper/lower value of each water input parameter individually while holding all other input parameters at their base-case values.

Figure 7.1 shows the sensitivity of household water demand estimation to the input parameters. The highest sensitivity is attributed to the frequency and duration of each session of garden watering. Their contribution to the sensitivity of water demand accounts approximately ±1.5% of the base-case demand value (i.e., the estimated demand when the values of all input parameters set to

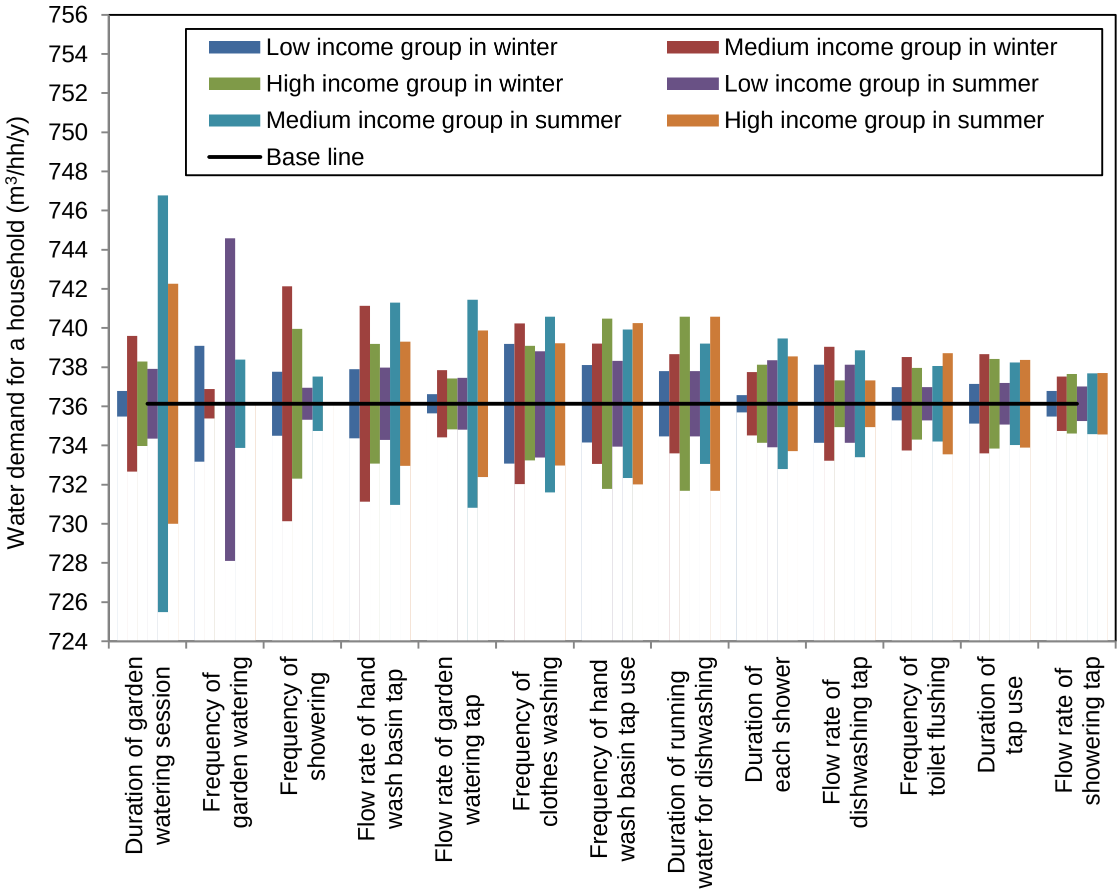


Figure 7.1 Sensitivity analysis of household water demand estimation

their mean). On the other hand, the household WEF model estimation for water demand is less sensitive to the other input parameters as shown in Figure 7.1.

7.2.2 Household energy demand estimation

7.2.2.1 Household electricity demand estimation

Similarly to the sensitivity analysis of household water demand, the upper and lower values for each parameter of energy end-use (no. of appliance in use, duration of use and wattage) are calculated. The average and standard deviation statistics of each energy use parameter are presented in Tables D3.1-D3.8 (Appendix D3). Using these statistics, the upper (Equation 3.30) and lower (Equation 3.31) values for each energy end-use parameter are determined. Then, the sensitivity of household energy demand estimation to each input parameter is analysed, using the upper/lower value for the parameter under consideration while holding the other input parameters at their base-case values.

The sensitivity analysis of household electricity demand estimation to the input parameters is presented in Figure 7.2. The results in this figure clearly show that the estimation of electricity demand is highly sensitive to the ownership level and duration of the use of air-conditioners in a household (±4% of the base-case estimated demand). This is due to the high variation in ownership level and the duration of the use of air-conditioners between Duhok households (Tables D3.1-D3.8 in Appendix D3). However, the estimation of electricity demand clearly shows low sensitivity to the other input parameters.

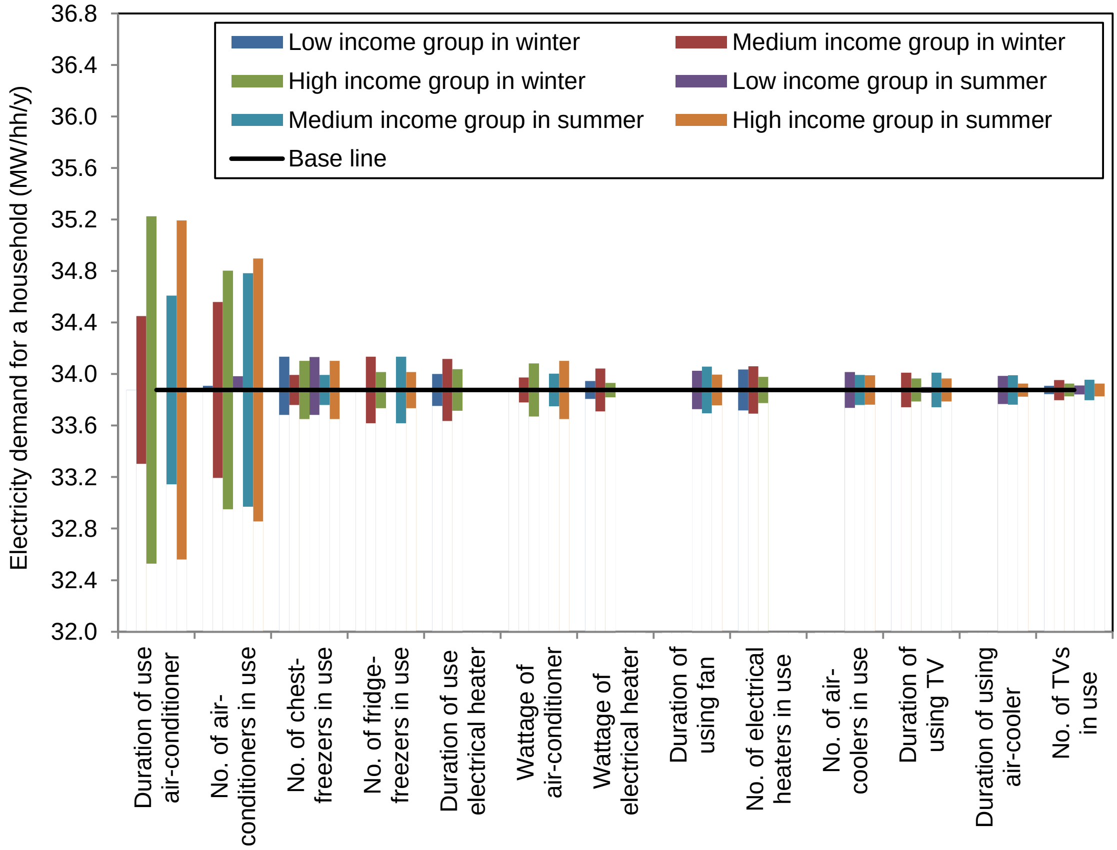


Figure 7.2 Sensitivity analysis of household electricity demand estimation

7.2.2.2 Household LPG demand estimation

Figure 7.3 presents the sensitivity of household LPG demand estimation to the input parameters. The analysis in this figure shows that the highest sensitivity of LPG demand estimation is attributed to the number of cooking sessions (±0.5% of the base-case estimated demand) and LPG consumption per cooking session of meat types (±1.5% of the base-case estimated demand), in general.

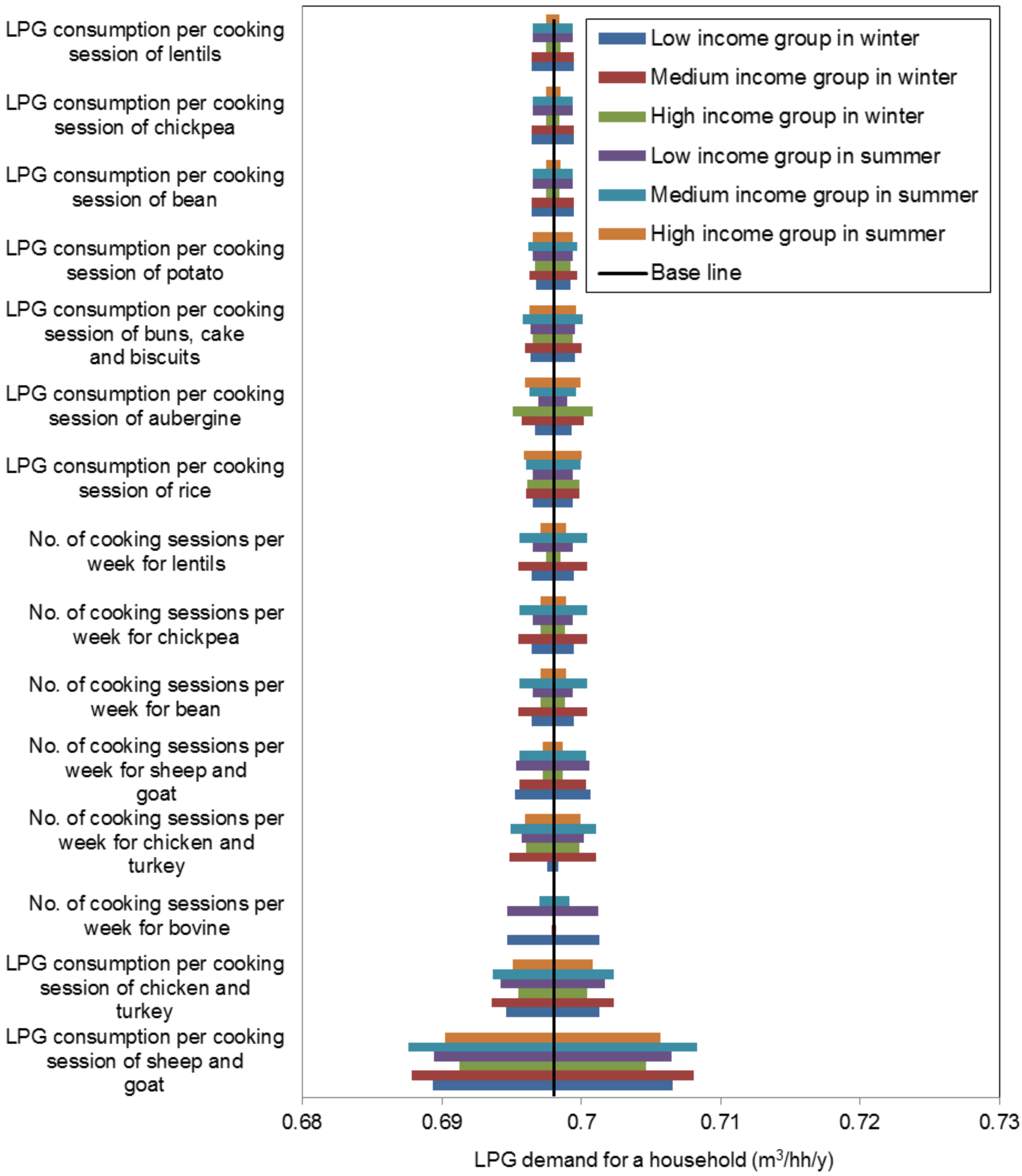


Figure 7.3 Sensitivity analysis of household LPG demand estimation

7.2.3 Household food demand estimation

Sensitivity of household food demand estimation to the input parameters (i.e., per capita food consumption) has been analysed. The values of upper (Equation 3.30) and lower (Equation 3.31) per capita consumption for each food commodity are calculated, using the average and standard deviation statistics for the food commodity under consideration. These statistics for each food commodity are presented in Tables E3.1-E3.8 (Appendix E3).

Figure 7.4 presents the sensitivity of household cereal grains demand estimation to the uncertainty in per capita consumption for each type of cereal grains and products from cereal grains. The figure shows that the household cereal grains demand estimation is sensitive to per capita wheat consumption, with less sensitivity to per capita rice consumption. Although, the influence of per capita wheat consumption on the total cereal grains demand accounts only ±0.5% of the base-case estimated demand.

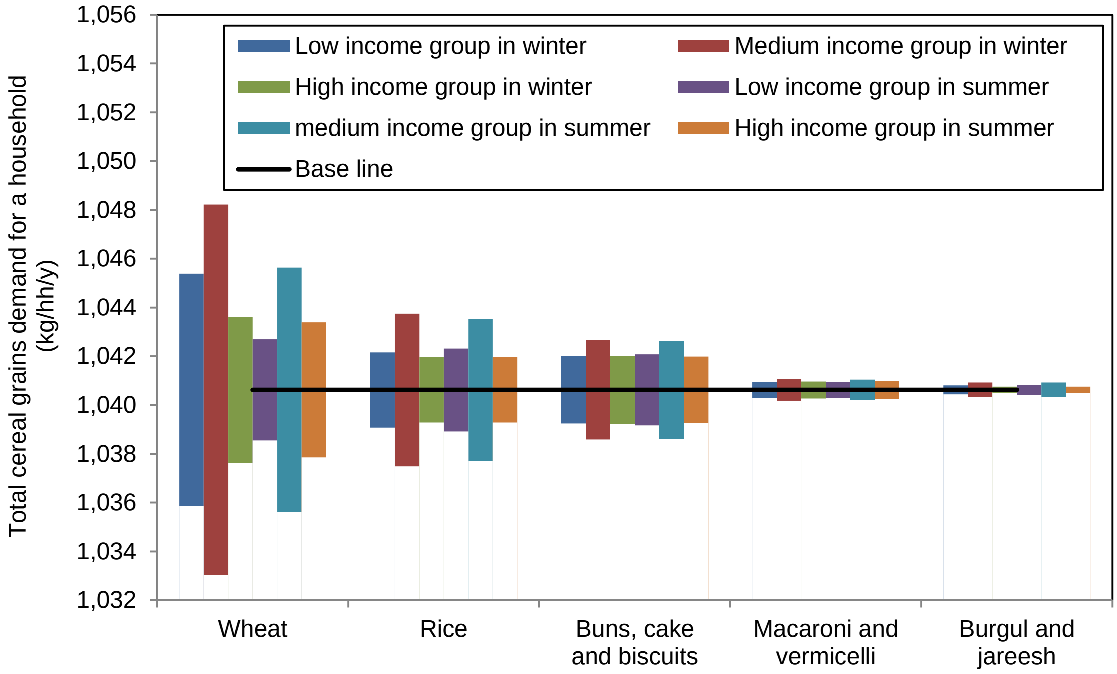


Figure 7.4 Sensitivity analysis of household cereal grains demand estimation

Figure 7.5 presents the sensitivity analysis of household meat demand estimation to per capita consumption for each type of meat. The figure shows that the sensitivity of household total meat demand estimation is mostly attributed to the per capita chicken and turkey consumption (±2.0% of the base-case estimated demand). The influence of per capita bovine consumption (±1.0% of the base-case estimated demand) has less impact on the household total meat demand estimation.

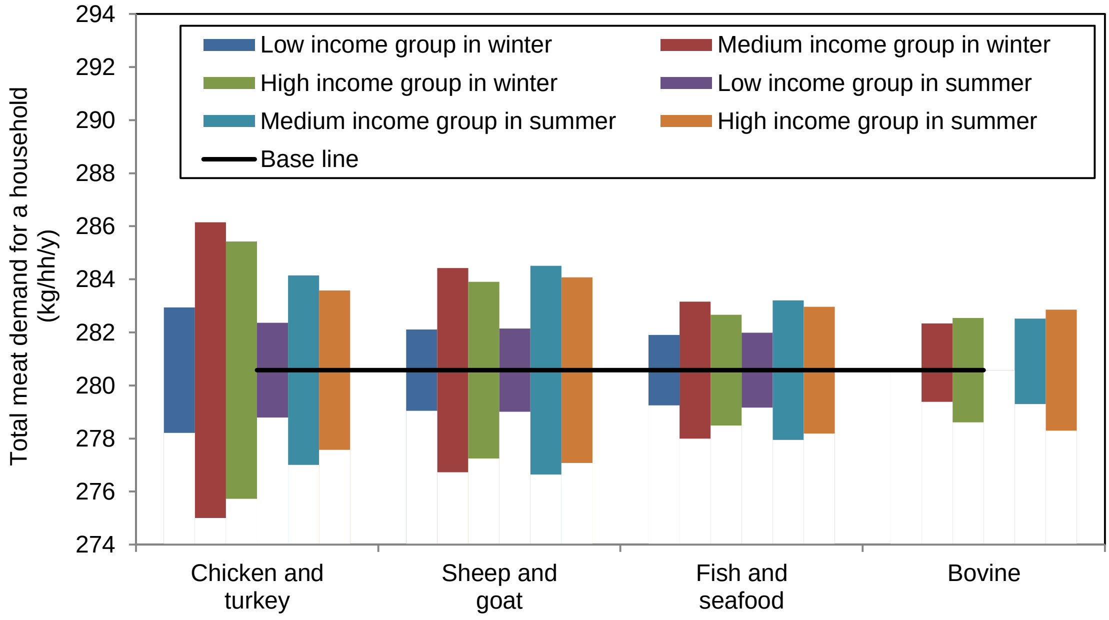


Figure 7.5 Sensitivity analysis of household meat demand estimation

The sensitivity of household dairy products demand estimation to the per capita consumption for each type of dairy products is analysed. The results in Figure 7.6 show that the per capita yogurt and milk consumption have the highest influence (±1.0% of the base-case estimated demand) on the household dairy products demand estimation. Less sensitivity is attributed to the per capita consumption for cheese and butter.

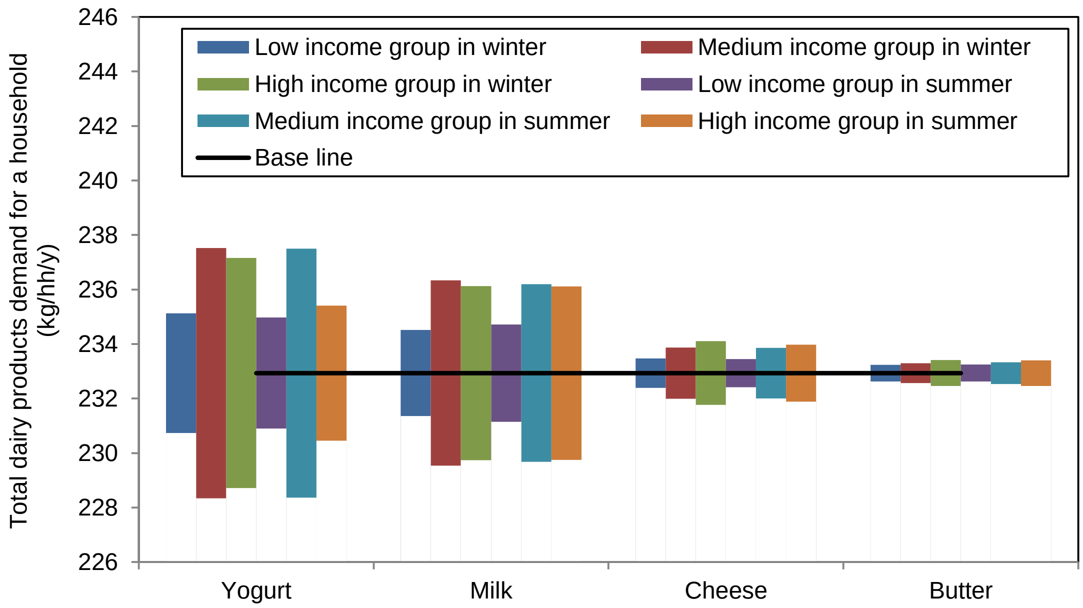


Figure 7.6 Sensitivity analysis of household dairy products demand estimation

In terms of roots and tubers, the sensitivity of household total demand estimation to the variation in per capita consumption for each type of roots and tubers is analysed. The results in Figure 7.7 show that the household total demand estimation for roots and tubers is sensitive to the per capita potato consumption (±2.2% of the base-case estimated demand), with a negligible sensitivity attributed to per capita consumption for carrots, garlic and radish.

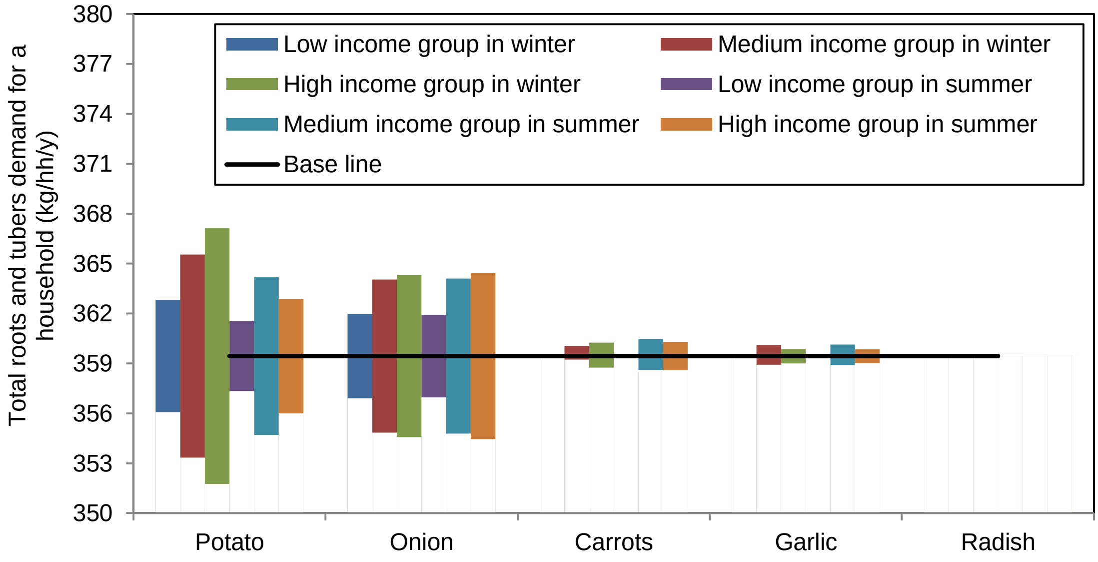


Figure 7.7 Sensitivity analysis of household roots and tubers demand estimation

The influence of per capita consumption for each type of vegetables on the household total vegetables demand estimation is shown in Figure 7.8 with the descending order. Within all types of vegetables, the highest influence is attributed to the daily per capita tomato consumption (±2.0% of the base-case estimated demand). Per capita consumption for other types of vegetables has less influence on the household total demand estimation for vegetables.

Figure 7.9 shows the sensitivity of household total fruits demand estimation to the variation in per capita consumption. It seems clear from the figure that the highest sensitivity of household total fruits demand estimation is attributed to per capita water melon consumption (±2.0% of the base-case estimated demand). The variation in per capita consumption for other types of fruits (i.e., orange, apple, melon, pumpkin, grape and banana) has approximately the same influence on the household total fruits demand estimation.

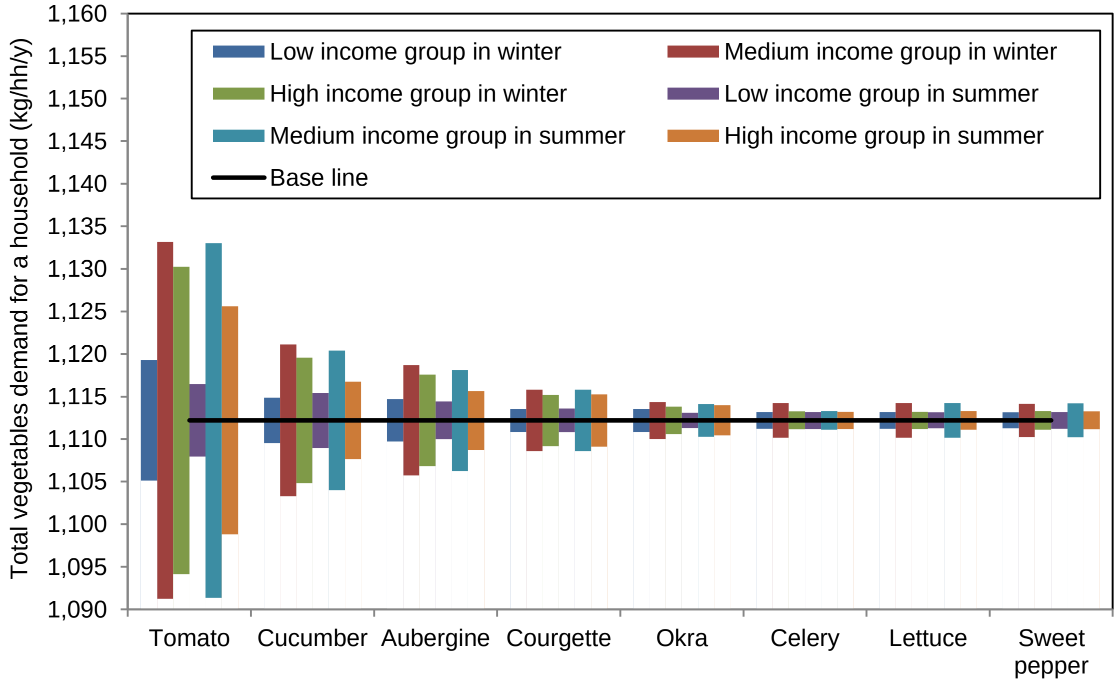


Figure 7.8 Sensitivity analysis of household vegetables demand estimation

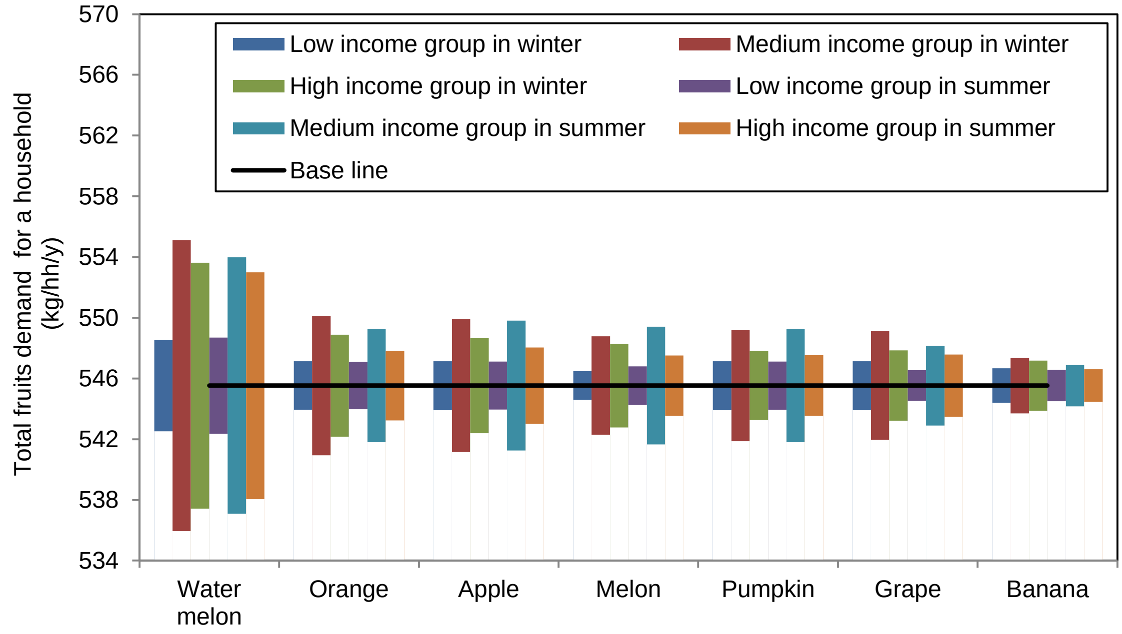


Figure 7.9 Sensitivity analysis of household fruits demand estimation

7.3 Uncertainty assessment

The uncertainty of the WEF model outputs is analysed using Monte Carlo simulation technique (Section 3.8). For each input parameter into the WEF model, random values are selected from the distribution of possible values for the input parameter under consideration. The random values of input parameters are used in the developed WEF model and the expected value of the output is calculated to evaluate the impact of multiple uncertain parameters. The process is repeated for a number of iterations (Section 3.8). Then, the probability distribution of the calculated outputs is plotted.

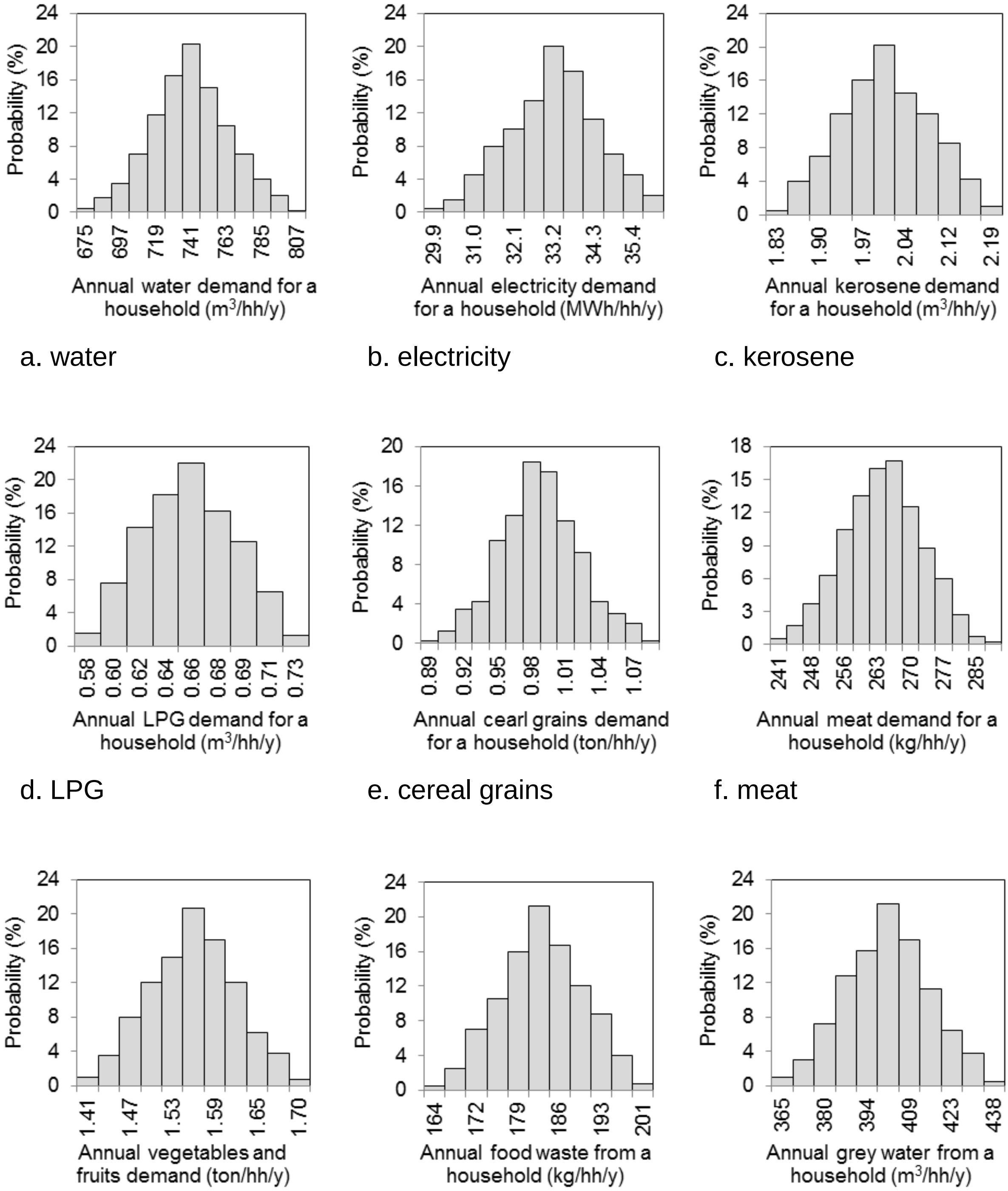
7.3.1 Household WEF model

Figure 7.10 shows the probability distribution of the calculated outputs from the household WEF model: water, electricity, kerosene, LPG, cereal grains, meat, vegetables and fruits, food waste and grey water. The analysis in this figure shows that the uncertainty for water demand estimation is lower than that for energy. This is because the relative width (standard deviation/average (Schaffner et al., 2009)) of estimated demand for water (0.03) is less than that for electricity, kerosene and LPG (0.04, 0.04 and 0.05, respectively). The relative width of estimated demand for food types in Figure 7.10 is less than 0.04.

7.3.2 City scale WEF model

The probability distribution for each output variable from the city scale WEF model is shown in Figure 7.11. The figure shows the influence of combinations of uncertain multiple input parameters on the total city demand for water, energy (electricity, kerosene and LPG) and food (cereal grains, meat, vegetables and fruits, dairy products, oilseeds and pulses, roots and tubers, oils and fats and sugar).

The relative width of the model output variables shown in Figure 7.11 is calculated, using mean and standard deviation statistics of the model output under consideration with Equation 3.32. The results show that the uncertainty of the estimated total city demand for water, electricity, LPG and each type of food is low (less than 0.05). The estimation of total demand for cereal grains in the city is less uncertain (relative width = 0.01) than the other variables while the highest uncertainty was attributed to kerosene estimation (relative width = 0.12).



a. water b. electricity c. kerosene

d. LPG e. cereal grains f. meat

g. vegetables and fruits h. food waste i. grey water

Figure 7.10 Probability distributions of Monte Carlo simulations for the household WEF model

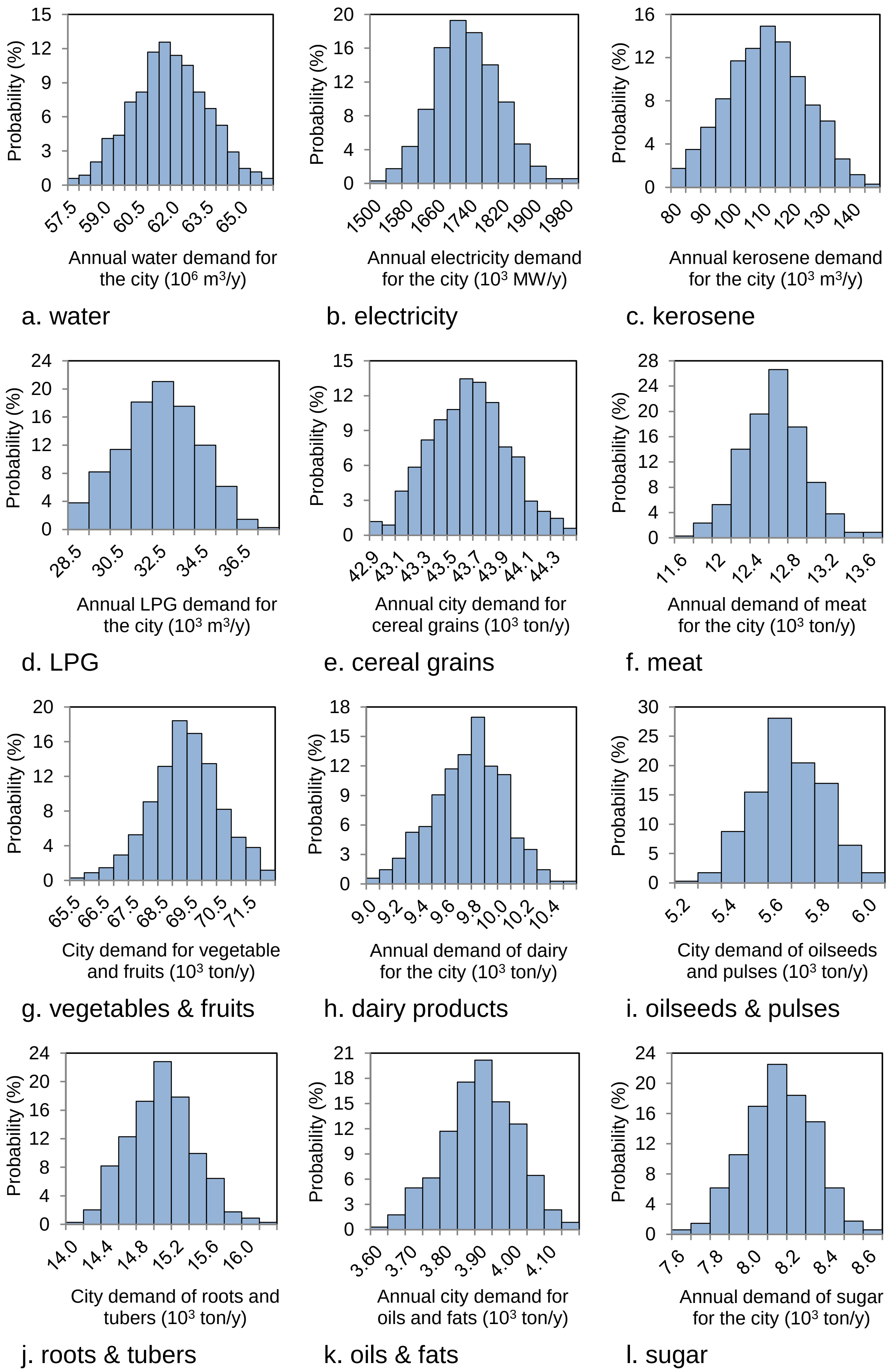


Figure 7.11 Probability distributions of Monte Carlo simulations for the city scale WEF model

7.4 Comparison of the model results with historical data

To test the validity of the developed WEF models (i.e., household and city scale), the results of the WEF models are compared against the available historical data for the Business as Usual (BaU) scenario. The historical data are collected from published reports and the local directorates (KRSO, 2013, KRSO, 2014; COSIT et al., 2010; CSO and KRSO, 2012; General Directorate of Duhok Electricity, 2014; Duhok Directorate of Water and Sewerage, 2014; Duhok Directorate of Groundwater, 2012; Kurdistan Ministry of Agriculture, 2014; Duhok Directorate of the Municipalities, 2014) in Duhok.

7.4.1 Household scale WEF model

The results of the household WEF model are compared against the available historical data in Duhok for the BaU scenario (i.e., current family size, household income, demographic and household characteristics). Table 7.1 presents the comparison between the household WEF model results and the available historical figures for water, energy, food consumption and waste generation. The results show that the estimated values of the household WEF model are close to the measured historical data.

However, the simulation results of household food consumption are slightly higher than the historical data. This is probably because the historical data of food consumption in Table 7.1 are based on daily per capita average calorie intake (2580 kcal/p/d) in Iraq, which is less than that in Duhok (2910 kcal/p/d) (COSIT et al., 2010). To prove the validity of the model results of food consumption, the simulation-results of the quantity of daily per capita average food consumption are converted into calories using the conversion factors given by COSIT et al. (2010). These factors are based on FAO (2004) and have been adapted to take into account the specifications of available food commodities in Iraq. The results show that the daily per capita average calorie intake is approximately 2880 kcal/p/d in Duhok. The detailed comparison at end-use level is not possible because WEF consumption at micro-level have not been addressed for Duhok households.

Table 7.1 comparison of the household scale WEF model results with historical measured data

Description	Unit	Model results	Historical data	Reference
Water consumption in winter	l/hh/d	1816	1896	KRSO (2014)
Water consumption in summer	l/hh/d	2238	2298	
Energy consumption in winter	kWh/hh/d	102	97	General Directorate of Duhok Electricity (2014)
Energy consumption in summer	kWh/hh/d	79	74	
Cereal grains consumption	g/hh/d	2702	2620	COSIT et al. (2010)
Meat consumption	g/hh/d	728	639	Kurdistan Ministry of Agriculture (2014)
Dairy consumption	g/hh/d	605	607	COSIT et al. (2010)
Roots and tubers consumption	g/hh/d	933	529	
Vegetables consumption	g/hh/d	2888	2396	
Fruits consumption	g/hh/d	1416	1175	
Oilseeds and pulses consumption	g/hh/d	350	241	
Oils and fats consumption	g/hh/d	240	241	
Sugar consumption	g/hh/d	505	489	
Food waste	g/hh/d	969	1005	Duhok Directorate of the Municipalities (2014)
Average family size	no.	7.04	6.7	CSO and KRSO (2012)

7.4.2 City scale WEF model

The city scale WEF model is used to quantify the demand for WEF in each sector (i.e., domestic, industrial, commercial and agricultural) in Duhok. The results are then compared with the historical records collected from reports and the local directorates as shown in Table 7.2. The comparison shows that the model estimations are in agreement with the historical records except for the domestic sector.

The historical recorded quantity of water supply (i.e., surface water and groundwater) to the domestic sector (74.4x10^6 m^3/y) is higher than the model water consumption estimation (32.4x10^6 m^3/y) (Table 7.2). This is in line with the reported leakage from water distribution systems which is around 50% of total water supply (Duhok Directorate of Water and Sewerage, 2014).

Table 7.2 comparison of the city scale WEF model results with historical records

Resources	Sectors	Unit	Model results	Historical records		Reference
				Surface water	Ground-water	
Water	Domestic	10^6 m^3/y	32.4	66.1	8.3	Duhok Directorate of Water and Sewerage (2014); Duhok Directorate of Groundwater (2012)
	Commercial		6.4	6.4	0	
	Industrial		0.76	0	0.75	
	Agricultural		22.4	-	12	
Electricity	Domestic	10^3 MW/y	1492	931		General Directorate of Duhok Electricity (2014)
	Agricultural		4.8	4.3		
	Commercial		100	100		
	Industrial		5.4	5.4		
Kerosene	Domestic	10^3 m^3/y	93.6	-		-
	Commercial		5.6	5.6		KRSO (2014)
	Industrial		14.2	14.2		KRSO (2014)
LPG	Domestic	10^3 m^3/y	29.2	-		-
	Commercial		0.3	0.3		KRSO (2014)
Rice	Commercial	ton/y	50	50		KRSO (2013)
Chicken			45	45		
Mutton			37	37		
Vegetables			72	72		
Fruits			9	9		

Table 7.2 also shows that the model estimation for domestic electricity consumption (1.49×10^6 MW/y) is higher than the historical recorded supplied electricity by the national distribution network (9.3×10^6 MW/y). This is because around 25% (0.4×10^6 MW/y) of electricity demand in housing units is supplied by community and private generators (General Directorate of Duhok Electricity, 2014). The summation of the electricity supplied by the national distribution network to the domestic sector and that was provided by community and private generators is 1.33×10^6 MW/y. This is consistent with the model estimations (1.49×10^6 MW/y) (Table 7.2).

7.5 Conclusions

For the WEF models developed at a household and city scale, sensitivity of the model output to the input parameters was analysed. Additionally, the validity of the models was tested using Monte Carlo simulation technique for uncertainty assessment and the comparison between the model results and historical data. The key findings are:

- Overall, for the parameters obtained from the survey, the model has shown reasonable predictions for WEF.
- The highest sensitivity of the model estimation for electricity demand accounts approximately ± 4% of the base-case demand value (i.e., the estimated demand when the values of all input parameters set to their mean).
- The contribution of input parameters to the sensitivity of model estimation for water and food demand is low, accounting less than 1.5% and 2% of the base-case demand value for water and meat demand estimation, respectively.
- The uncertainty of the household WEF model for estimating water demand is lower than that for energy and food.
- For the city scale WEF model, the highest uncertainty is attributed to the estimation of total city kerosene demand. The uncertainty of the estimated total city demand for water, electricity, LPG and each type of food is low.

CHAPTER EIGHT: RISK AND RESILIENCE ASSESSMENT FOR WEF

8.1 Introduction

This chapter presents the results and applications of the WEF model. The chapter investigates the impact of seasonal variability (i.e., increase/decrease in the number of summer days) on WEF demand. Using the WEF model, risk-based assessment approach has been applied to estimate the risk of exceeding acceptable level of shortage in per capita demand for water and energy under the impact of seasonal variability. Additionally, the resilience of WEF systems for providing per capita demand under the impact of seasonal variability has been quantifies.

Moreover, a number of demand management strategies have been investigated in water and energy systems. This is in order to decrease the risk of exceeding acceptable level of shortage in per capita demand for water and energy and increase the resilience of systems for providing per capita demand under the impact of seasonal variability.

8.2 Risk assessment of WEF nexus under the impact of seasonal variability

8.2.1 Impact of seasonal variability on the future water demand

The risk-based approach (Section 3.9.2) is applied to estimate the risk of exceeding acceptable level of shortage in per capita water demand due to seasonal variability in Duhok. Seasonal variability in this context is represented by the increase/decrease in the number of summer days. In the north of Iraq where the case study is located, the climate trend is toward more warm days and nights as shown in Table 3.24. Based on the weather forecast in this table, the duration of summer season is assumed to increase by 1 to 30 days (i.e., 1, 2, 3,…, 30 days) by 2050. Each increase is assumed to be lineare. For example, when the duration of summer season increases by 30 days by 2050, it means that the annual increase in summer season duration is 0.85 days/year (i.e., 30 days of increase divided by 35 years of simulation).

For each assumed value of increase in summer days, the annual water demand has been simulated for 35 years ahead (i.e., from 2016 to 2050) using the household scale WEF model. Hence, the number of simulations is 30 representing the increase in summer season from 1 to 30 days. The simulation results in Figure 8.1 show the impact of increasing the summer season duration by 1, 10, 20 and 30 days on annual per capita average water demand. The figure indicates that the annual per capita average water demand increases with increase in summer season duration.

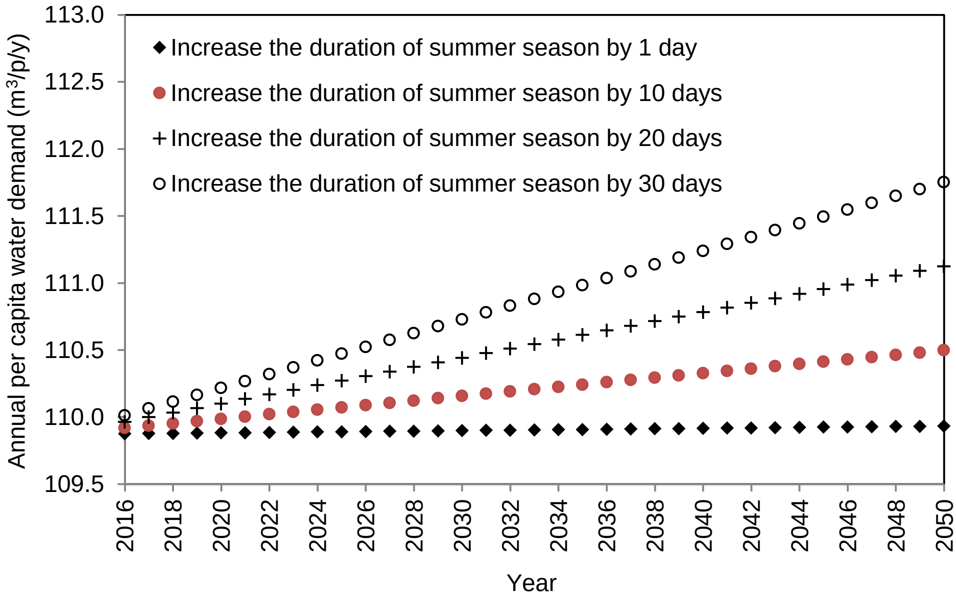


Figure 8.1 Impact of increase in the duration of summer season on per capita water demand

The daily available per capita water during each year of the simulation period is calculated (Figure 8.2) using the annual total quantity of available water in Duhok (Table 3.2 and Table 3.3) with Equation 3.34 in the WEF model. Then, the per capita water supply-demand balance (ΔSD_i) is calculated in each year of the simulation period (Equation 3.35). The values of water ΔSD_i are quantified for the 30 simulations individually.

Using the values of water ΔSD_i for a particular year (i) of all 30 simulations, the frequency distribution of water supply-demand balance is obtained for the year under consideration. The frequency distributions are calculated for each year of the simulation period, individually. Consequently, the number of frequency distributions obtained was 35 (each representing one year from 2016 to 2050).

Each frequency distribution has been compared with the acceptance level of shortage in daily per capita water demand.

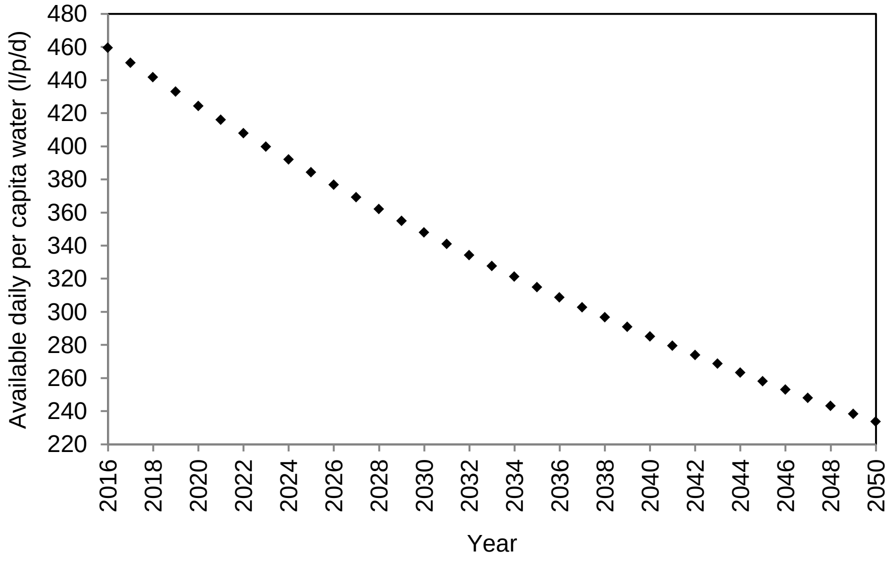


Figure 8.2 Impact of population growth on available per capita water

In Iraq, the minimum daily per capita water required in a household to sustain a modern lifestyle is 270 l/p/d (Beaumont, 2009). Hence, the difference between the normal per capita demand (based on the conducted survey is 300 l/p/d, Figure 4.9) and the minimum requirements (270 l/p/d) can be assumed as the acceptable shortage level in daily per capita water demand (30 l/p/d). Any reduction in supply greater than 30 l/p/d is likely to cause undesirable consequences or be unacceptable to users.

The frequency distributions of supply-demand balance for three decades of the simulation period are shown in Figure 8.3. The solid vertical line in each sub figure represents the acceptable level of shortage in per capita water demand (i.e., 30 l/p/d). The results in this figure show that the probability of exceeding acceptable level of shortage in per capita water demand increases in the future due to increase in the number of hot days and population growth. These distributions incorporate the uncertainty around the frequency of shortage in daily per capita water demand due to seasonal variability. The negative value of water supply-demand balance in this figure represents the quantity of shortage in daily per capita water demand. In contrast, the positive values mean that the available water exceeds the per capita demand.

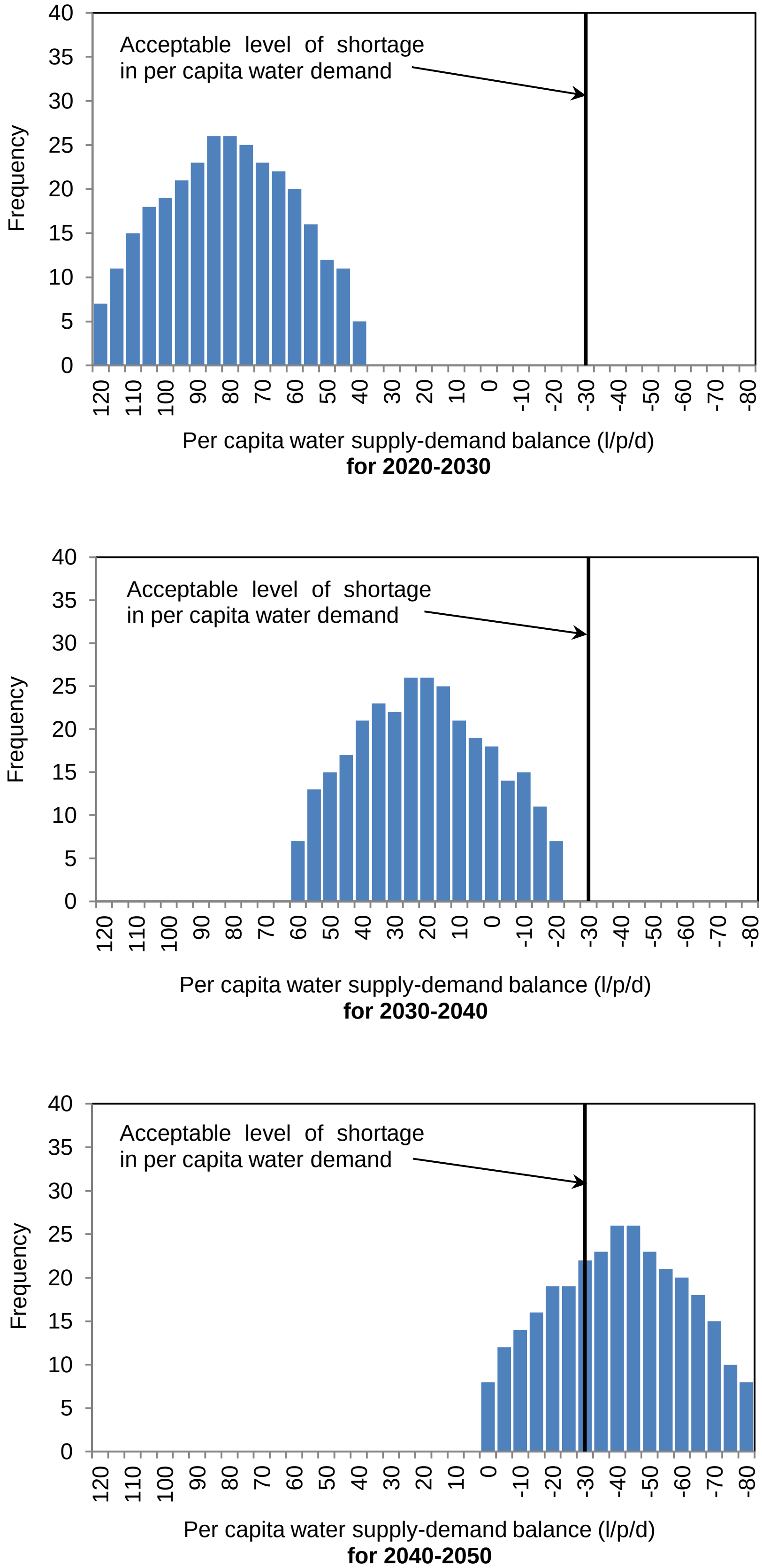


Figure 8.3 The uncertainty around the frequency of shortage in per capita water demand due to seasonal variability

Finally, the cumulative probability of water supply-demand balance has been obtained for each year of the simulation period using the frequency distribution diagram of the year under consideration. Consequently, the number of cumulative probability diagrams was 35, representing each year of the simulation period individually. Figure 8.4 shows the cumulative probability of water supply-demand balance for three different decades of the simulation period. The risk of exceeding acceptable level of shortage in daily per capita water demand in each year has been obtained using the cumulative probability of the year under consideration (Equation 3.36). The risk of exceeding acceptable level of shortage in per capita water demand during the 2040s increases to approximately 60% as shown in Figure 8.4. In order to manage this risk, the impact of different WDM strategies was investigated. This is discussed in the section as below (Section 8.2.1.1).

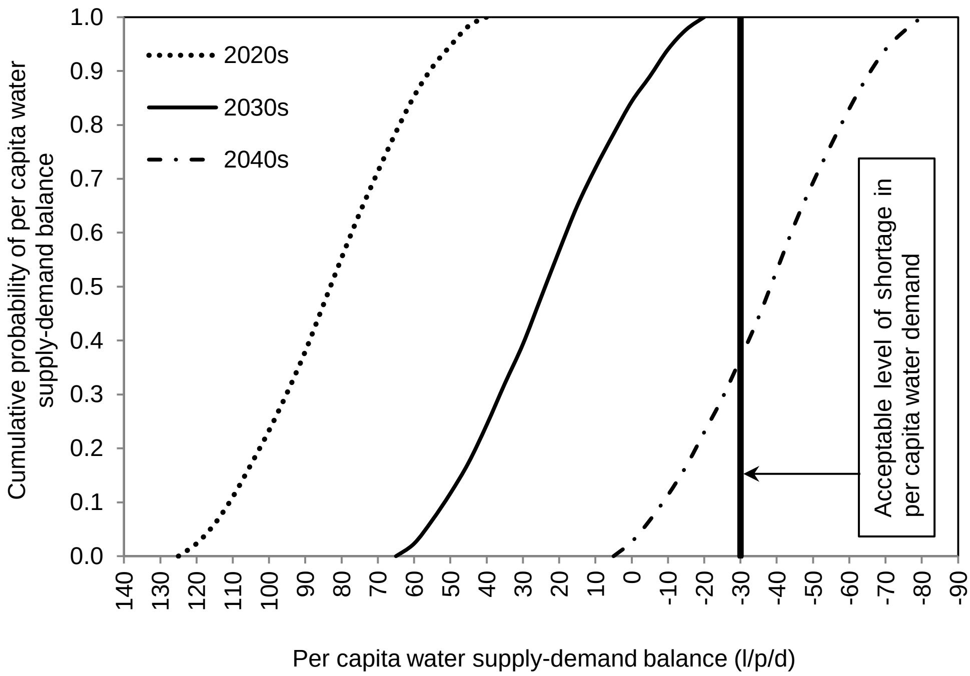


Figure 8.4 Cumulative probability of per capita water supply-demand balance for three different decades

8.2.1.1 Impact of water demand management (WDM) strategies

The performance of a number of WDM strategies is investigated to decrease the risk of exceeding acceptable level of shortage in per capita water demand due to future seasonal variability. The WDM strategies (i.e., strategy A, B and C) considered are presented in Section 3.9.3.

The household scale WEF model (Section 3.5) has been used with the risk-based approach (Section 3.9.2) to explore the performance of WDM strategies. The results show that using strategy B (i.e., the use of recycled grey water for non-potable applications) is the most effective strategy for decreasing the risk of exceeding acceptable level of shortage in per capita water demand (Figure 8.5). The risk reduction with using recycled grey water strategy was 60% in 2050.

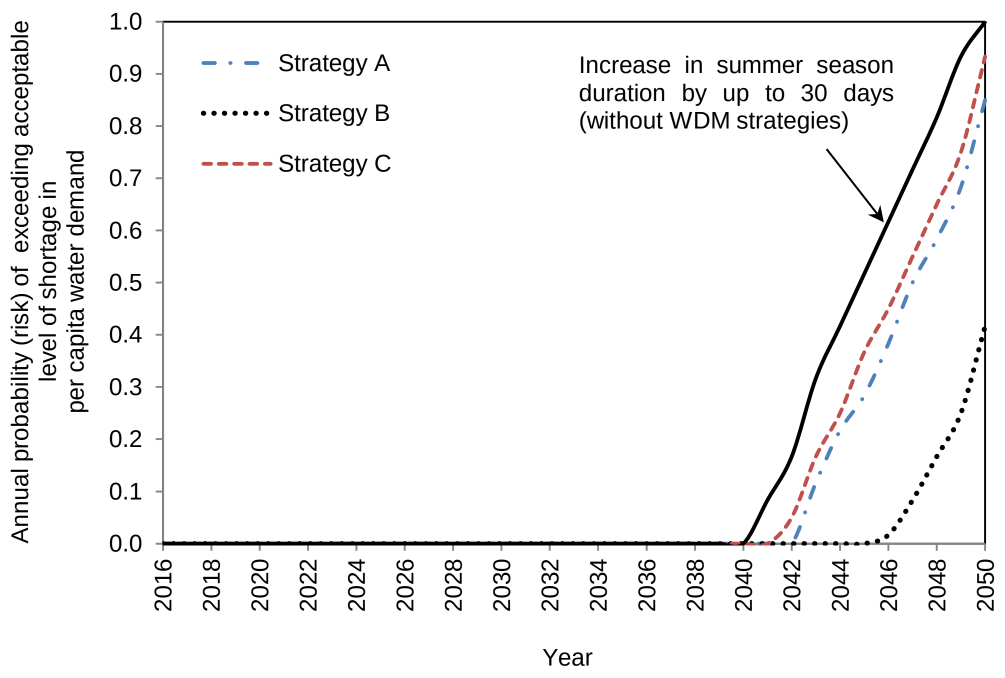


Figure 8.5 The impact of WDM strategies on the risk of exceeding acceptable level of shortage in per capita water demand

The impact of using the WDM strategies on the annual quantity of water demand for domestic sector is shown in Figure 8.6. The comparison between the demand management strategies in this figure shows that using recycled grey water for non-potable applications is the most effective management strategy to decrease the future water demand.

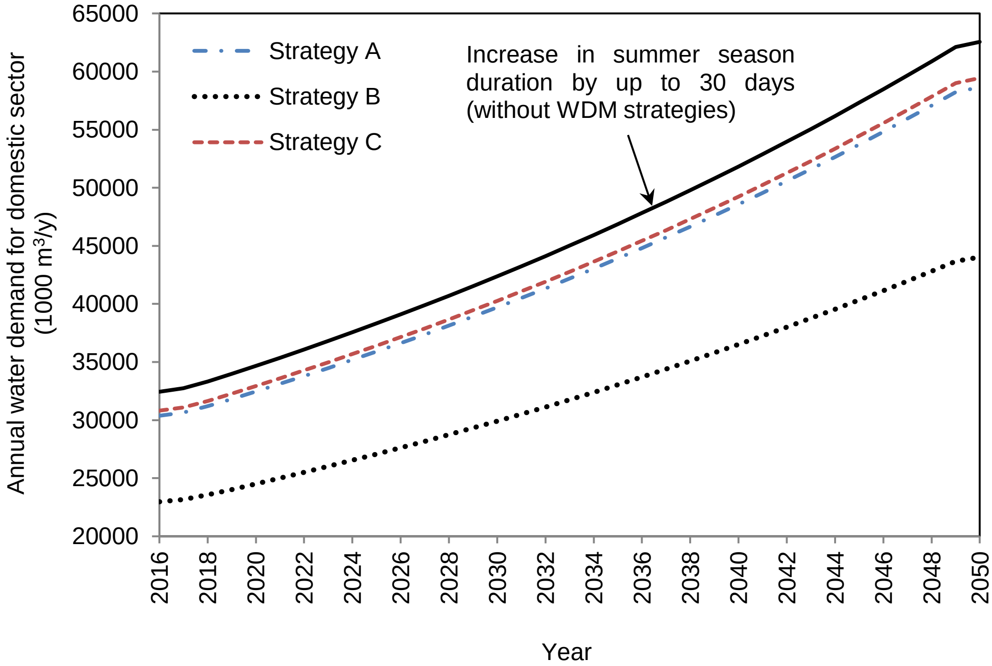


Figure 8.6 Impact WDM strategies on the water demand for domestic sector

8.2.1.2 Water-related energy demand of WDM strategies

The water-related energy demand (i.e., energy required for water pumping and treatment processes) has been calculated for all applied WDM strategies (Table 8.1). It has been determined using the energy required to obtain 1 m^3 of potable water (Table 3.4) and the domestic water demand for each WDM strategy (Figure 8.6). The results in Table 8.1 indicate that the total energy demand for water treatment increases when using recycled grey for non-potable applications strategy. On the other hand, water-related energy demand decreases approximately 6.3% with the use water efficient fixtures at a household and decreases 5.0% with the leakage reduction by 5% in water distribution network.

Table 8.1 Impact of WDM strategies on annual water-related energy demand in Duhok

WDM strategies	Water-related energy demand (1000 MW/y)			
	2020	2030	2040	2050
Increase in summer season duration by up to 30 days (without WDM strategies)	87.6	107.1	130.9	158.1
Strategy A: Use water efficient fixtures in a household	82.0 (-6.3%)	100.3 (-6.3%)	122.8 (-6.3%)	148.2 (-6.3%)
Strategy B: Use recycled grey water for non-potable applications	88.9 (+3.2%)	108.8 (+3.2%)	133.0 (+3.2%)	160.6 (+3.2%)
Strategy C: Reduce leakage by 5% in water distribution network	83.2 (-5.0%)	101.7 (-5.0%)	124.4 (-5.0%)	150.2 (-5.0%)

Note: the + and – values in brackets represent the increase and decrease in water-related energy demand, respectively, as a percentage of base case (i.e., without any WDM application).

8.2.2 Impact of seasonal variability on the future food demand

The impact of increase the duration of summer season (Table 3.24) on the annual per capita demand for each type of food was investigated using the household scale WEF model as presented in Table 8.2. The results in this table show that the annual average demand for each type of food is slightly sensitive to the increase in number of summer days. Therefore, the increase in summer season duration has a very small impact on the organic waste generated by a household (Figure 8.7). The annual food waste generated by the domestic sector in 2050 is approximately 68.4×10^3 and 68.6×10^3 ton/y when the duration of summer season does not change and increases by 30 days, respectively.

Table 8.2 Impact of increase in the duration of summer season on annual per capita food demand

Types of food	No increase in summer days	Impact of increase in summer duration by 30 days			
		2020	2030	2040	2050
Cereal grains (kg/p/y)	147.2	147.2	147.1	147.1	147.0
Meat (kg/p/y)	39.7	39.7	39.7	39.7	39.7
Vegetable and fruits (kg/p/y)	234.5	234.7	235.0	235.3	235.5
Dairy products (kg/p/y)	33.0	33.0	33.1	33.2	33.2
Roots and tubers (kg/p/y)	50.8	50.7	50.6	50.4	50.4
Oilseeds and pulses (kg/p/y)	19.1	19.1	19.0	19.0	19.0
Oils and fats (kg/p/y)	13.1	13.1	13.1	13.1	13.1
Sugar (kg/p/y)	27.5	27.5	27.5	27.5	27.5

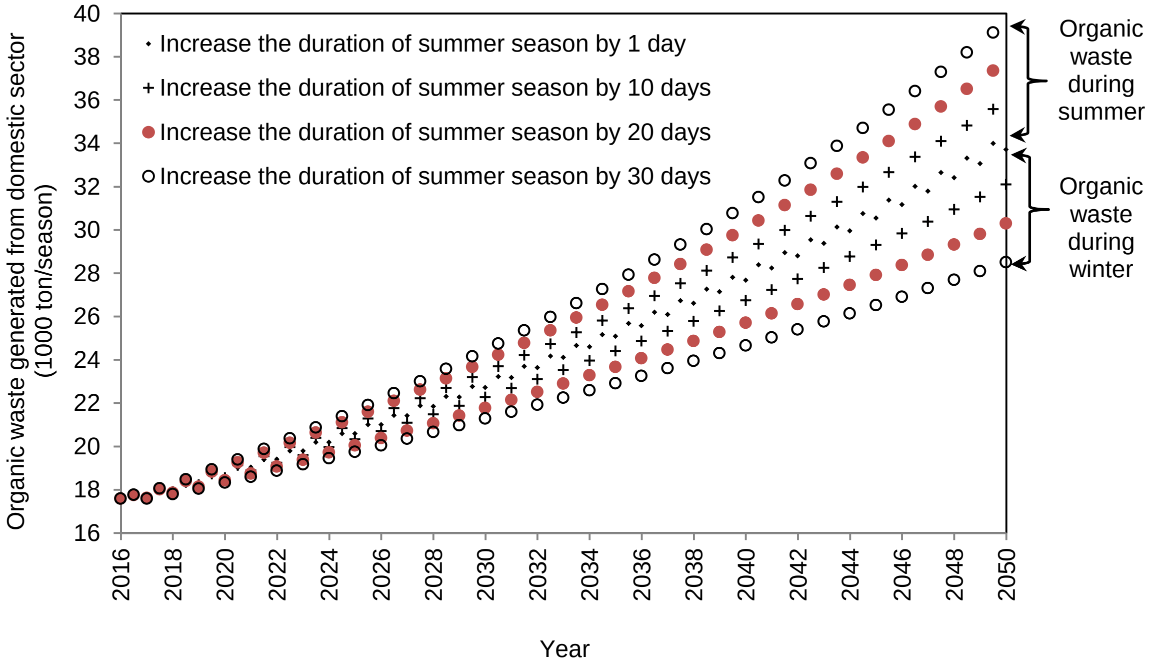


Figure 8.7 Impact of increasing the duration of summer season on the generated organic waste from households

8.2.3 Impact of seasonal variability on the future energy demand

To estimate the risk of exceeding acceptable level of shortage in per capita electricity demand due to seasonal variability, the methodology explained in Section 3.9.2 was applied. The impact of increased summer season duration on future energy demand was investigated. Based on the climate trends shown in Table 3.24, the increase in the duration of summer season until 2050 is assumed to vary between 1 and 30 days. For each assumed value of increase in summer season duration, the future electricity demand for household energy consuming activities (Figure 3.9) has been simulated using the household scale WEF model. Figure 8.8 shows the impact of summer season duration increases of 1, 10, 20 and 30 days on annual per capita energy demand. The results in this figure show that the annual per capita average electricity demand decreases with increase in summer season duration. The annual per capita average electricity consumption decreases by around 100 kWh/p/y when the duration of summer season increases by 30 days. This is in line with the energy consumption trends as presented in Figure 5.9.

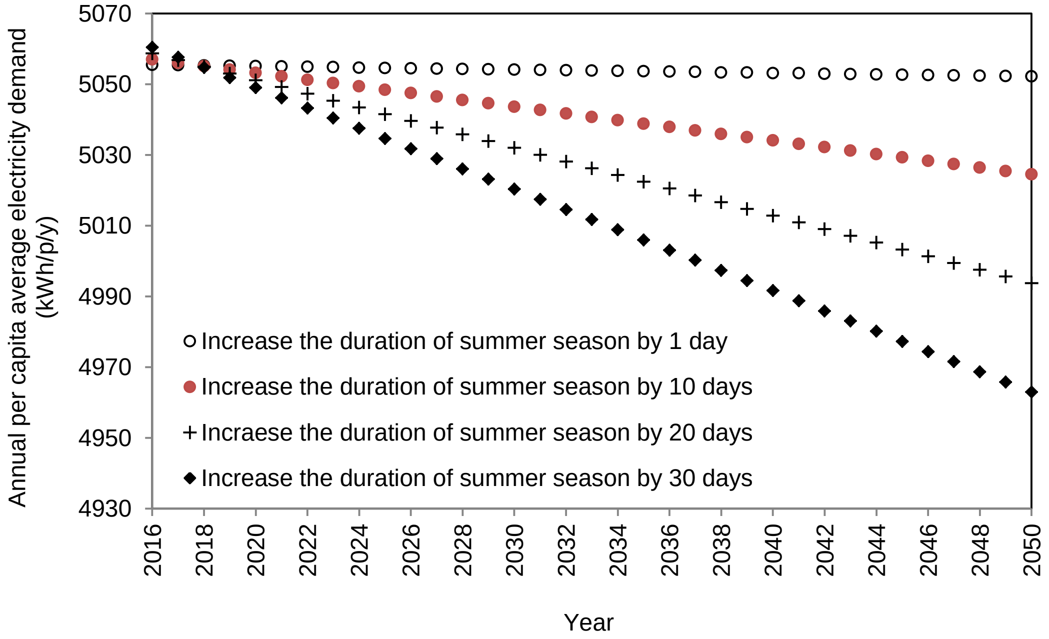


Figure 8.8 Impact of increase the duration of summer season on energy demand

The available per capita energy supply in each simulation year is calculated using the data in Table 3.5 and an equation similar to Equation 3.34 in the household scale WEF model. Then, the energy ΔSD_i is calculated in each year of the simulation period for the 30 simulations individually, using equation similar to Equation 3.35. The frequency distribution of energy ΔSD_i is determined for each year of the simulation period using the values of energy ΔSD_i for the year under consideration.

The energy supply-demand balance frequency distributions were compared with the acceptable level of shortage in daily per capita energy demand. In this study, it is assumed that 10% reduction in the normal energy supply is unlikely to cause any serious disruption of energy dependent household activities. Any further energy reduction could have negative implications. The 10% reduction in energy consumption equal to 1 kWh/p/d. Figure 8.9 shows the frequency distribution diagrams for three decades of the simulation period. The results in this figure clearly show that the probability of exceeding acceptable level of shortage in per capita energy demand increases during the 2030s and 2040s. The uncertainty around the frequency of shortage in per capita electricity demand due to seasonal variability is shown in these distributions.

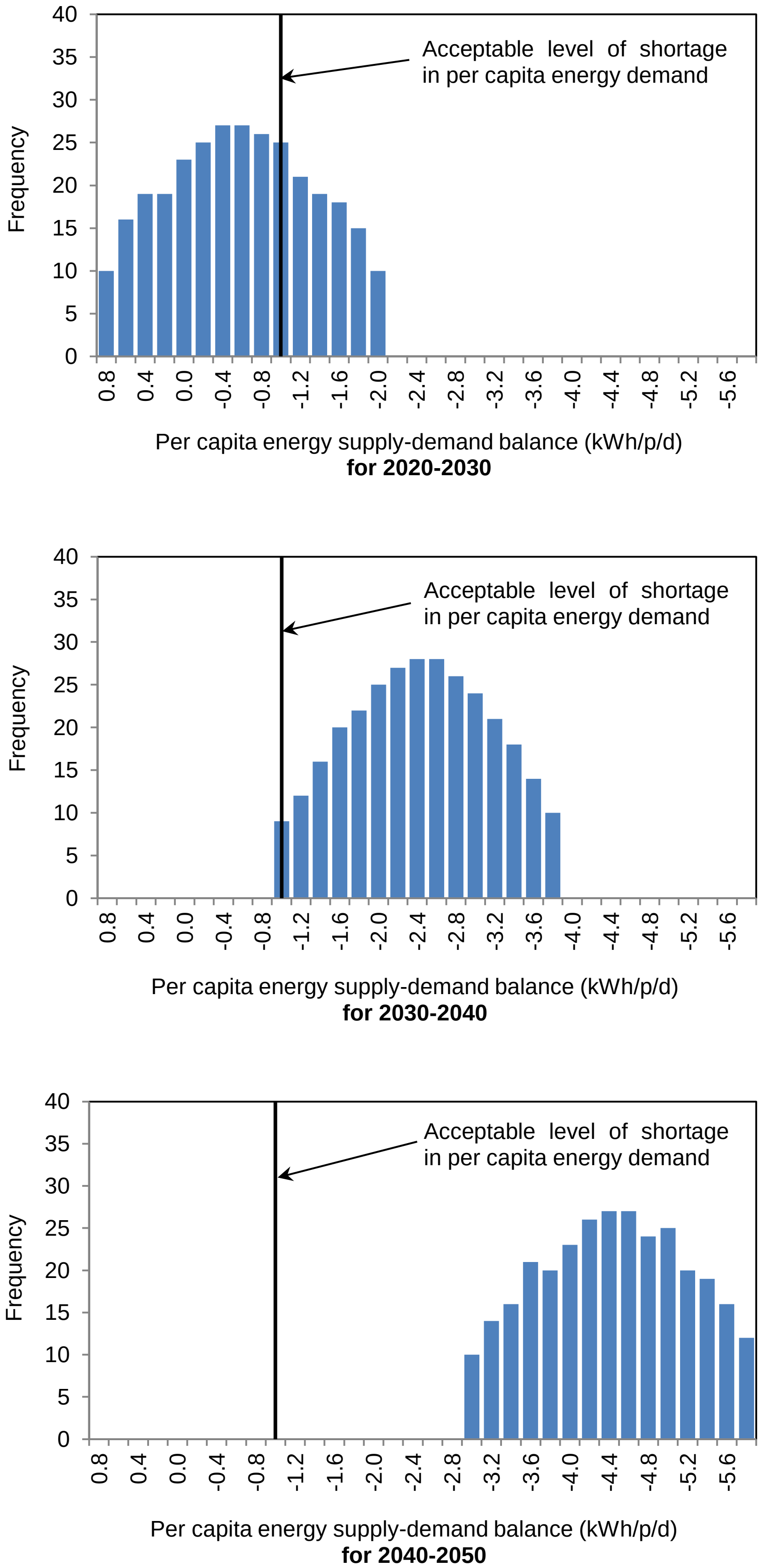


Figure 8.9 The uncertainty around the frequency of shortage in per capita energy demand due to seasonal variability

The frequency distributions are used to obtain the cumulative probability of energy supply-demand balance for each year of the simulation period. The cumulative probability of each year of the simulation period is used to calculate the risk of exceeding acceptable level of shortage in per capita energy demand for the year under consideration. The cumulative probabilities for three different decades are shown in Figure 8.10. The figure indicates that the risk of exceeding acceptable level of shortage in per capita electricity demand during the 2020s is approximately 30% and increases considerably during 2030s and 2040s.

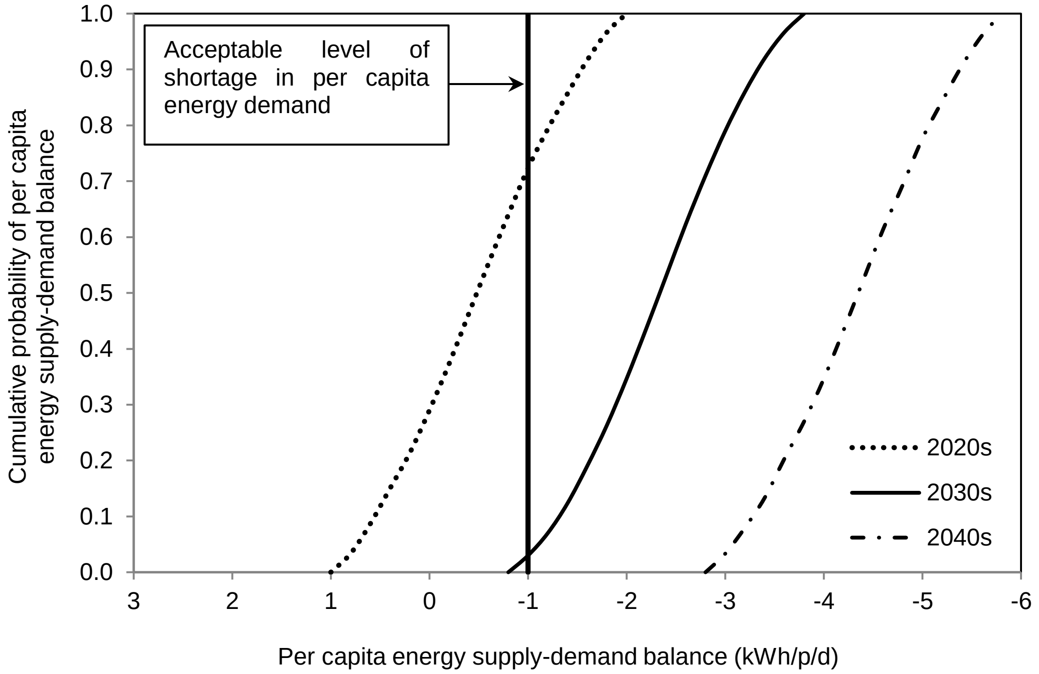


Figure 8.10 Cumulative probability of per capita energy supply-demand balance for three different decades

8.2.3.1 Impact of energy management (EM) strategies

In order to decrease the risk of exceeding acceptable level of shortage in per capita energy demand due to seasonal variability, a number of EM strategies are applied. The household scale WEF model is used to investigate the performance of the management strategies. The energy management strategies (i.e., strategy D, E and F) are presented and explained in Section 3.9.4.

Figure 8.11 shows a comparison between performance under each of the EM strategies. The results of comparison show that strategy F (using both anaerobic digestion of food waste and wastewater sludge together for energy recovery) provides the greatest reduction in the probability of exceeding acceptable level of shortage in per capita energy demand.

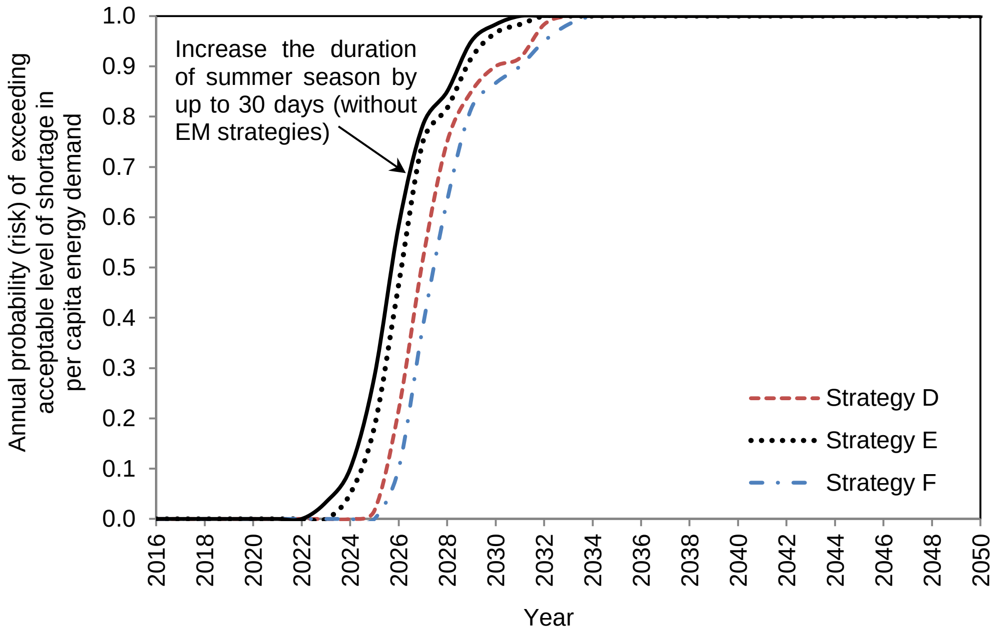


Figure 8.11 The impact of EM strategies on the risk of exceeding acceptable level of shortage in per capita energy demand

8.3 Resilience of WEF systems under the impact of seasonal uncertainty

8.3.1 Resilience of water system

The resilience approach presented in Section 3.9.5 is applied to estimate resilience of Duhok water system for providing per capita demand under the impact of seasonal variability (i.e., the increase/decrease in the number of summer days). The climate trend in the north of Iraq is toward more warm days and nights as illustrated in Table 3.24 (Section 3.9.2.1). Therefore, for the case study located in the north of Iraq, the duration of summer season is assumed to increase by 1 to 30 days (i.e., 1, 2, 3,…, 30 days) by 2050, based on the weather forecasts in Table 3.24.

For each assumed value of increase in summer days, the annual total water demand has been simulated for 35 years ahead (i.e., until 2050) using the WEF model. Consequently, the number of simulations is 30 representing the increase in the duration of summer season by 1, 2, 3,…, 30 days. These simulations explore the impact of increasing summer season duration on per capita average water demand. Figure 8.1 shows the impact of increasing the summer season duration by 1, 10, 20 and 30 days on annual per capita average water demand. The results show that the annual per capita average water demand increases with increase in number of summer days.

Per capita available water during each year of the simulation period is then calculated using the annual total quantity of available water in Duhok (Table 3.2 and Table 3.3) with Equation 3.34 in the WEF model. The results are shown in Figure 8.2, indicating that the available water per capita decreases in the future due to the population growth.

Then, the per capita water supply-demand balance (ΔSD_i) is calculated in each year of the simulation period (Equation 3.35). The values of water ΔSD_i are quantified for the 30 simulations individually. Hence, the number of simulations is 30 representing the impact of each increase in summer season duration (i.e., 1, 2, 3,…, 30 days). Figure 8.12 shows the impact of increase in summer season duration by 10, 20 and 30 days on per capita water supply-demand balance. The results in this figure indicate that water supply-demand balance decreases with increase in summer season duration.

Each simulation is then compared with the critical water supply-demand balance ($\Delta SD=0$). This is to identify the starting and end of system disturbance (i.e., inability of the system to provide normal demand) as shown in Figure 8.12. The figure indicates that the system disruption starts in 2035 when water supply is less than per capita demand (i.e., $\Delta SD<0$). In order to recover the water system, different water demand management (WDM) strategies are investigated using the WEF model. The investigated WDM strategies (i.e., A, B and C) are described in Section 3.9.3. The impact of these WDM strategies is shown in Figure 8.13A, Figure 8.13B and Figure 8.13C, respectively.

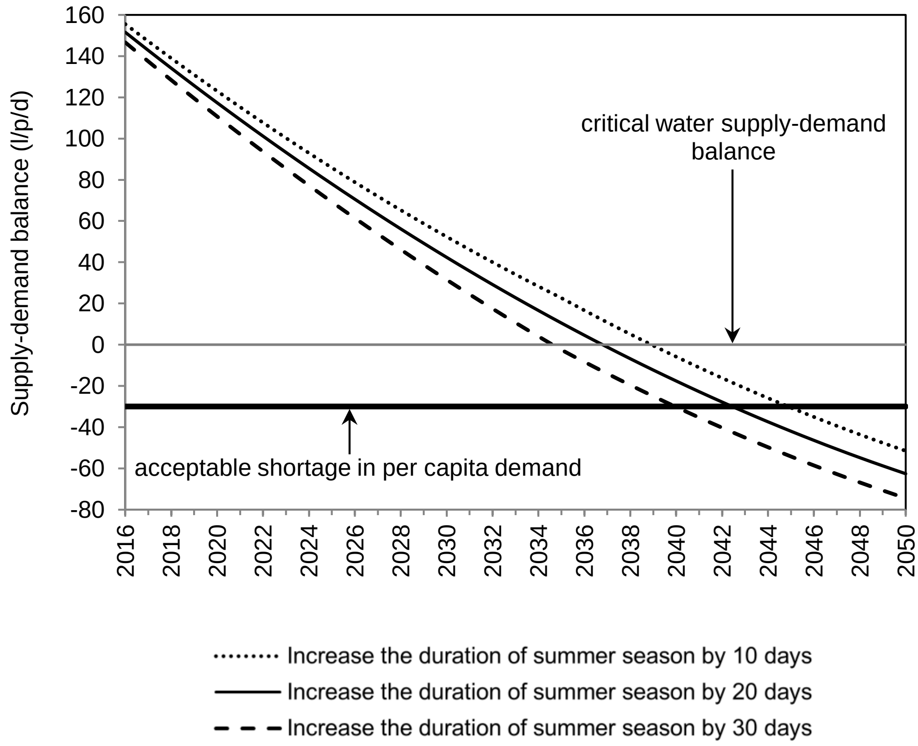
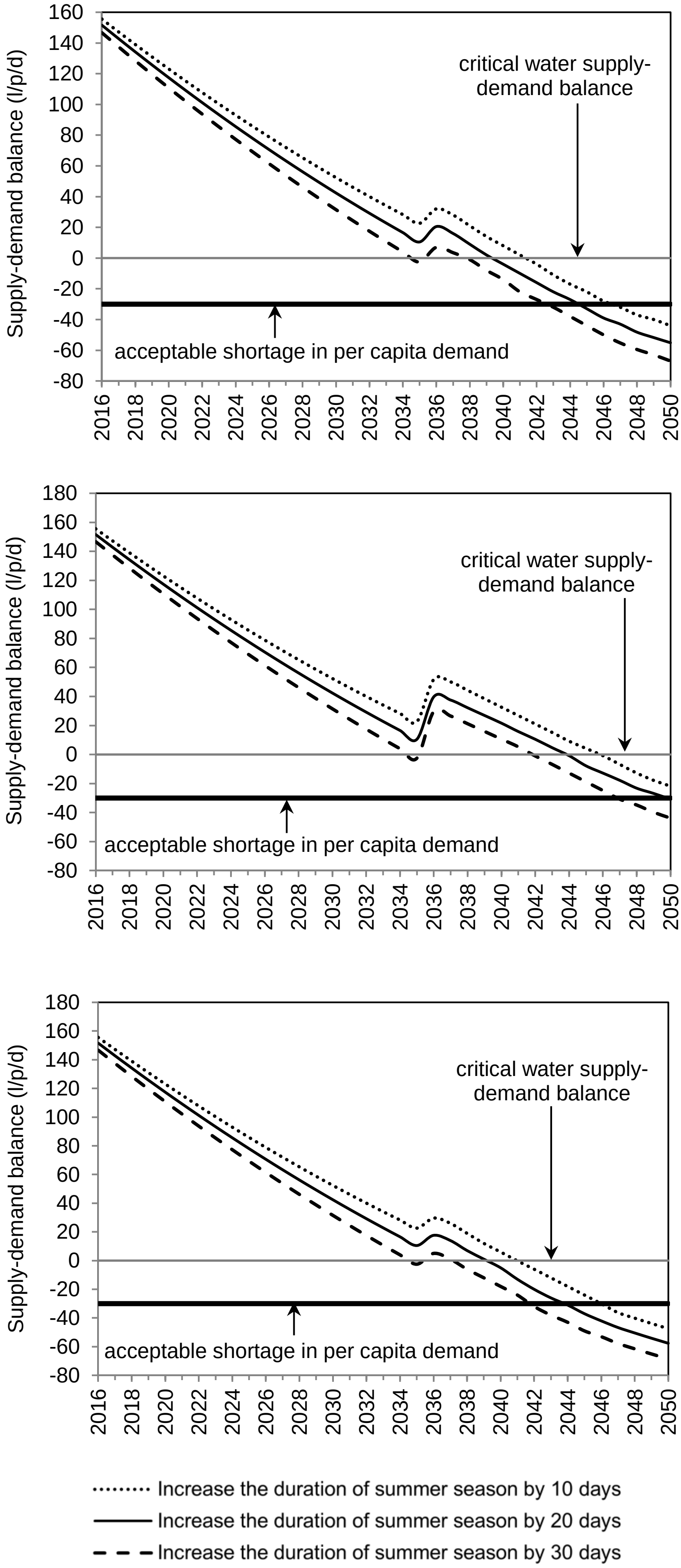


Figure 8.12 Impact of seasonal variability and population growth on per capita water supply-demand balance

The results show that all investigated strategies are able to recover the system. However, strategy B (Figure 8.13B) is more efficient than the others as it recovers the system for longer period. In another meaning, water system is able to provide per capita demand for longer duration after recovery when strategy B is applied.

For each WDM strategy, the performance of the water system is quantified under the impact of population growth and seasonal variability (Equation 3.39). The performance has been quantified for each simulation of water supply-demand balance presented in Figure 8.13 for the strategy under consideration. Also, for the rest of simulations which represent the impact of increase in summer season duration by 1, 2, 3…, 30 day.



A. Use strategy A: water efficient fixtures in a household

B. Use strategy B: recycled grey water for non-potable applications

C. Use strategy C: leakage reduction in water distribution network by 5%

Figure 8.13 Impact of WDM strategies on the performance of water system

Then, using the performance value for a particular impact (i.e., increase the duration of summer season by *j* days) with Equation 3.40, system resilience is obtained for the impact under consideration. Similarly, the resilience ($r_{i,j}$) across the impact of each variation in the duration of summer season (i.e., 1, 2, 3,…, 30) in each year (*i*) of the simulation period is quantified. The values of resilience ranges between 0 (i.e., no performance is available) and 1 (i.e., no degradation in system performance).

Finally, the integral resilience of the water system over all impacts of variation in summer season duration in each year (*i*) of the simulation period is calculated (Equation 3.41). Figure 8.14 shows the integral resilience of the water system during each year of the studied period when the WDM strategies are applied. The results indicate that the water system in Duhok is more resilient when using strategy B than the other strategies.

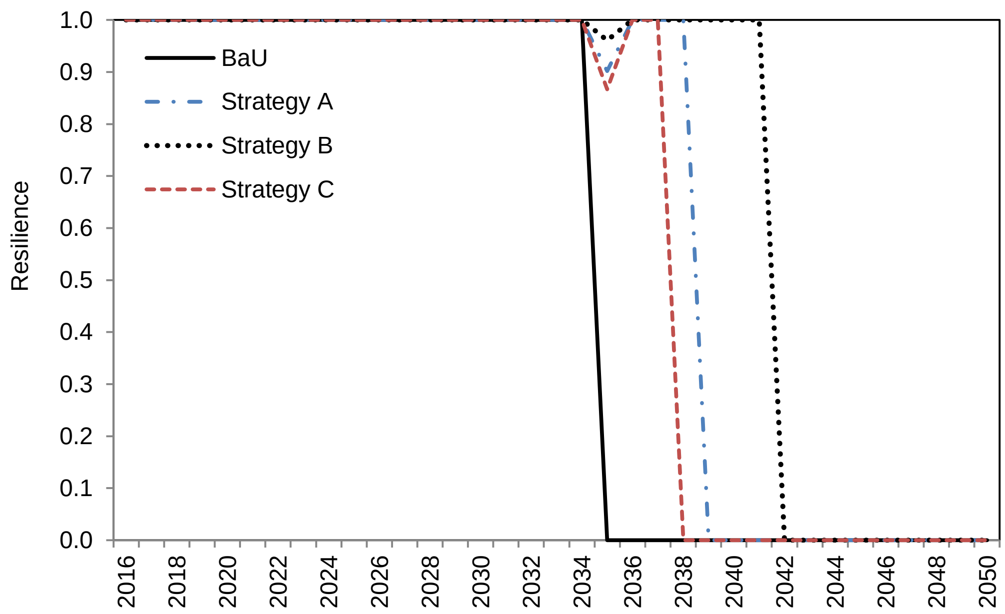


Figure 8.14 Integral resilience of the water system over all impacts of variation in the duration of summer season

8.3.2 Resilience of energy system

Resilience approach presented in Section 3.9.5 is applied to estimate the resilience of Duhok energy system for providing per capita energy demand under the impact of seasonal variability. Based on the climate trend data for the city of Duhok in Table 3.24, the duration of summer season is assumed to increase up to 30 days (i.e., 1, 2, 3,…, 30 days) by 2050.

For each assumed value of increase in summer season duration, the future electricity demand for domestic sector has been simulated using the WEF model. Each one of these simulations (i.e., $s_1, s_2, s_3, \ldots, s_{30}$) represents the impact of the assumed increase under consideration on per capita energy demand. Figure 8.8 shows the impact of summer season duration increases of 1, 10, 20 and 30 days on annual per capita energy demand. The results in this figure show that the annual per capita average electricity demand decreases with increase in summer season duration.

Afterwards, per capita available energy in each simulation year is calculated using the data of available energy (Table 3.5) with an equation similar to Equation 3.34 in the WEF model.

Then, per capita energy supply-demand balance (ΔSD_i) is calculated in each year of the simulation period (i.e., year 2016 to 2050), using equation similar to Equation 3.35. This is for the 30 simulations (i.e., $s_1, s_2, s_3, \ldots, s_{30}$), individually. Consequently, the number of simulations is 30, representing the impact of each assumed increase in summer season duration on per capita energy supply-demand balance. Figure 8.15 shows the impact of increase in summer season duration by 10, 20 and 30 days on per capita energy supply-demand balance. The figure clearly indicates that the energy supply-demand balance increases with longer summer season.

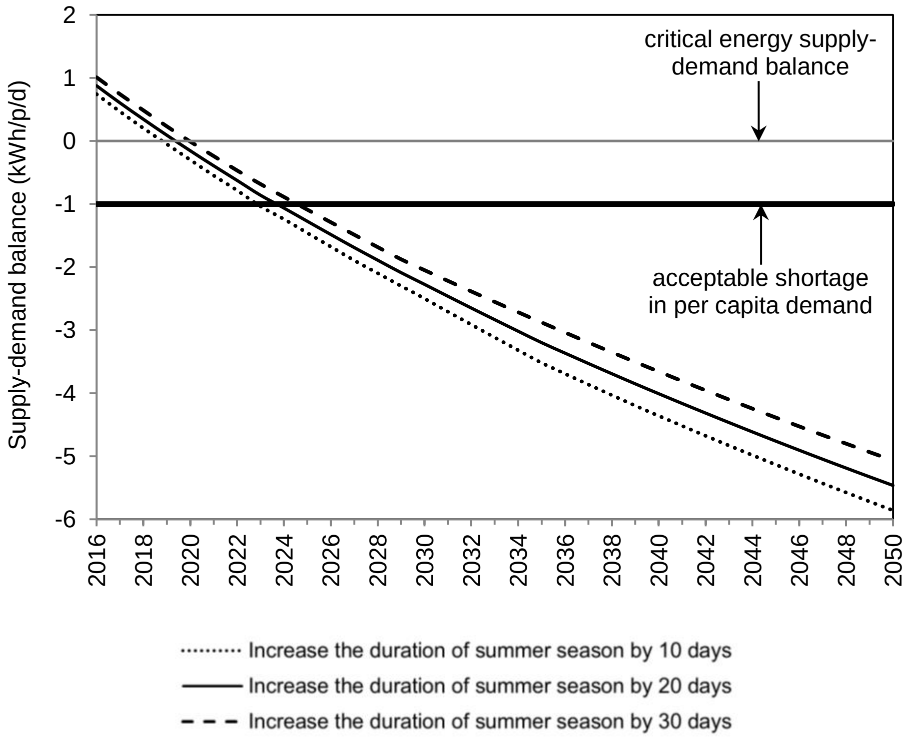
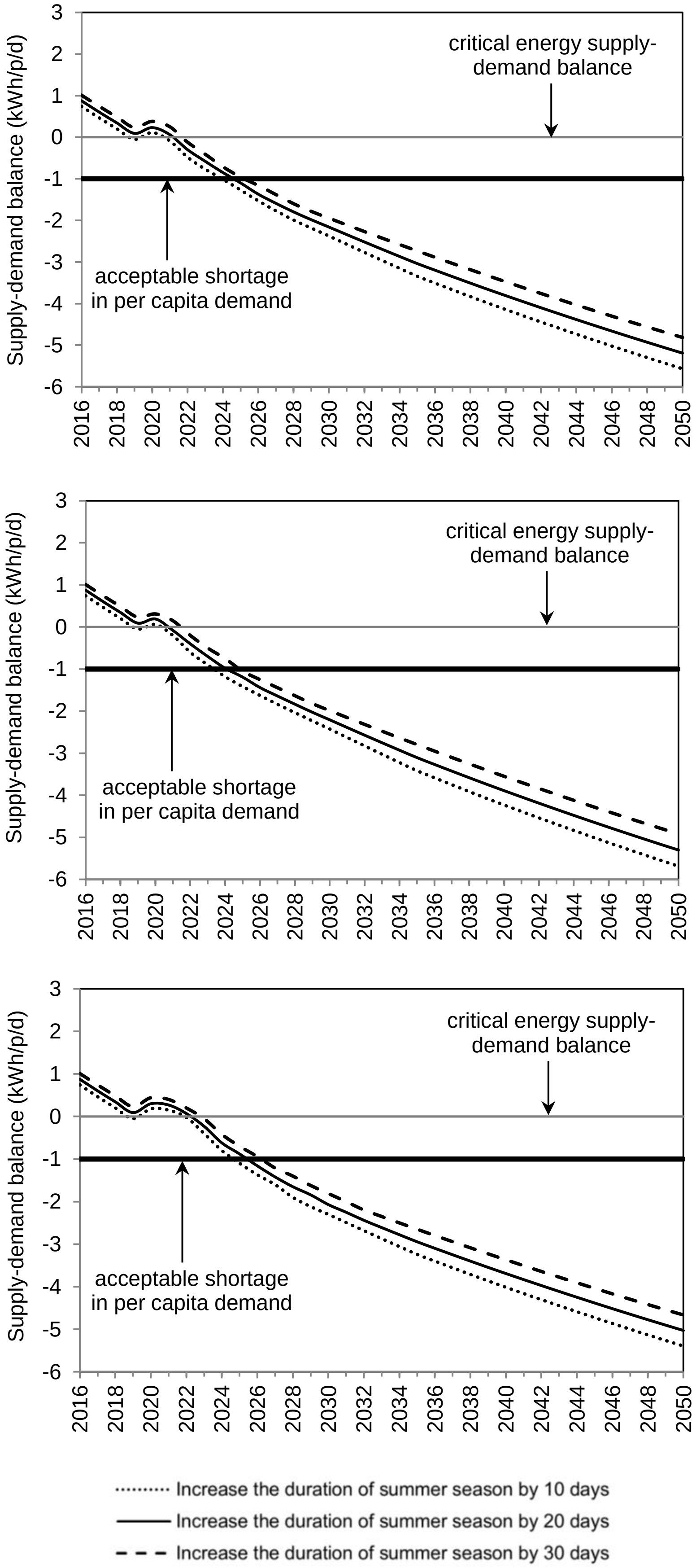


Figure 8.15 Impact of seasonal variability and population growth on per capita energy supply-demand balance

Each simulation is then compared with the critical energy supply-balance (*ΔSD=0*) to identify the starting and end of system disturbance as shown in Figure 8.15. This figure clearly shows that the disruption of Duhok energy system starts in 2019 when the supply is less than the demand (i.e., *ΔSD<0*). Therefore, energy management (EM) strategies are investigated for system recovery.

Using the WEF model, the impact of three EM strategies is investigated. These EM strategies (i.e., D, E and F) are listed and explained in Section 3.9.4. The impact of each of these EM strategies on the ability of Duhok energy system for recovery is shown in Figure 8.16. The figure shows that the energy system can recover with using these management strategies. However, strategy F is more efficient than the other investigated strategies. With applying this strategy, the energy system is able to recover providing per capita demand for longer duration than the other strategies.



A. Use Strategy D: alternative additional energy through anaerobic digestion of food waste

B. Use strategy E: energy recovery from anaerobic digestion of municipal wastewater sludge

C. Use strategy F: use of both strategies D and E

Figure 8.16 Impact of EM strategies on the performance of energy system

For each EM strategy, the performance of the energy system is quantified under the impact of seasonal variability using Equation 3.39. This has been calculated for each simulation in Figure 8.16 for the strategy under consideration, as well as the rest of simulations which represent the impact of increase in summer season duration by 1, 2, 3…, 30 days.

Using the performance value for a particular impact, the resilience of energy system is obtained for the impact under consideration (Equation 3.40). Similarly, the resilience ($r_{i,j}$) across the impact of each variation in the duration of summer season (i.e., 1, 2, 3,…, 30) is quantified for each year of the simulation period (i).

Finally, the integral resilience of the energy system over all impacts of variation in the duration of summer season (*1, 2, 3,…, 30 days*) is calculated using Equation 3.41. The integral resilience of the energy system is shown in Figure 8.17. The figure indicates that Duhok energy system is more resilient when using strategy F than the other strategies.

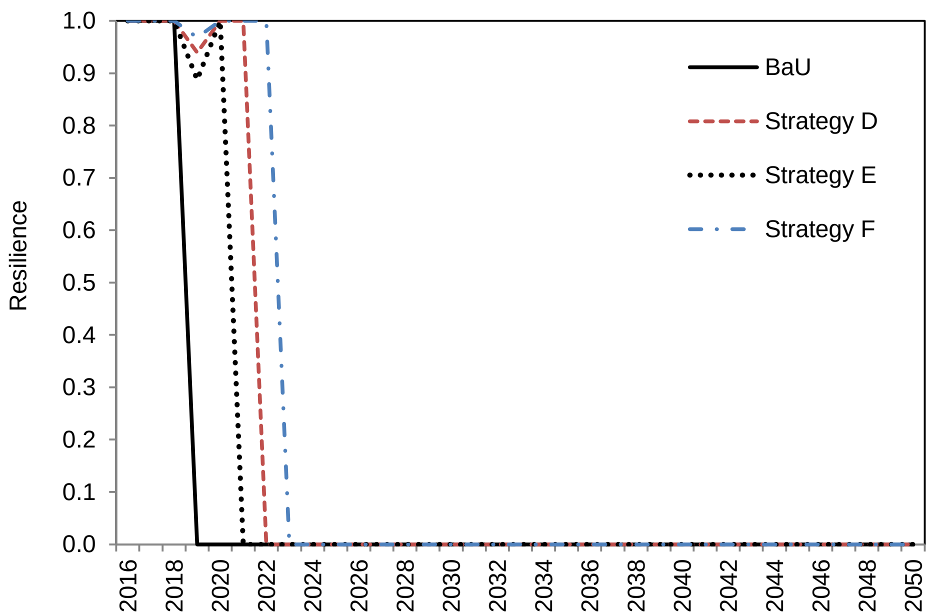


Figure 8.17 Integral resilience of the energy system over all impacts of variation in the duration of summer season

8.4 Conclusions

The purpose of this chapter was to investigate the impact of seasonal variability on the demand for WEF using the household scale WEF model. The seasonal variability in this context is represented by an increase or decrease in the number of summer days.

A risk-based approach assessment method was applied. Within this approach, risk is defined as the probability of exceeding acceptable level of shortage in per capita demand for water, energy or food in any year of the studied period due to seasonal variability. The risk-based approach incorporates the uncertainties associated with supply-demand balance and seasonal variability. Using this approach, the performance of management strategies was investigated to decrease the risk of exceeding acceptable level of shortage in per capita demand for water and energy due to seasonal variability. The key findings are:

- Seasonal variability (increase in the duration of summer season) and population growth have a high impact on per capita demand for water and energy.
- The annual average quantity of per capita food demand and generated food waste are much less sensitive to seasonal variability than water and energy demand.
- Use of recycled grey water for non-potable applications in a household is the most effective strategy to decrease the risk of exceeding acceptable level of shortage in per capita water demand.
- The quantity of water-related energy demand for recycling grey water for non-potable applications is higher than the other applied water demand management strategies.
- Using anaerobic digestion of food waste and wastewater sludge for energy recovery provides the greatest reduction in the probability of exceeding acceptable level of shortage in per capita energy demand.

CHAPTER NINE: IMPACT OF FUTURE SCENARIOS

9.1 Introduction

This chapter investigates the implications of global scenario group (GSG) scenarios on WEF demand and the generated waste at a household scale (Section 9.2). The current demand for water and energy in the city of Duhok is analysed in Section 9.3. Section 9.4 investigates the implications of GSG scenarios on the future demand for WEF and the generated organic waste as well as land-use in the city. The future quantity of water demand for each sector including the water-related energy has been analysed (Section 9.4.1). Additionally, the future demand for energy in each sector is discussed in Section 9.4.2. Section 9.4.3 investigates the future demand for food and the food-related water as well as food-related energy in the city. Moreover, the variation in the monthly demand for water and energy has been analysed (Section 9.5).

9.2 Implications of GSG scenarios on WEF at a household scale

The implications of GSG scenarios (Section 3.9.1) on WEF demand at a household level are investigated. This is using the household WEF model (Section 3.5). The investigated scenarios are Market Force, Fortress World, Great Transition and Policy Reform. According to GSG, WEF consumption and poor/rich income ratio are assumed to vary from region to region. For the case study located in Iraq, values associated with the Middle East have been used as given in Table 3.23. The growth rates in this table reflect percentage change in consumption. The model initially used to calculate the base consumption, based on parameter values obtained from the survey. The consumption in each scenario is then calculated by the household WEF model using respective values for poor/rich income ratio in Table 3.23. The annual demand for WEF has been simulated for 35 years ahead.

Figure 9.1 shows the impact of GSG scenarios on the future demand for WEF and the generated waste. In this figure, the simulated future changes in the household demand are presented as a percentage of the current demand. The results show that within these scenarios, the highest increase in the household demand is attributed to the Fortress World scenario. This is mainly due to the increase in high income households which leads to increase the family size.

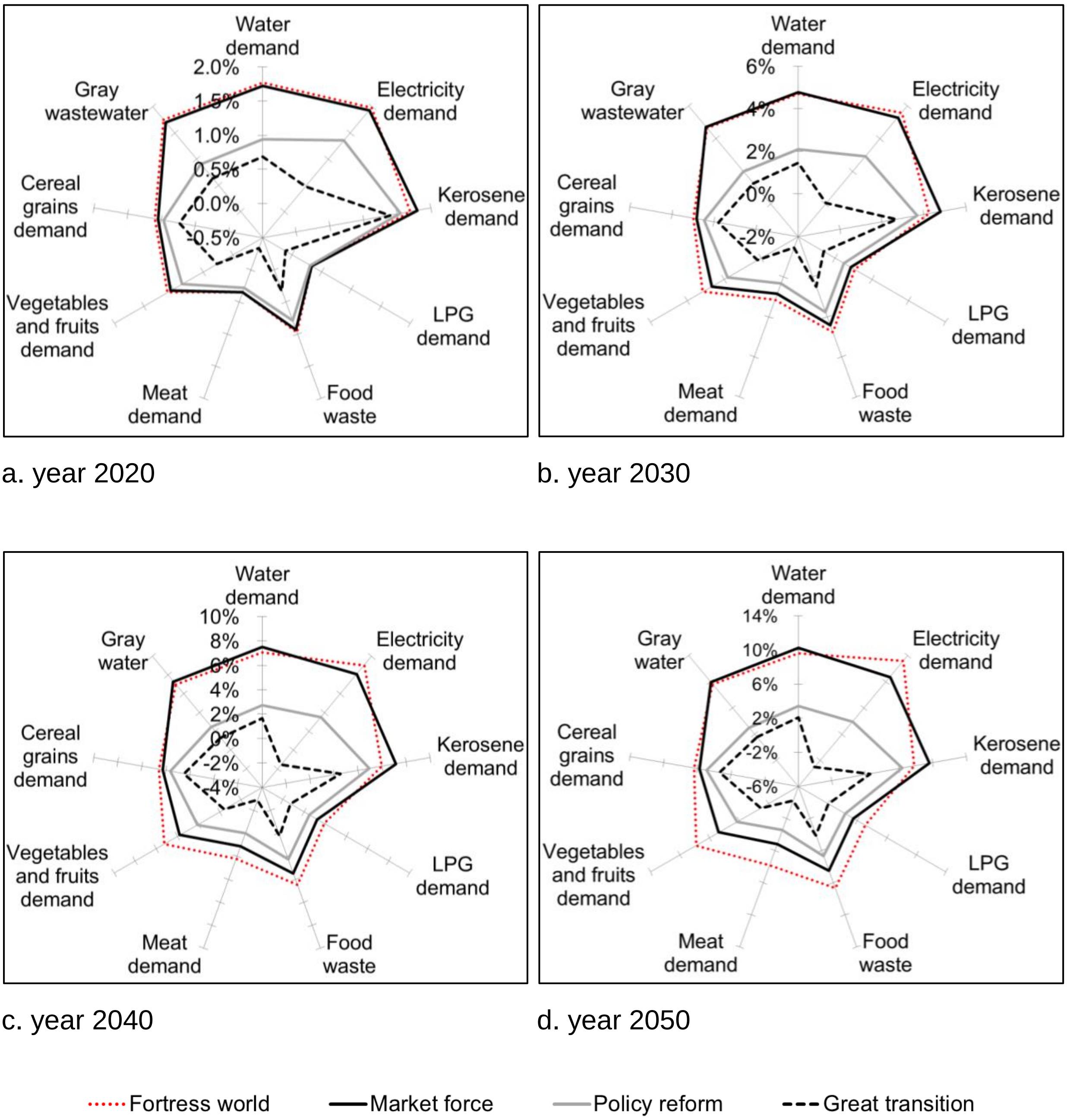


Figure 9.1 The impact of GSG scenarios on WEF at a household level

The impact of GSG scenarios on the interactions between WEF is also simulated as shown in Table 9.1. The results in this table show that the food-related energy in Fortress World scenario is higher than the other scenarios. The water-related energy in Market Force scenario is slightly higher than that in the Fortress World scenario. At a household level, the impacts of different scenarios are marginal (Table 9.1). However, when extrapolated to a city level, noticeable differences and resources implication were observed.

Table 9.1 The impact of GSG scenarios on the interactions between WEF at a household level

	Year	BaU	GSG scenarios			
			MF	PR	FW	GT
Energy for water (GJ/hh/y)	2030	24.3	25.5	24.9	25.4	24.7
	2040	24.3	26.2	25.1	26.0	24.9
	2050	24.3	26.9	25.3	26.6	25.1
Energy for food (GJ/hh/y)	2030	20.9	21.1	21.0	21.1	20.8
	2040	20.9	21.2	21.0	21.3	20.7
	2050	20.9	21.2	21.0	21.6	20.5
Water for food (m^3/hh/y)	2030	35.7	36.4	36.2	36.5	35.8
	2040	35.7	36.7	36.3	37.0	35.6
	2050	35.7	37.0	36.5	37.6	35.5

9.3 Current WEF demand at a city scale

Figure 9.2 shows the estimated water flow for all end-uses in the city of Duhok. The results in this figure are based on both seasonal surveys (Section 3.3) conducted at a household level and the collected data from local directorates (Table 3.17 and Table 3.18). The figure shows that approximately 65% of the city water demand is obtained from surface water. The figure also indicates that the domestic sector consumes approximately 50% of the total city water demand. The agricultural sector requires less water accounting about 36% of the total city water demand. More detailed analysis in Figure 9.2 shows that approximately 25% and 15% of the total city water demand is attributed to the irrigation purposes for cereal grains and household hand wash basin tap usage, respectively. Additionally, the quantity of evaporated water (i.e., irrigation, garden watering and space cooling purposes) accounts for more than 40% of the total water supplied to the city.

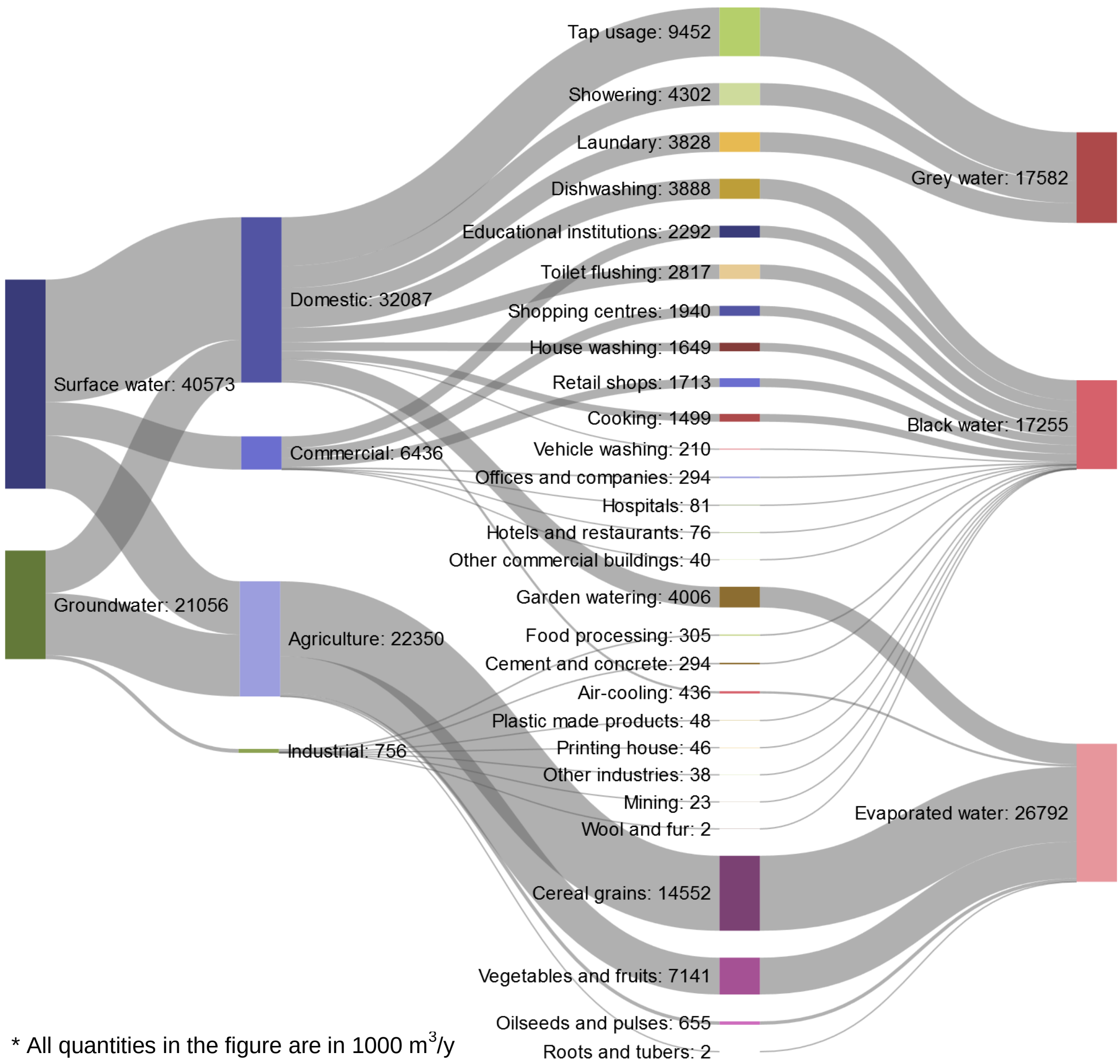


Figure 9.2 Summary of Duhok water flow in 2016

The energy flow in the city of Duhok is analysed as shown in Figure 9.3. The results indicate that the city relies heavily on electricity (55% of the total city energy consumption) to meet its energy requirements. The energy gained from kerosene accounts for less than 40% of the total energy demand in the city. The main finding in Figure 9.3 is that the domestic sector dominates the energy demand with more than 80% of the total city demand. The analysis in this figure also shows that around half of the total city energy demand is attributed to space heating and cooling.

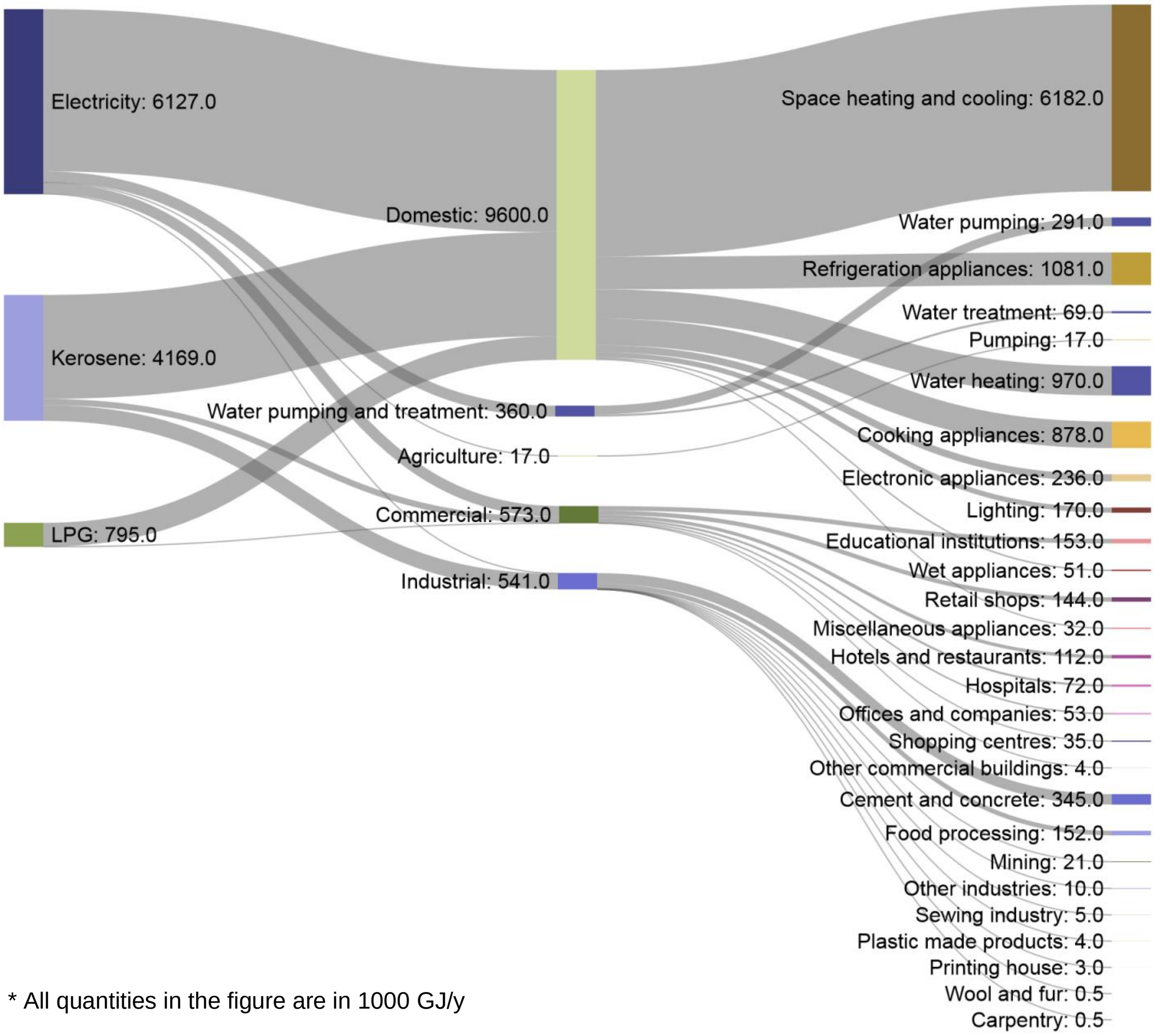


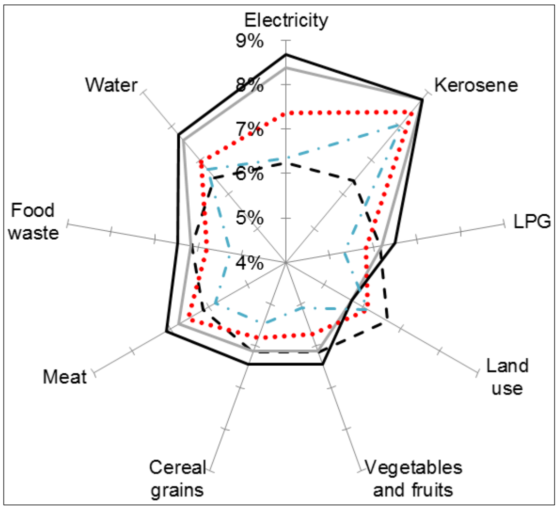
Figure 9.3 Summary of Duhok energy flow in 2016

9.4 Future WEF demand at a city scale

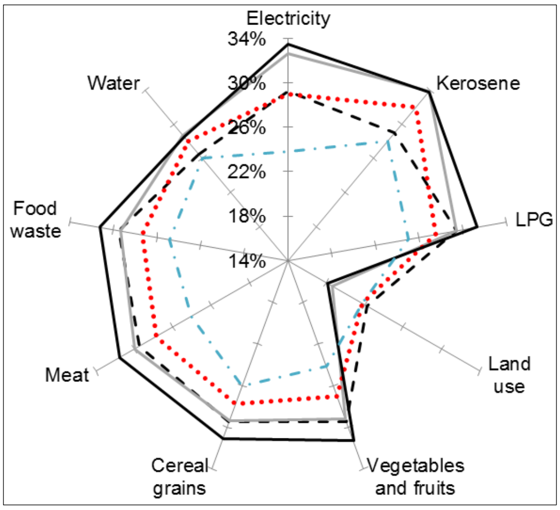
The implications of GSG scenarios on the future demand for WEF and the generated organic wastes as well as the land-use in Duhok are investigated. The GSG scenarios are Market Force, Fortress World, Policy Reform and Great Transition (Section 3.9.1). The characteristics of these scenarios and their average annual growth rate values are estimated by GSG as presented in Table 3.23. Using these values in the city scale WEF model, the future demand for WEF and the generated organic waste as well as land-use are simulated from year 2016 to 2050. The simulation results are shown in Figure 9.4 for different decades (i.e., from 2020 to 2050). The results in this figure are presented as a percentage of the present estimation (i.e., at 2016).

It can be seen from the results in Figure 9.4 that the land-use for agricultural purposes in Fortress World scenario is less than the other GSG scenarios. This leads to decrease in water demand for the city. However, within the GSG scenarios, the city demand for energy and food as well as the generated organic waste is the highest in the Fortress World scenario.

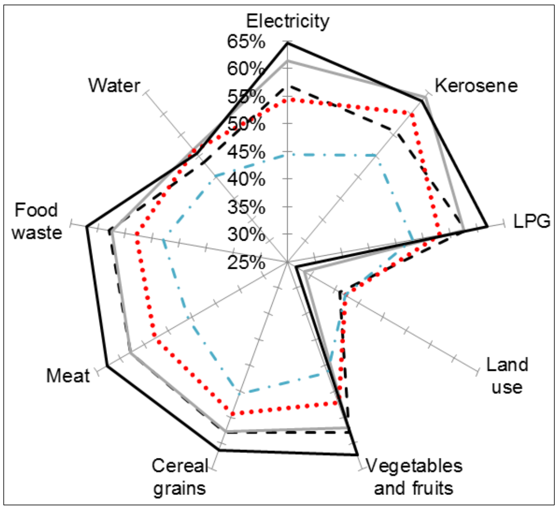
Clearly, the future demand for energy and food as well as the generated organic waste from the city are the lowest in Great Transition and Policy Reform scenario. However, agricultural land-use is the highest in the Policy Reform scenario, causing increase the quantity of water demand for irrigation.



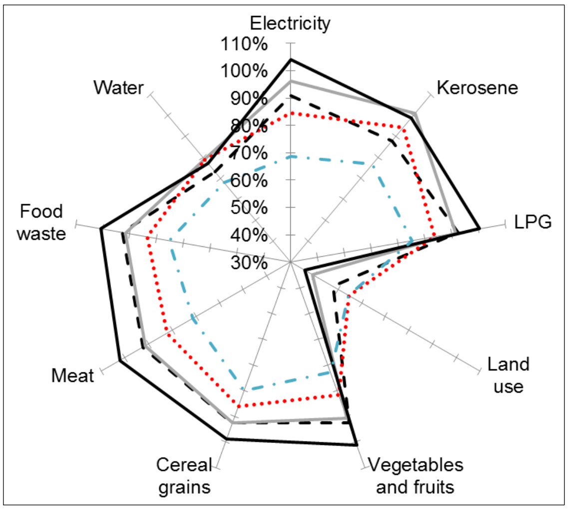
a. year 2020



b. year 2030



c. year 2040



d. year 2050

- - - Business as usual
— Market force
••• Policy reform
— Fortress world
-·- Great transition

Figure 9.4 Implications of GSG scenarios on the total demand and generated waste in Duhok

9.4.1 Future water demand

Using the city scale WEF model, the implications of GSG scenarios on the future water demand for domestic, agricultural, commercial and industrial sector are investigated. The results show that the agricultural water demand in the Fortress World scenario is less than the other scenarios (Table 9.2). This is due to the lower land-use for agriculture in the Fortress World scenario (Table 3.23 and Figure 9.4). The future water demand for agriculture, commercial and industrial sectors is the highest in the Policy Reform scenario. This is because the GDP growth rate and agricultural land-use are higher in this scenario than the other GSG scenarios (Table 3.23). The Great Transition scenario has low water demand for domestic, commercial and industrial sectors as a result of low population and GDP growth (Table 3.23).

Table 9.2 Impact of GSG scenarios on water demand for each sector

	water demand (10^6 m^3/y)									
	year 2020					year 2030				
	BaU	MF	PR	FW	GT	BaU	MF	PR	FW	GT
Domestic	34.4	34.9	34.3	35.0	34.2	42.0	42.5	41.1	42.7	40.6
Agricultural	23.8	23.6	23.7	23.6	23.7	27.3	26.5	27.2	26.4	27.2
Commercial	6.9	7.3	7.4	7.3	7.4	8.1	9.6	9.8	9.4	9.2
Industrial	0.8	0.9	0.9	0.9	0.9	1.0	1.1	1.2	1.1	1.1
Total city	66.0	66.7	66.3	66.8	66.1	78.4	79.7	79.3	79.6	78.1
	year 2040					year 2050				
	BaU	MF	PR	FW	GT	BaU	MF	PR	FW	GT
Domestic	51.2	51.8	49.7	52.6	48.5	62.5	63.2	60.0	64.9	58.0
Agricultural	30.4	28.7	30.7	28.3	30.7	33.1	31.1	34.5	30.4	34.5
Commercial	9.4	12.0	12.0	11.0	9.8	10.6	14.9	14.6	12.9	10.4
Industrial	1.1	1.4	1.4	1.3	1.1	1.2	1.7	1.7	1.5	1.2
Total city	92.1	93.9	93.7	93.3	90.1	107.3	110.9	110.8	109.6	104.1

9.4.1.1 Water-related energy demand

The water-related energy demand is investigated for BaU (Figure 9.5) and the GSG scenarios (Table 9.3). This includes the quantity of energy demand for water treatment and pumping in each sector (i.e., domestic, agricultural, commercial and industrial) as well as the energy required for household water uses (i.e., water heating, water pumping and evaporative air-cooler). The results show that the present energy demand for water treatment and pumping together accounts for approximately 7% of the total city electricity demand. Figure 9.5 shows that the water-related energy demand for water treatment processes is low (5% of the total water-related energy demand), compared to that required for water pumping. Additionally, energy required for household water uses accounts for over 70% of the total water-related energy uses in the city. The analysis also shows that the quantity of energy presently required for water pumping to the agricultural sector is about 4824 MW/y. This is in agreement with the estimated value (4247 MW/y) by General Directorate of Duhok Electricity (2014).

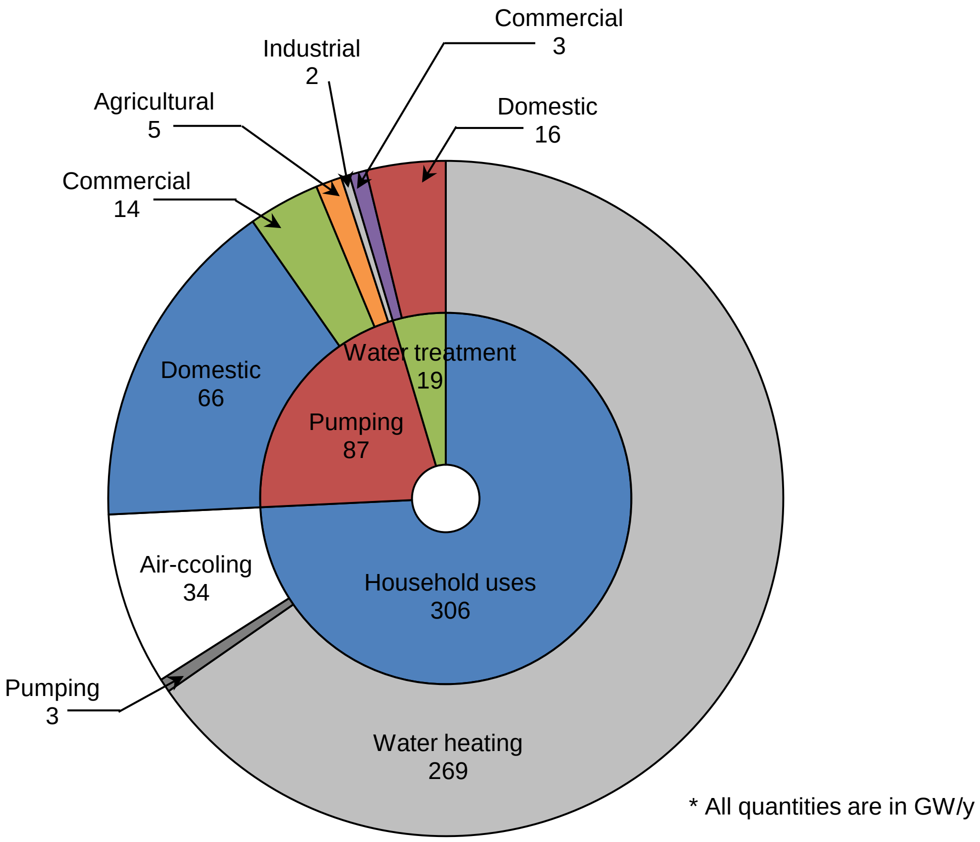


Figure 9.5 Summary of present water-related energy demand in Duhok

In the future, energy required for household water uses increases to more than 75% of the total water-related energy uses in the city (Table 9.3). This has been noticed in all GSG scenarios. Additionally, the city total water-related energy is higher in MF and FW than that in Business as Usual scenario. However, it is low in PR and GT scenario.

Table 9.3 Impact of GSG scenarios on water-related energy demand

Water-related energy uses		Water-related energy demand (10^3 MW/y)									
		year 2020					year 2030				
		BaU	MF	PR	FW	GT	BaU	MF	PR	FW	GT
Pumping from water source to each sector	Domestic	70	71	70	71	70	86	87	84	87	83
	Agricultural	5	5	5	5	5	6	6	6	6	6
	Commercial	14	15	15	15	15	17	20	20	19	19
	Industrial	2	2	2	2	2	2	2	2	2	2
Water treatment	Domestic	17	17	17	17	17	20	21	20	21	20
	Commercial	3	4	4	4	4	4	5	5	5	4
Household uses		325	325	324	326	323	397	396	392	401	387
Total		436	438	436	440	435	531	536	529	541	521
		year 2040					year 2050				
		BaU	MF	PR	FW	GT	BaU	MF	PR	FW	GT
Pumping from water source to each sector	Domestic	105	106	102	108	99	128	129	123	133	118
	Agricultural	7	6	7	6	7	7	7	7	7	7
	Commercial	19	24	24	23	20	22	30	30	26	21
	Industrial	2	3	3	3	2	3	4	4	3	2
Water treatment	Domestic	25	25	24	25	23	30	31	29	31	28
	Commercial	5	6	6	5	5	5	7	7	6	5
Household uses		484	484	474	494	464	590	591	574	608	557
Total		646	654	639	663	620	784	798	774	814	739

9.4.2 Future energy demand

9.4.2.1 Future electricity demand

The implications of GSG scenarios on the future energy demand for each sector are investigated as shown in Table 9.4. In agreement with General Directorate of Duhok Electricity (2014), the results show that the present electricity demand for domestic sector accounts approximately 80% of the total city demand. The future demand increases to more than that in Business as Usual scenario because of population growth. Table 9.4 also shows that the Policy Reform scenario has the highest electricity demand in all sectors except for domestic. This is due to the GDP growth and increased land-use for agriculture which requires energy for pumping water (Table 3.23). The Great Transition scenario achieves low energy demand (Table 9.4) due to the lower growth in GDP and population (Table 3.23).

Table 9.4 Impact of GSG scenarios on energy demand for each sector

	energy demand (10^3 MW/y)									
	year 2020					year 2030				
	BaU	MF	PR	FW	GT	BaU	MF	PR	FW	GT
Domestic	1583	1611	1594	1616	1578	1932	1962	1899	1979	1826
Agricultural	5.1	5.1	5.1	5.1	5.1	5.9	5.7	5.9	5.7	5.9
Commercial	108	113	115	113	114	126	149	153	146	143
Industrial	6.9	7.3	7.4	7.3	7.3	8.1	9.6	9.8	9.4	9.2
Total city	1703	1737	1721	1742	1704	2072	2127	2067	2140	1985
	year 2040					year 2050				
	BaU	MF	PR	FW	GT	BaU	MF	PR	FW	GT
Domestic	2357	2384	2270	2451	2148	2875	2891	2708	3050	2526
Agricultural	6.6	6.2	6.6	6.1	6.6	7.1	6.7	7.5	6.6	7.5
Commercial	145	186	186	171	152	164	231	227	201	161
Industrial	9.4	11.9	12.0	11.0	9.8	10.6	14.9	14.6	12.9	10.4
Total city	2518	2588	2475	2640	2316	3057	3144	2957	3270	2705

9.4.2.2 Future kerosene demand

The implications of GSG scenarios on the future kerosene demand for all sectors in the city are investigated. The WEF model was used with the annual growth rate of the indictors in Table 3.23. Similarly to the electricity demand analysis, the results show that kerosene demand for domestic sector is high (80% of the total city demand). The rest of the city demand for kerosene is attributed to commercial and industrial sectors. The results also show that the overall city demand for kerosene in the Fortress World scenario is higher than the other GSG scenarios.

9.4.3 Future food demand

The growth rate values of the indicators shown in Table 3.23 are used with the WEF model to investigate the impact of GSG scenarios on the future food demand and the generated organic waste (Table 9.5). The results show that the Fortress World scenario has the highest demand for cereal grains, meat, vegetables and fruits as well as the generated organic waste due to the high population growth rate (Table 3.23). In contrast, the Great Transition scenario achieves the lowest demand for the city. Food demand estimates in the Business as Usual scenario are approximately equal to the Market Force scenario (Table 9.5).

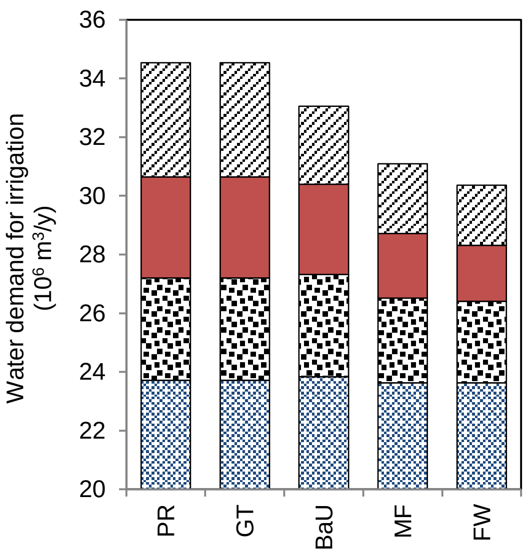
Table 9.5 Impact of GSG scenarios on food demand and generated organic waste

	food demand and generated organic waste (10^3 ton/y)									
	year 2020					year 2030				
	BaU	MF	PR	FW	GT	BaU	MF	PR	FW	GT
Meat	12.5	12.5	12.5	12.6	12.4	15.2	15.2	15.0	15.4	14.6
Cereal grains	46.2	46.2	46.1	46.3	45.9	56.4	56.3	55.6	57.1	54.9
Vegetable and fruits	73.6	73.6	73.3	73.8	72.9	89.8	89.6	88.1	91.0	86.1
Organic waste	16.6	16.6	16.5	16.6	16.4	20.2	20.2	19.9	20.5	19.5
	year 2040					year 2050				
	BaU	MF	PR	FW	GT	BaU	MF	PR	FW	GT
Meat	18.5	18.5	17.9	19.1	17.1	22.6	22.5	21.3	23.7	20.1
Cereal grains	68.8	68.7	67.1	70.3	65.6	83.9	83.8	81.1	86.6	78.4
Vegetable and fruits	109.6	108.9	105.5	112.6	101.6	133.7	132.2	126.1	139.7	119.8
Organic waste	24.7	24.6	23.9	25.3	23.1	30.1	29.9	28.6	31.3	27.4

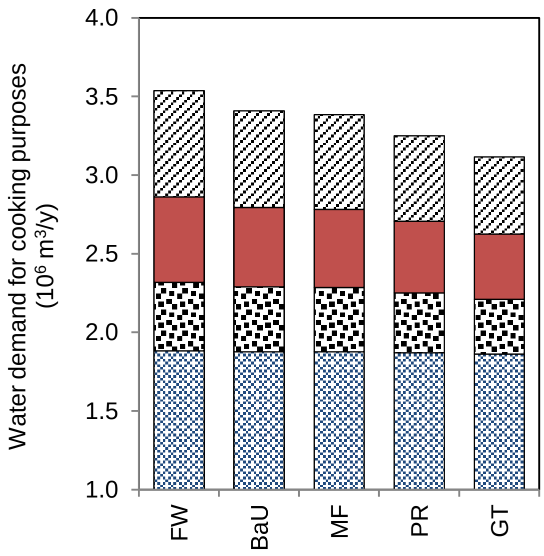
9.4.3.1 Food-related water demand

The implications of GSG scenarios on food-related water demand are investigated. The quantity of food-related water demand (i.e., irrigation, food processing, cooking in a household) in the city is quantified as shown in Figure 9.6. The figure shows that the quantity of present water demand for irrigation accounts approximately 90% of the total food-related water demand in the city. However, it decreases to less than 80% in the Market Force and

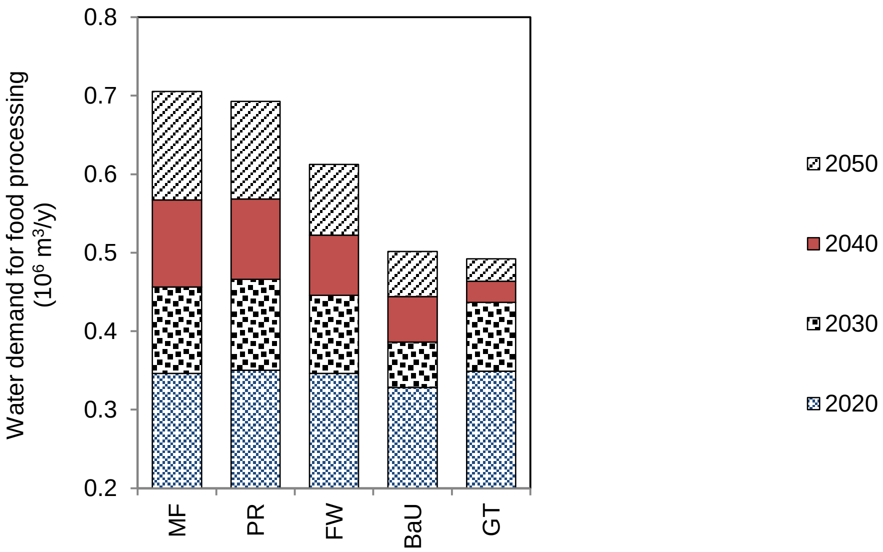
Fortress World scenarios. The results in Figure 9.6 also show that the quantity of water demand for irrigation and food processing is considerably high in the Policy Reform scenario. This is due to the higher growth rate in agricultural land-use and GDP. In terms of water demand for cooking purposes in a household, the Fortress World scenario causes the highest demand.



a. irrigation



b. cooking purposes

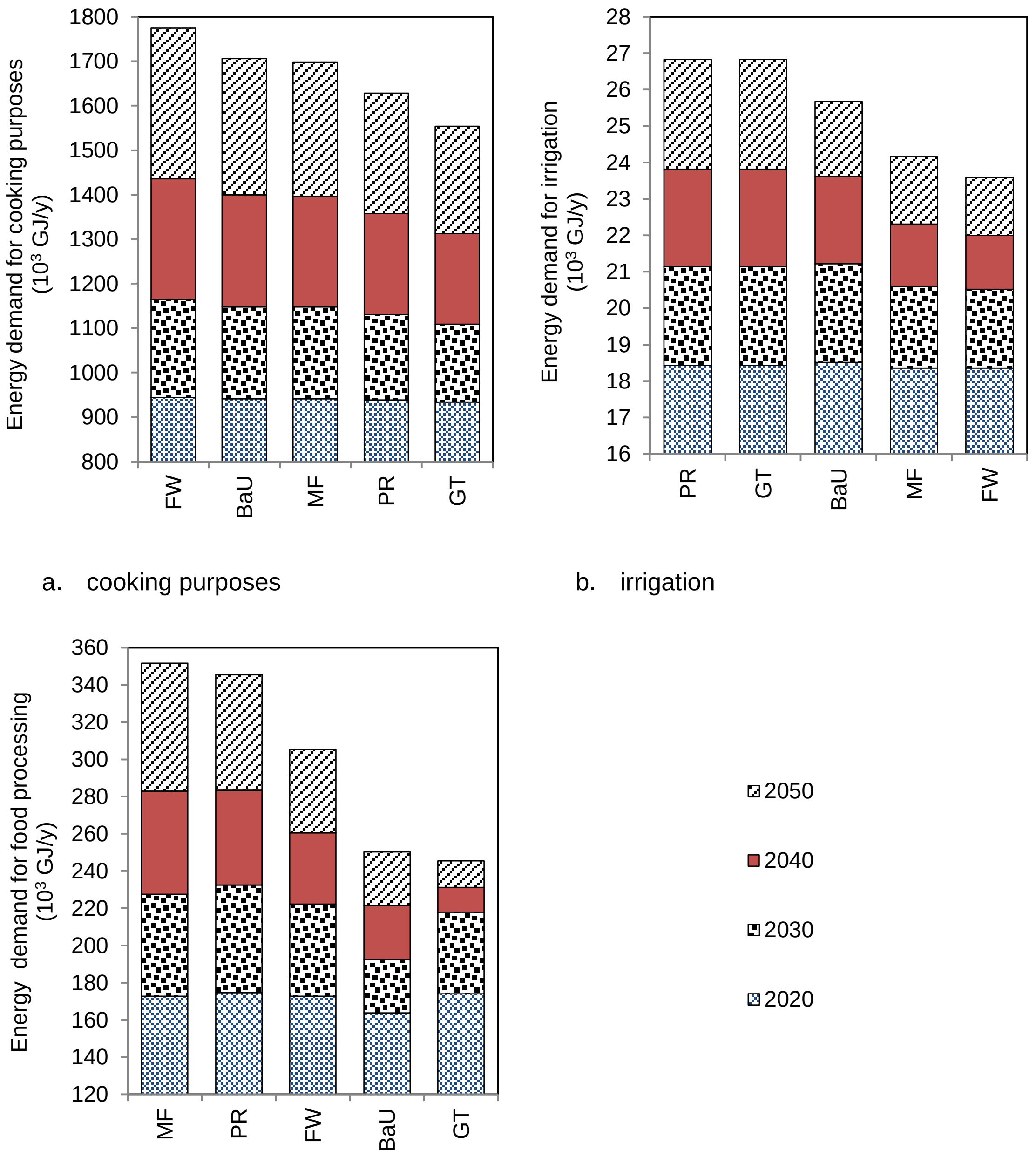


c. food processing

Figure 9.6 Summary of food-related water demand in the city of Duhok

9.4.3.2 Food-related energy demand

The food-related energy demand in Duhok is investigated using the WEF model as shown in Figure 9.7. The figure shows the implications of GSG scenarios on the energy demand for irrigation, food processing and cooking purposes. Clearly, the results in this figure indicate that the energy required for cooking purposes in a household is higher than that for irrigation (water pumping) and food processing.



a. cooking purposes

b. irrigation

c. food processing

Figure 9.7 Summary of food-related energy demand in the city of Duhok

Figure 9.7 also shows that the energy demand for cooking purposes is higher in Fortress World scenario than the other scenarios due to the higher population growth (Table 3.23). Energy demand for irrigation purposes is the highest in Policy Reform scenario due to the high use for agricultural land requiring energy for pumping water.

9.5 Monthly demand for the city

Monthly demand for water and energy in all sectors (i.e., domestic, agricultural, commercial and industrial) is analysed using the city scale WEF model. The results show that the total city water demand is considerably higher ($12x10^6$ m^3) in the month of May while it is only $3x10^6$ m^3 during winter months. The distribution of monthly demand for water in all sectors is shown in Figure 9.8. This figure indicates that the proportion of water required for agricultural sector is higher than that for the other sectors during the irrigation period (March to June). The domestic sector dominates the water demand in the city during the rest of months.

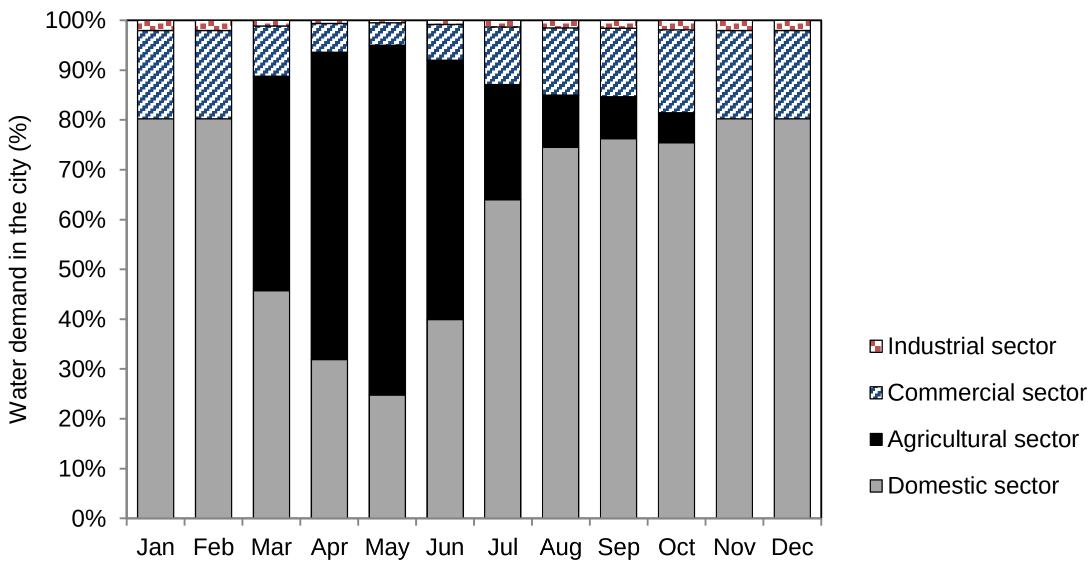


Figure 9.8 Distribution of monthly water demand in all sectors

In terms of monthly energy demand for the city, it is much higher during winter months ($1260x10^3$ GJ/mon) than that during summer months ($590x10^3$ GJ/mon). Figure 9.9 shows the distribution of monthly energy demand in all sectors. The figure shows that the proportion of energy demand for domestic uses is approximately 90% of the total city demand during winter months.

However, it decreases to less than 80% of the total city energy demand during summer months due to less energy consumption in households.

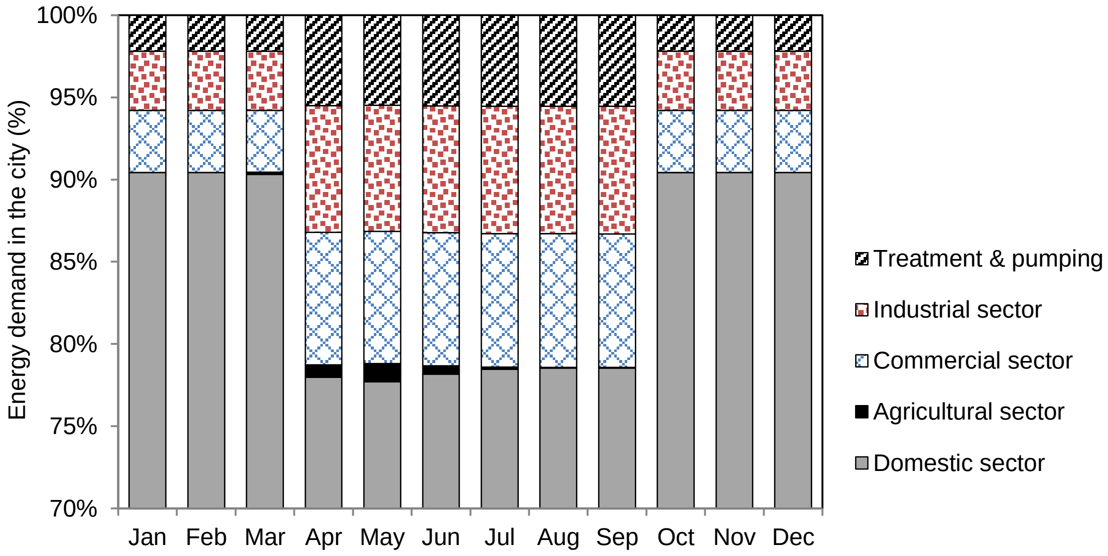


Figure 9.9 Distribution of monthly energy demand in all sectors

9.6 Conclusions

The purpose of this chapter was to present the applications of the city scale WEF model. The city scale model was applied to investigate the impact of four possible GSG scenarios: Market Force, Fortress World, Great Transition and Policy Reform. The findings are:

- Water use for irrigation of cereal grains and household hand wash basin tap usage accounts for 25 and 15% of the city demand, respectively.
- Around 50% of the total energy demand in the city is attributed to space heating and cooling purposes.
- The water-related energy (i.e., water treatment, pumping, water heating) accounts approximately 25% of the total city electricity consumption. In the future, Policy Reform and Great Transition scenarios achieve less water-related energy in the city than Business as Usual and Market Force scenario
- Food-related water (i.e., irrigation, food processing and cooking at a household) accounts approximately 40% of the total water demand in the city. However, it decreases in the Market Force and the Fortress World scenario due to the less use for agricultural land.

- Around 20% of the total city energy demand is food-related (i.e., pumping water for irrigation, food processing and cooking appliances). The energy demand for food preparation in Duhok households is higher in the Fortress World scenario than the other scenarios due to the higher population growth.
- Fortress World scenario causes the highest demand for WEF compared to the other GSG scenarios. However, land-use is the lowest due to low agricultural production.
- The domestic sector dominates water and energy demand for the city during winter months. However, the proportion of water demand for agricultural sector is the highest during irrigation period in summer months.

CHAPTER TEN: CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

10.1 Conclusions

The key conclusions for each element of the research are summarised in the following sections (Section 10.1.1 to 10.1.6):

10.1.1 Impact of household characteristics on WEF consumption

The relationship between household characteristics (i.e., number of children, elders, adult males and adult females, total household built-up area, garden area, number of rooms, number of floors and income) and the consumption for each of WEF has been investigated (Chapter 4, 5 and 6). A summary of the key findings is provided as follows:

- The per capita average water consumption increases with the rise in household *income* and decreases with the increase in the *household occupancy*.
- Per capita average water consumption decreases with the increase in *male adults*, *elders* and *children* but increases with the increase in number of *adult females* in a household.
- Per capita electricity consumption increases with the increase in number of *adults* and *elders* in the households, while it decreases with the increase in number of *children*.
- The daily per capita average *energy* (i.e., electricity, LPG and kerosene) consumption increases with the increase in per capita *income*.
- Daily per capita average electricity and *water* consumption in the *apartments* (8.0 kWh/p/d and 247 l/p/d) is much lower than that in the *stand alone houses* (15.9 kWh/p/d and 274 l/p/d).
- Electricity is used as the main energy source for *space heating* in the high income group. On the other hand, in the low income households, kerosene remains a significant energy source for space heating.
- The total average household food consumption (kg/hh/d) increases with the increase in *household occupancy* and *income*. Daily per capita average

total food consumption is approximately 1180, 1460 and 1900 g/p/d in low, medium and high income households, respectively.

- The average daily calorie intake for *adult males* (2800 kcal/p/d) is higher than that for *adult females* (2750 kcal/p/d).

10.1.2 Household end-uses of WEF

WEF consumption at end-use level has been analysed in Duhok households. Factors affecting the household consumption and the contribution of each end-use into the total consumption were also investigated. The key findings are summarised as below:

- *Frequency* of all water end-uses increases with the increase in per capita income except for toilet usage. Toilet use frequency in low income households (5.4 fl/p/d) is higher than that in medium (4.7 fl/p/d) and high (4.1 fl/p/d) income groups.
- The *duration* of hand wash basin tap use in Duhok (10.6 min/p/d) is much higher than the typical values in the developed world. This indicates an additional water use activities (e.g., ablution) via the hand wash basin tap in Iraq.
- *Flow rate* from different water end-uses decreases with increase in the per capita income, suggesting that households in high income group are relatively new and fitted with water efficient appliances.
- The *ownership level* of all household appliances (e.g., electrical heaters, air-conditioners, washing machine, freezer, oven, etc.) increases with the increase in per capita income.
- The *duration* of use for energy consuming appliances increases with the increase in household income.
- Approximately half of the daily calorie intake is provided from *cereal grains* and products. However, the proportion of calorie intake from cereal grains decreases with the increase in per capita income.
- The consumption of vegetables, fruits and meat increases with the increase in per capita income.
- Daily per capita *meat* consumption in Duhok (108 g/p/d) is high compared to the average consumption in the developing countries.

- Although the *meat* consumption is much lower than many other types of food (e.g., vegetables, fruits and cereal grains), it requires the highest quantity of *water* (2 m^3/p/y) and *LPG* (50 l/p/y) consumption for its preparation.

10.1.3 Seasonal variability of WEF consumption

The variability of household consumption for WEF at end-use level between winter and summer season has been investigated. The main conclusions are summarised as below:

- Daily per capita average *water* consumption in summer (334 l/p/d) is higher than that in winter (270 l/p/d). In contrast, per capita *energy* consumption increases in winter (15.5 kWh/p/d) compared to that in summer (12.1 kWh/p/d).
- The *frequency* and per capita consumption of all water end-uses increase in summer, except for toilet flushing and dishwashing. The frequency of toilet flushing and dishwashing remains broadly unchanged during summer and winter.
- Seasonal variation does not seem to influence the *flow rate* of different appliances and end-uses.
- The *duration* of showering decreases in summer (8.6 min/p/shw in winter and 4.8 min/p/shw in summer) while the duration of other water end-uses does not vary throughout winter and summer.
- Within water end-uses, the highest difference between winter and summer consumption appears because of *garden watering* (19 l/p/d in winter and 57 l/p/d in summer).
- The average *number of each electrical appliance* in use in the household and *wattage* remain broadly unchanged throughout winter and summer season.
- The *duration* of use of most electrical appliances is longer during summer than in winter. However, the duration of using lights decreases in summer season due to the long daylight hours.
- The energy consumption of *refrigeration appliances* (2.86 kWh/p/d) does not vary throughout winter and summer, with a decrease in *lighting*

consumption during summer. However, the consumption of other energy end-uses is higher in summer than in winter.

- Apart from kettle use, the energy consumption for *water heating* is nonexistent during summer season.
- Due to use kerosene fuel as another source of energy for space heating in winter, the electricity consumption for *space heating* (5.9 kWh/p/d) is less than that for *space cooling* (7.5 kWh/p/d).
- Daily per capita average consumption for meat, sugar and oils and fats remains constant throughout winter and summer season.
- The average consumption of some types of food (cereal grains, roots and tubers, oilseeds and pulses) decreases during summer. However, the daily per capita consumption for dairy products, vegetables and fruits is higher in summer than in winter.

10.1.4 Modelled per capita consumption with household characteristics

Per capita consumption for each of water and energy has been modelled as a function of household demographic characteristics (i.e., number of children, elders, adult males and adult females) and physical characteristics (i.e., total household built-up area, garden area, number of rooms, number of floors and income) using evolutionary polynomial regression (EPR) and stepwise multiple linear regression technique. In order to test the quality of the model prediction, the full data set was disaggregated into three income group households (i.e., low, medium and high) and the regression models developed for each income group, individually. The key results obtained are as below:

- Using the collected survey data, it is possible to predict daily per capita consumption for water and energy. The quality of prediction improves when the full data was disaggregated into low, medium and high income group households.
- The *demographic characteristics* provide more accurate predictions of per capita water consumption than the predictions resulting from the use of *physical characteristics* of the investigated households. In contrast, the energy prediction models based on physical characteristics show better predictions than those based on demographic characteristics.

- The models based on *EPR* offer a marginal improvement in the predictions quality.

10.1.5 Risk and resilience assessment of WEF

The WEF model has been used to assess the risk and resilience of WEF systems under the impact of seasonal variability. The risk in this study is defined as the probability of exceeding acceptable level of shortage in per capita demand under the impact of seasonal variability. Resilience is the ability of WEF system to absorb disturbance (supply deficit) to maintain acceptable functionality level (minimum demand) and recover from failure once it occurs. The main findings are given as below:

- Using *grey water recycling* for non-potable applications (i.e., garden watering, car washing and toilet flushing) in a household can decrease the *risk* probability to 0.4 in 2050 while other applied water demand management strategies can have a marginal effect (i.e., *risk* probability reaches up to 0.85).
- The most effective strategy to increase the *resilience* of water system is use of *grey water recycling* for non-potable applications in a household.
- Using *recycled grey water* for non-potable applications increases energy demand by 3%. However, the other applied water demand management strategies (i.e., use of water efficient fixtures in a household and leakage reduction in water distribution network) can decrease the *water-related energy* demand by up to 6%.
- Using *anaerobic digestion* of food waste and wastewater sludge for energy recovery can decrease the *risk* and increase the *resilience* of energy system for meeting per capita energy demand.

10.1.6 Impact of future scenarios on WEF nexus

The impacts of GSG scenarios on WEF, the generated waste (food waste and wastewater) and the agricultural land-use have been investigated. The implications resulting from GSG scenarios were evaluated and quantified using the integrated WEF model. The main finding are summarised as below:

- Water use for *irrigation* of cereal grains and household *hand wash basin tap usage* accounts for 25 and 15% of the total city demand, respectively.
- Around 50% of the total energy demand in the city is attributed to *space heating and cooling purposes*.
- Fortress World scenario causes the highest demand for WEF compared to the other GSG scenarios. However, *land-use* is the lowest due to low agricultural production in the city.
- The *water-related energy* (i.e., water treatment, pumping, water heating) accounts approximately 25% of the total city electricity consumption. Policy Reform and Great Transition scenarios achieve less water-related energy consumption in the city than Business as Usual and Market Force scenario.
- *Food-related water* (i.e., irrigation, food processing and cooking in a household) accounts approximately 40% of the total water demand in the city. However, it decreases in the Market Force and the Fortress World scenario due to the less use for agricultural land.
- Around 20% of the total city *energy* demand is *food-related* (i.e., pumping water for irrigation, food processing and cooking appliances). The energy demand for food preparation in Duhok households is higher in the Fortress World scenario than the other scenarios due to the higher population growth.
- The *domestic sector* dominates water and energy demand for the city during winter months. However, the proportion of water demand for *agricultural sector* is the highest during irrigation period in summer months.

10.2 Recommendations

This section suggests possible directions for future research to extend and improve the methodologies and the outcomes presented in this study. A considerable effort has been made to cover a wide range of important aspects in modelling and analysing water-energy-food at a household and city scale. However, during the research, certain parts of the planned research could not be carried out, because of time and resource constraints. A summary of the recommendations for future research is listed here:

- Investigate the other environmental impacts associated with abstraction, production, generation and distribution of water-energy-food, for example, greenhouse gas emissions.
- Apart from food waste within the consumption stage at a household level which has been addressed in this study, food waste in the other stages of food supply chain (production, processing and distribution) can be investigated.
- Although, the available water varies seasonally, the analysis of risk assessment and resilience quantification in this study was based on the annual total available water. In the future, risk and resilience of water system for providing per capita demand can be assessed based on the available water during each season (i.e., winter and summer). An integration of climate change models results with WEF models can provide more realistic estimation.
- Investigate fuel consumption and the related GHG emissions in transportation sector (e.g., importing food, exporting fuel and household activities).
- WEF consumption data collection is based on paper based questionnaire survey. It will be interesting to monitor the actual consumption.
- The developed WEF models have been applied for a situation in a developing country. It will be interesting to explore the developed models application using the consumption data for several developed countries.

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APPENDIX A: WATER, ENERGY AND FOOD SURVEY FORM (WINTER SURVEY)

Household Water, Energy and Food Consumption Survey (Duhok, Kurdistan Region, Iraq)

This survey is carried out as a part of a research project to collect and analyse the information on water use patterns in the residential areas of Duhok.

The information provided by you will be used anonymously and solely for educational purposes.

Please tick the relevant box.

Participant No. ……. **Date ……………………**

Demographic characteristics of household:

Gender	Male ……….	Female …….			
How many people live in your household?	1 ……..	2 ……..	3 ……..	4 ……..	Other ……..
How many children under 15 live in your household?	0 ……..	1 ……..	2 ……..	3 ……..	Other ……..
How many adult males (15- 65 years) live in your household?	0 ……..	1 ……..	2 ……..	3 ……..	Other ……..
How many adult females (15- 65 years) live in your household?	0 ……..	1 ……..	2 ……..	3 ……..	Other ……..
How many people above 65 years live in your household?					

Socio-economic characteristics of the household:

How many rooms are there in your household?	1 ……..	2 ……..	3 ……..	4 ……..	Other ……..
How many floors in your household?	1 ……..	2 ……..	3 ……..	Other ……..	
What is your household type?	House ……….	Apartment…..	Clay/cane …….	Other …….....	
What is the total area of all floors in m^2 of your household?	100-150 ……..	150-200 ……..	200-250 ……..	250-300 ……..	Other ……..
What is the garden area in m^2 of your household?	0 ……..	1-20 ……..	20-40 ……..	40-60 ……..	Other ……..
How much is your family income in Iraqi Dinar per month?	………………..… ID/month				

Water consumption survey of the household

1) Shower/bucket bath

How many showers do you take per week?	1 ……..	2 ……..	3 ……..	4 ……..	5 ……..	Other…..
How many minutes do you run the water for each shower?	<2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10 ……..	Other…..
How much is the shower flow rate in litres/minute?	…….. litres/minute					

2) Bath

How many baths do you take per week?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other …..
How much is the volume of water use for each bathing in litre?	1-40 ……..	40-80 …..	80-120 …..	120-160…..	160-200…..	Other …...

3) Bathroom taps (tooth brushing, hand and face washing, ablution, etc.)

How many times do you use a bathroom sink (tap) for washing per day?	<= 3 ……..	4 ……..	5 ……..	6 ……..	7 ……..	8 ……..	Other …..
How many seconds does water run in each use (e.g. hand and face washing)?	1-10 ……..	10-20 …..	20-30 …..	30-40 …..	40-50 …..	50-60 …..	Other …..
How much is the average flow rate of each tap use in litres/minute?	…….. litres/minute						

4) Toilet flushing

How many times a day do you use a toilet?	1 ……..	2 ……..	3 ……..	4 ……..	5 ……..	Other ….
How much is the volume of water use in each flush in litres?	……….. litres					

5) Dishwashing

Manually	How many times does your family wash dishes per day?	0 ……..	1 ……..	2 ……..	3 ……..	4 ……..	Other …..
	How many minutes does water run in each wash?	1-3 ……..	3-6 ……..	6-9 …..	9-12 …..	12-15 …..	Other …..
	How much is the flow rate of washing tap in litres/minute?	…….. litres/minute					
Machines	How often do you use a dishwasher per week?	N/A …..	0 ……..	1 ……..	2 ……..	3 ……..	Other …..
	What is the brand of dishwashing machine?						
	What is the model of dishwashing machine?						

6) Laundry

Manually	How many times a week do you hand wash clothes?	0 ……..	1 ……..	2 ……..	3 ……..	4 ……..	Other …..
	How many minutes does water run in each wash?	1-4 ……..	4-8 ……..	8-12 …..	12-16 …..	16-20 …..	Other …..
	How much is the flow rate of washing tap in litres/minute?	…….. litres/minute					
Machines	How many loads of laundry do you use per week?	N/A …..	0 ……..	1 ……..	2 ……..	3 ……..	Other …..
	What is the brand of clothes washing machine?						
	What is the model of clothes washing machine?						
	What is the capacity of each wash in kilogram?	…….. kilogram					

7) Garden watering

How many times a week do you water the garden?	N/A ……	0..........	1 ……….	2 ……….	3 ……….	Other....
How many minutes does the water run in each watering?	1-15 …..	15-30 …..	30-45 …..	45-60 …..	60-75 …..	Other....
How much is the flow rate in litres/minute for irrigating the garden?	…….. litres/minute					

8) Other water consumptions

House washing	How often do you hose your paths, garage, bathrooms, driveways/house per week?	0 ……….	1 ……….	2..........	3 ……….	4 ……….	Other …...
	How many minutes does the water run each time?	1-4 …..	4-8 …..	8-12 …..	12-16 …..	16-20 …..	Other …...
	How much is the flow rate in litres/minute for hosing paths, driveways or house?	…….. litres/minute					
Vehicle washing	How many cars are washed at your household per week?	0..........	1 ……….	2..........	3 ……….	4 ……….	Other …...
	How many minutes does water run for washing each car?	1-2 ……..	2-4 …..	4-6 …..	6-8 …..	8-10 …..	Other …...
	How much is the flow rate in litres/minute for washing car?	…….. litres/minute					
Swimming pool	How many times a year does your household replace water in a swimming pool?	N/A …….	0 …….	1 …….	2 …….	3 …….	Other …...
	How many m^3 of water are provided to fill the swimming pool?	……………….. m^3					

Energy consumption of the household

1) Space heating

Electrical heater	How many electrical heaters are in use in your household?	N/A …….	0 ……..	1 ……..	2 ……..	3 ……..	Other.…….
	How many hours on average is each electrical heater used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8……	8-10……	Other.…….
	How much is the wattage of each electrical heater (Watt)?						
Kerosene heater	How many kerosene heaters are in use in your household?	N/A …….	0 ……..	1 ……..	2 ……..	3 ……..	Other.…….
	How many hours on average is each kerosene heater used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8……	8-10……	Other.…….
	How many litres of kerosene are used by each heater per day?	1-2 ……..	2-3 ……..	3-4 ……..	4-5……	5-6……	Other.…….
Gas heater	How many gas heaters are in use in your household?	N/A …….	0 ……..	1 ……..	2 ……..	3 ……..	Other.…….
	How many days on average the gas bottle is last for using per gas heater?	…….. days					
Air conditioners	How many air-conditioners are in use in your household?	N/A …….	0 ……..	1 ……..	2 ……..	3 ……..	Other.…….
	How many hours on average is each air-conditioner used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8……	8-10……	Other.…….
	How much is the wattage of each air-conditioner (Watt)?						

2) Water heating

a) What type of water heater is in use in your household? (If the answer is **electrical water heater**, pass to the **section b**

Kerosene water heater ……..   Electrical water heater ……..

For kerosene water heater	How many kerosene water heaters are in use in your household?	1 ……..	2 ……..	3 ……..	Other.…….
	How many litres of kerosene are used by each heater per day?				

b) Heated water use in the household:

Do you use heated water for bath and showering?	Yes ……….	No ……….	Sometimes ……….
Do you use heated water for hand washing, tooth brushing and ablution?	Yes ……….	No ……….	Sometimes ……….
Do you use heated water for manually dishwashing?	Yes ……….	No ……….	Sometimes ……….
Do you use heated water for laundry from water heater?	Yes ……….	No ……….	Sometimes ……….
Do you use heated water for cooking from water heater?	Yes ……….	No ……….	Sometimes ……….

3) Cooking appliances

Electrical hob	How many electrical hobs are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many hours is each electrical hob used per day?	0-1 ……..	1-2 ……..	2-3 ……..	3-4 ……..	4-5 ……..	Other……..
	How much is the wattage of each electrical hob (Watt)?						
Electrical oven	How many electrical ovens are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many hours is each electrical oven used per week?	0-1 ……..	1-2 ……..	2-3 ……..	3-4 ……..	4-5 ……..	Other……..
	How much is the wattage of each electrical oven (Watt)?						
Electrical kettle	How many electrical kettles are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many minutes is each electrical kettle used per day?	0-5 ……..	5-10 ……..	10-15…...	15-20 …...	20-25 …...	Other……..
	How much is the wattage of each electrical kettle (Watt)?						
Microwave oven	How many microwave ovens are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many minutes is each microwave oven used per day?	0-5 ……..	5-10 ……..	10-15…...	15-20 …...	20-25 …...	Other……..
	How much is the wattage of each microwave oven (Watt)?						
Toaster	How many toasters are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many minutes is each toaster used per day?	0-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10 ……..	Other……..
	How much is the wattage of each toaster (Watt)?						
Gas hob	How many gas hobs are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many days the gas bottle is last for each gas hob?	……….. days					
Kerosene hob	How many kerosene hobs are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How much kerosene do you use for cooking for each kerosene hob?	……….. litres/day					

4) Refrigeration appliances

Chest freezer	How many chest-freezers are in use in your household?	N/A……..	0 ……..	1 ……..	2 ……..	3 ……..	Other..…..
	How much is the wattage of each chest-freezer (Watt)?						
Fridge-freezer	How many refrigerator-freezers are in use in your household?	N/A……..	0 ……..	1 ……..	2 ……..	3 ……..	Other..…..
	How much is the wattage of each fridge-freezer (Watt)?						

5) Lighting

Spot lights	How many spot lights are switched on per day in your household?	N/A…….	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	Other …..
	How many hours on average are these lights switched on?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10 …...	Other …..
Tube lights	How many tube lights are switched on per day in your household?	N/A…….	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	Other …..
	How many hours on average are these lights switched on?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10 …...	Other …..

6) Electronic appliances

TV	How many TVs are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other..……
	How many hours each TV is used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10……..	Other..……
	How much is the wattage of each TV (Watt)?						
Radio	How many radios are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other..……
	How many hours each radio is used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10……..	Other..……
	How much is the wattage of each radio (Watt)?						
Computer	How many computers are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other..……
	How many hours is each computer used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10……..	Other..……
	How much is the wattage of each computer (Watt)?						
Video cassette record	How many video records are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other..……
	How many hours is each video record used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10……..	Other..……
	How much is the wattage of each video record (Watt)?						
CD/DVD player	How many CD players are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other..……
	How many hours is each CD player used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10……..	Other..……
	How much is the wattage of each CD player (Watt)?						
Video games	How many play stations are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other..……
	How many hours is each play station used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10……..	Other..……
	How much is the wattage of each play station (Watt)?						

7) Wet appliances

Water pump	How many water pumps are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other....…
	How many hours on average is each pump used per week?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 …..	8-10 …..	Other....…
	How much is the wattage of each water pump (Watt)?						
Dishwasher	How many dishwashers are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other....…
	How many hours is each dishwasher used per week?	0-2 ……..	2-4 ……..	4-6 ……..	6-8…..	8-10 …..	Other....…
	How much is the wattage of each dishwasher (Watt)?						
Clothes washer	How many clothes washers are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other....…
	What type of clothes washer is in use in your household?	Top loader ………………			Front loader ………………		
	Does your clothes washer contain internal water heater?	Yes ………………			No ………………		
	Do you wash clothes in warm or cold mode?	Warm mode ………………			Cold mode ………………		

8) Miscellaneous appliances

Hair dryer	How many hair dryers are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other....….
	How many minutes is each hair dryer used per week?	1-10 ……..	10-20…….	20-30 …....	30-40 …....	40-50.......	Other....….
	How much is the wattage of each hair dryer (Watt)?						
Vacuum cleaner	How many vacuum cleaners are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other....….
	How many hours is each vacuum cleaner used per week?	0-1 ……..	1-2 ……..	2-3 ……..	3-4 ……..	4-5 ……..	Other....….
	How much is the wattage of each vacuum cleaner (Watt)?						
Sewing machine	How many sewing machines are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other....….
	How many hours is each sewing machine used per week?	0-1 ……..	1-2…….	2-3 …....	3-4 …....	4-5.......	Other....….
	How much is the wattage of each sewing machine (Watt)?						
Iron	How many irons are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other....….
	How many hours is each iron used per week?	0-1 ……..	1-2…….	2-3 …....	3-4 …....	4-5.......	Other....….
	How much is the wattage of each iron (Watt)?						

Food consumption of the household

1) Cereal grains and products (wheat flour, rice, burgul, jareesh, sameed, macaroni, vermicelli, buns, biscuits, etc.)

Cereals and products	wheat flour	rice	burgul & jareesh	macaroni & vermicelli	buns, cake & biscuits	other ………	other ………	other ………
How many times does your family cook each type of cereal grains and products per week?								
How many kilograms does your family consume of each type of cereal grains and products per week?								
How many litres of water are consumed in each cooking session (including washing) of each cereal and products type?								
How many minutes is a hob ring used in each cooking session of each cereal and products type?								
What type of fuel is used for cooking? choose one of these (LPG, electricity, kerosene)								

2) Meat (beef, lamb, chicken, turkey, fish, seafood, etc.)

Meat	sheep & goat	bovine	chicken & turkey	fish & seafood	other ………	other ………	other ………
How many times does your family cook each type of meat per week?							
How many kilograms does your family consume of each type of meat per week?							
How many litres of water are consumed in each cooking session (including washing) of each type of meat?							
How many minutes is a hob ring used in each cooking session of each type of meat?							
What type of fuel is used for cooking? choose one of these (LPG, electricity, kerosene)							

3) Vegetables and fruits (tomato, aubergine, courgette, celery, lettuce, cucumber, sweet pepper, cabbage, broccoli, other fresh-frozen and dried vegetables, water melon, apple, grape, orange, pumpkin, avocado, etc.)

Vegetables	tomato	aubergine	courgette	celery	lettuce	cucumber	sweet pepper	okra	other ………	other ………
How many times does your family cook/wash each type of vegetables per week?										
How many kilograms does your family consume of each type of vegetables per week?										
How many litres of water are consumed in each cooking session (including washing) of each type of vegetables?										
How many minutes is a hob ring used in each cooking session of each type of vegetables?										
What type of fuel is used for cooking? choose one of these (LPG, electricity, kerosene)										

Fruits	apple	orange	grape	water melon	melon	banana	pumpkin	other ………	other ………	other ………
How many times does your family wash each type of fruits per week?										
How many kilograms does your family consume of each type of fruits per week?										
How many litres of water are consumed in each washing session of each type of fruits?										

4) **Dairy** (yogurt, cheese, egg, milk, butter, etc.)

Dairy	yogurt	cheese	egg	milk	butter	other ………	other ………
How many times does your family cook each type of diary per week?							
How much is the consumed quantity of each dairy product by your family per week?	.... kg	.... kg	.... eggs	.... litres	.... kg		
How many litres of water are consumed in each cooking session of each type of dairy?							
How many minutes is a hob ring used in each cooking session of each type of dairy?							
What type of fuel is used for cooking? choose one of these (LPG, electricity, kerosene)							

5) **Roots and tubers** (potato, onion, carrots, radishes, garlic, etc.)

Roots and tubers	potato	onion	carrot	radish	garlic	other ………	other ………
How many times does your family cook/wash each type of roots and tubers per week?							
How many kilograms does your family consume of each type of roots and tubers per week?							
How many litres of water are consumed in each cooking session (including washing) of each type of roots and tubers?							
How many minutes is a hob ring used in each cooking session of each type of roots and tubers?							
What type of fuel is used for cooking? choose one of these (LPG, electricity, kerosene)							

6) Oils and fats (vegetable oil, animal fats, etc.)

Oils and fats	vegetable oil	animal fats	other ………	other ………	other ………
How many kilograms/litres does your family consume of each type of oils and fats per week?					

7) Oilseeds and pulses (chickpeas, lintels, beans, peas, etc.)

Oilseeds and pulses	chickpeas	lentils	bean	peas	other ………	other ………	other ………
How many times does your family cook each type of oilseeds and pulses per week?							
How many kilograms does your family consume of each type of oilseeds and pulses per week?							
How many litres of water are consumed in each cooking session (including washing) of each type of oilseeds and pulses?							
How many minutes is a hob ring used in each cooking session of each type of oilseeds and pulses?							
What type of fuel is used for cooking? choose one of these (LPG, electricity, kerosene)							

8) Sugar and products

Sugar and products	Sugar
How many kilograms does your family consume of sugar per week?	

WATER, ENERGY AND FOOD SURVEY FORM (SUMMER SURVEY)

Household Water, Energy and Food Consumption Survey (Duhok, Kurdistan Region, Iraq)

This survey is carried out as a part of a research project to collect and analyse the information on water use patterns in the residential areas of Duhok.

The information provided by you will be used anonymously and solely for educational purposes.

Please tick the relevant box.

Participant No. ……. **Date …………………….**

Demographic characteristics of household:

Gender	Male ……….	Female …….			
How many people live in your household?	1 ……..	2 ……..	3 ……..	4 ……..	Other ……..
How many children under 15 live in your household?	0 ……..	1 ……..	2 ……..	3 ……..	Other ……..
How many adult males (15- 65 years) live in your household?	0 ……..	1 ……..	2 ……..	3 ……..	Other ……..
How many adult females (15- 65 years) live in your household?	0 ……..	1 ……..	2 ……..	3 ……..	Other ……..
How many people above 65 years live in your household?					

Socio-economic characteristics of the household:

How many rooms are there in your household?	1 ……..	2 ……..	3 ……..	4 ……..	Other ……..
How many floors in your household?	1 ……..	2 ……..	3 ……..	Other ……..	
What is your household type?	House ….…….	Apartment…..	Clay/cane …....	Other …….....	
What is the total area of all floors in m^2 of your household?	100-150 ……..	150-200 ……..	200-250 ……..	250-300 ……..	Other ……..
What is the garden area in m^2 of your household?	0 ……..	1-20 ……..	20-40 ……..	40-60 ……..	Other ……..
How much is your family income in Iraqi Dinar per month?	…………….…. ID/month				

Water consumption survey of the household

1) Shower

How many showers do you take per week?	1 ……..	2 ……..	3 ……..	4 ……..	5 ……..	Other…..
How many minutes do you run the water for each shower?	<2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10 ……..	Other…..
How much is the shower flow rate in litres/minute?	…….. litres/minute					

2) Bath

How many baths do you take per week?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other …..
How much is the volume of water use for each bathing in litre?	1-40 ……..	40-80 …..	80-120 …..	120-160…..	160-200…..	Other …...

3) Bathroom sink (Tooth brushing, hand and face washing, ablution, etc.)

How many times do you use a bathroom sink (tap) for washing per day?	<= 3 ……..	4 ……..	5 ……..	6 ……..	7 ……..	8 ……..	Other …..
How many seconds does water run in each use (e.g. hand and face washing)?	1-10 ……..	10-20 …..	20-30 …..	30-40 …..	40-50 …..	50-60 …..	Other …..
How much is the average flow rate of each tap use in litres/minute?	…….. litres/minute						

4) Toilet flushing

How many times a day do you use a toilet?	1 ……..	2 ……..	3 ……..	4 ……..	5 ……..	Other ….
How much is the volume of water use in each flush in litres?	……….. litres					

5) Dishwashing

Manually	How many times does your family wash dishes per day?	0 ……..	1 ……..	2 ……..	3 ……..	4 ……..	Other …..
	How many minutes does water run in each wash?	1-3 ……..	3-6 ……..	6-9 …..	9-12 …..	12-15 …..	Other …..
	How much is the flow rate of washing tap in litres/minute?	…….. litres/minute					
Machines	How often do you use a dishwasher per week?	N/A …..	0 ……..	1 ……..	2 ……..	3 ……..	Other …..
	What is the brand of dishwashing machine?						
	What is the model of dishwashing machine?						

6) Laundry

Manually	How many times a week do you hand wash clothes?	0 ……..	1 ……..	2 ……..	3 ……..	4 ……..	Other …..
	How many minutes does water run in each wash?	1-4 ……..	4-8 ……..	8-12 …..	12-16 …..	16-20 …..	Other …..
	How much is the flow rate of washing tap in litres/minute?	…….. litres/minute					
Machines	How many loads of laundry do you use per week?	N/A …..	0 ……..	1 ……..	2 ……..	3 ……..	Other …..
	What is the brand of clothes washing machine?						
	What is the model of clothes washing machine?						
	What is the capacity of each wash in kilogram?	…….. kilogram					

7) Garden watering

How many times a week do you water the garden?	N/A ……	0..........	1 …….....	2 ….......	3 ….......	Other....
How many minutes does the water run in each watering?	1-15 …..	15-30 …..	30-45 …..	45-60 …..	60-75 …..	Other....
How much is the flow rate in litres/minute for irrigating the garden?	…….. litres/minute					

8) Other water consumptions

House washing	How often do you hose your paths, garage, bathrooms, driveways/house per week?	0 ……….	1 ……….	2..........	3 …….....	4 ….......	Other …...
	How many minutes does the water run each time?	1-4 …..	4-8 …..	8-12 …..	12-16 …..	16-20 …..	Other …...
	How much is the flow rate in litres/minute for hosing paths, driveways or house?	…….. litres/minute					
Vehicle washing	How many cars are washed at your household per week?	0..........	1 ……….	2..........	3 …….....	4 ….......	Other …...
	How many minutes does water run for washing each car?	1-2 ……..	2-4 …..	4-6 …..	6-8 …..	8-10 …..	Other …...
	How much is the flow rate in litres/minute for washing car?	…….. litres/minute					
Swimming pool	How many times a year does your household replace water in a swimming pool?	N/A …….	0 …….	1 …….	2 …….	3 …….	Other …...
	How many m^3 of water are provided to fill the swimming pool?	……………….. m^3					

Energy consumption of the household

1) Space cooling

Fan	How many fans are in use in your household?	N/A …....	0 ……..	1 ……..	2 ……..	3 ……..	Other..……
	How many hours on average is each fan used per day?	1-4 ……..	4-8 ……..	8-12 ……..	12-16…...	16-20…...	20-24..……
	How much is the wattage of each fan (Watt)?						
Evaporative air-cooler	How many air-coolers are in use in your household?	N/A …....	0 ……..	1 ……..	2 ……..	3 ……..	Other..……
	How many hours on average is each air-cooler used per day?	1-4 ……..	4-8 ……..	8-12 ……..	12-16…...	16-20…...	20-24..……
	How much is the wattage of each air-cooler (Watt)?	1-2 ……..	2-3 ……..	3-4 ……..	4-5…...	5-6…...	Other..……
	How much is the water consumption in litres of each air-cooler per day?	1-10 …….	10-20 ……	20-30 ……	30-40 ……	40-50 ……	Other..……
Air conditioners	How many air-conditioners are in use in your household?	N/A …....	0 ……..	1 ……..	2 ……..	3 ……..	Other..……
	How many hours on average is each air-conditioner used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8…...	8-10…...	Other..……
	How much is the wattage of each air-conditioner (Watt)?						

2) Water heating

a) What type of water heater is in use in your household? (If the answer is **electrical water heater**, pass to the **section b**

Kerosene water heater ……..   Electrical water heater ……..

For kerosene water heater	How many kerosene water heaters are in use in your household?	1 ……..	2 ……..	3 ……..	Other..……
	How many litres of kerosene are used by each heater per day?				

b) Heated water use in the household:

Do you use heated water for bath and showering?	Yes ……….	No ……….	Sometimes ……….
Do you use heated water for hand washing, tooth brushing and ablution?	Yes ……….	No ……….	Sometimes ……….
Do you use heated water for manually dishwashing?	Yes ……….	No ……….	Sometimes ……….
Do you use heated water for laundry from water heater?	Yes ……….	No ……….	Sometimes ……….
Do you use heated water for cooking from water heater?	Yes ……….	No ……….	Sometimes ……….

3) Cooking appliances

Electrical hob	How many electrical hobs are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many hours is each electrical hob used per day?	0-1 ……..	1-2 ……..	2-3 ……..	3-4 ……..	4-5 ……..	Other……..
	How much is the wattage of each electrical hob (Watt)?						
Electrical oven	How many electrical ovens are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many hours is each electrical oven used per week?	0-1 ……..	1-2 ……..	2-3 ……..	3-4 ……..	4-5 ……..	Other……..
	How much is the wattage of each electrical oven (Watt)?						
Electrical kettle	How many electrical kettles are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many minutes is each electrical kettle used per day?	0-5 ……..	5-10 ……..	10-15…...	15-20 …...	20-25 …...	Other……..
	How much is the wattage of each electrical kettle (Watt)?						
Microwave oven	How many microwave ovens are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many minutes is each microwave oven used per day?	0-5 ……..	5-10 ……..	10-15…...	15-20 …...	20-25 …...	Other……..
	How much is the wattage of each microwave oven (Watt)?						
Toaster	How many toasters are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many minutes is each toaster used per day?	0-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10 ……..	Other……..
	How much is the wattage of each toaster (Watt)?						
Gas hob	How many gas hobs are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many days the gas bottle is last for each gas hob?	……….. days					
Kerosene hob	How many kerosene hobs are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How much kerosene do you use for cooking for each kerosene hob?	……….. litres per day					

4) Refrigeration appliances

Chest freezer	How many chest-freezers are in use in your household?	N/A……..	0 ……..	1 ……..	2 ……..	3 ……..	Other…….
	How much is the wattage of each chest-freezer (Watt)?						
Fridge-freezer	How many refrigerator-freezers are in use in your household?	N/A……..	0 ……..	1 ……..	2 ……..	3 ……..	Other…….
	How much is the wattage of each fridge-freezer (Watt)?						

5) Lighting

Spot lights	How many spot lights are switched on per day in your household?	N/A…….	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	Other …..
	How many hours on average are these lights switched on?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10 …...	Other …..
Tube lights	How many tube lights are switched on per day in your household?	N/A…….	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	Other …..
	How many hours on average are these lights switched on?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10 …...	Other …..

6) Electronic appliances

TV	How many TVs are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many hours each TV is used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10……..	Other……..
	How much is the wattage of each TV (Watt)?						
Radio	How many radios are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many hours each radio is used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10……..	Other……..
	How much is the wattage of each radio (Watt)?						
Computer	How many computers are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many hours is each computer used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10……..	Other……..
	How much is the wattage of each computer (Watt)?						
Video cassette record	How many video records are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many hours is each video record used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10……..	Other……..
	How much is the wattage of each video record (Watt)?						
CD/DVD player	How many CD players are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many hours is each CD player used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10……..	Other……..
	How much is the wattage of each CD player (Watt)?						
Video games	How many play stations are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many hours is each play station used per day?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 ……..	8-10……..	Other……..
	How much is the wattage of each play station (Watt)?						

7) Wet appliances

Water pump	How many water pumps are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other…….
	How many hours on average is each pump used per week?	1-2 ……..	2-4 ……..	4-6 ……..	6-8 …..	8-10 …..	Other…….
	How much is the wattage of each water pump (Watt)?						
Dishwasher	How many dishwashers are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other…….
	How many hours is each dishwasher used per week?	0-2 ……..	2-4 ……..	4-6 ……..	6-8…..	8-10 …..	Other…….
	How much is the wattage of each dishwasher (Watt)?						
Clothes washer	How many clothes washers are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other…….
	What type of clothes washer is in use in your household?	Top loader ………………			Front loader ………………		
	Does your clothes washer contain internal water heater?	Yes ………………			No ………………		
	Do you wash clothes in warm or cold mode?	Warm mode ………………			Cold mode ………………		

8) Miscellaneous appliances

Hair dryer	How many hair dryers are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many minutes is each hair dryer used per week?	1-10 ……..	10-20…….	20-30 …….	30-40 …….	40-50…….	Other……..
	How much is the wattage of each hair dryer (Watt)?						
Vacuum cleaner	How many vacuum cleaners are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many hours is each vacuum cleaner used per week?	0-1 ……..	1-2 ……..	2-3 ……..	3-4 ……..	4-5 ……..	Other……..
	How much is the wattage of each vacuum cleaner (Watt)?						
Sewing machine	How many sewing machines are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many hours is each sewing machine used per week?	0-1 ……..	1-2…….	2-3 …….	3-4 …….	4-5…….	Other……..
	How much is the wattage of each sewing machine (Watt)?						
Iron	How many irons are in use in your household?	N/A ……..	0 ……..	1 ……..	2 ……..	3 ……..	Other……..
	How many hours is each iron used per week?	0-1 ……..	1-2…….	2-3 …….	3-4 …….	4-5…….	Other……..
	How much is the wattage of each iron (Watt)?						

Food consumption of the household

1) Cereal grains and products (wheat flour, rice, burgul, jareesh, sameed, macaroni, vermicelli, buns, biscuits, etc.)

Cereals and products	wheat flour	rice	burgul & jareesh	macaroni & vermicelli	buns, cake & biscuits	other ………	other ………	other ………
How many times does your family cook each type of cereal grains and products per week?								
How many kilograms does your family consume of each type of cereal grains and products per week?								
How many litres of water are consumed in each cooking session (including washing) of each cereal and products type?								
How many minutes is a hob ring used in each cooking session of each cereal and products type?								
What type of fuel is used for cooking? choose one of these (LPG, electricity, kerosene)								

2) Meat (beef, lamb, chicken, turkey, fish, seafood, etc.)

Meat	sheep & goat	bovine	chicken & turkey	fish & seafood	other ………	other ………	other ………
How many times does your family cook each type of meat per week?							
How many kilograms does your family consume of each type of meat per week?							
How many litres of water are consumed in each cooking session (including washing) of each type of meat?							
How many minutes is a hob ring used in each cooking session of each type of meat?							
What type of fuel is used for cooking? choose one of these (LPG, electricity, kerosene)							

3) Vegetables and fruits (tomato, aubergine, courgette, celery, lettuce, cucumber, sweet pepper, cabbage, broccoli, other fresh-frozen and dried vegetables, water melon, apple, grape, orange, pumpkin, avocado, etc.)

Vegetables	tomato	aubergine	courgette	celery	lettuce	cucumber	sweet pepper	okra	other ………	other ………
How many times does your family cook/wash each type of vegetables per week?										
How many kilograms does your family consume of each type of vegetables per week?										
How many litres of water are consumed in each cooking session (including washing) of each type of vegetables?										
How many minutes is a hob ring used in each cooking session of each type of vegetables?										
What type of fuel is used for cooking? choose one of these (LPG, electricity, kerosene)										

Fruits	apple	orange	grape	water melon	melon	banana	pumpkin	other ………	other ………	other ………
How many times does your family wash each type of fruits per week?										
How many kilograms does your family consume of each type of fruits per week?										
How many litres of water are consumed in each washing session of each type of fruits?										

4) Dairy (yogurt, cheese, egg, milk, butter, etc.)

Dairy	yogurt	cheese	egg	milk	butter	other ………	other ………
How many times does your family cook each type of diary per week?							
How much is the consumed quantity of each dairy product by your family per week?	.... kg	.... kg	.... eggs	.... litres	.... kg		
How many litres of water are consumed in each cooking session of each type of dairy?							
How many minutes is a hob ring used in each cooking session of each type of dairy?							
What type of fuel is used for cooking? choose one of these (LPG, electricity, kerosene)							

5) Roots and tubers (potato, onion, carrots, radishes, garlic, etc.)

Roots and tubers	potato	onion	carrot	radish	garlic	other ………	other ………
How many times does your family cook/wash each type of roots and tubers per week?							
How many kilograms does your family consume of each type of roots and tubers per week?							
How many litres of water are consumed in each cooking session (including washing) of each type of roots and tubers?							
How many minutes is a hob ring used in each cooking session of each type of roots and tubers?							
What type of fuel is used for cooking? choose one of these (LPG, electricity, kerosene)							

6) Oils and fats (vegetable oil, animal fats, etc.)

Oils and fats	vegetable oil	animal fats	other ………	other ………	other ………
How many kilograms/litres does your family consume of each type of oils and fats per week?					

7) Oilseeds and pulses (chickpeas, lintels, beans, peas, etc.)

Oilseeds and pulses	chickpeas	lentils	bean	peas	other ………	other ………	other ………
How many times does your family cook each type of oilseeds and pulses per week?							
How many kilograms does your family consume of each type of oilseeds and pulses per week?							
How many litres of water are consumed in each cooking session (including washing) of each type of oilseeds and pulses?							
How many minutes is a hob ring used in each cooking session of each type of oilseeds and pulses?							
What type of fuel is used for cooking? choose one of these (LPG, electricity, kerosene)							

8) Sugar and products

Sugar and products	Sugar
How many kilograms does your family consume of sugar per week?	

APPENDIX B: HOUSEHOLD CHARACTERISTICS ANALYSIS

Appendix B1: Frequency Distribution of Household Characteristics

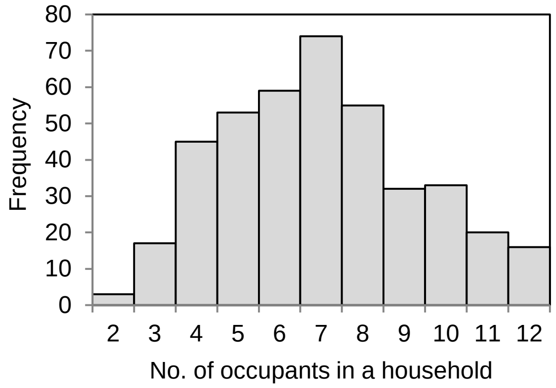

Figure B1.1 Frequency distribution of number of occupants in a household

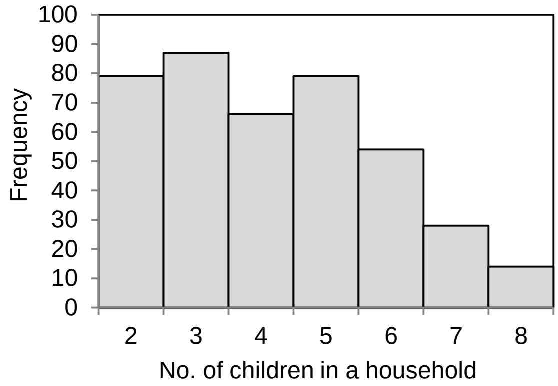

Figure B1.2. Frequency distribution of number of children in a household

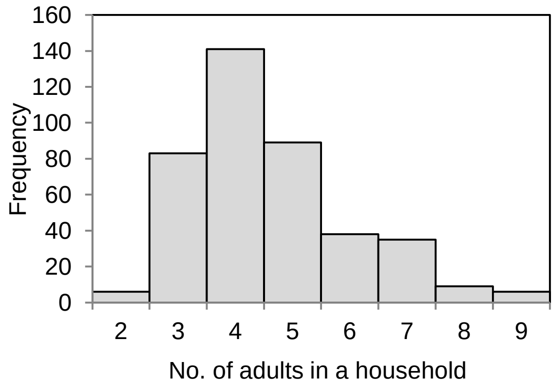

Figure B1.3 Frequency distribution of number of adults in a household

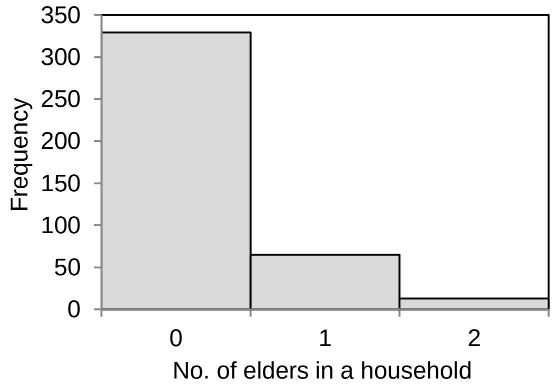

Figure B1.4 Frequency distribution of number of elders in a household

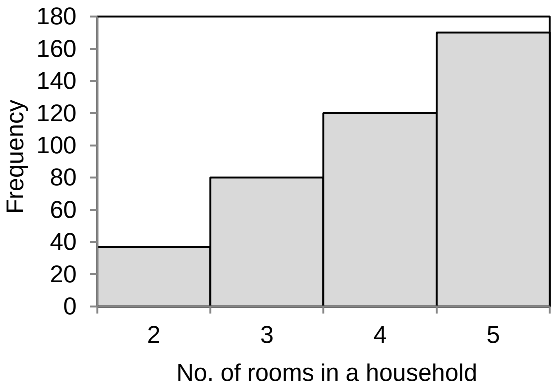

Figure B1.5 Frequency distribution of number of room in a household

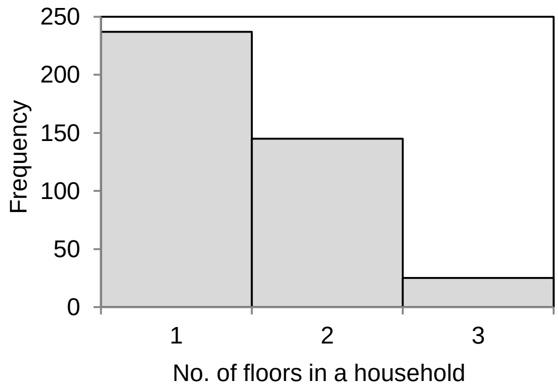

Figure B1.6 Frequency distribution of number of floors in a household

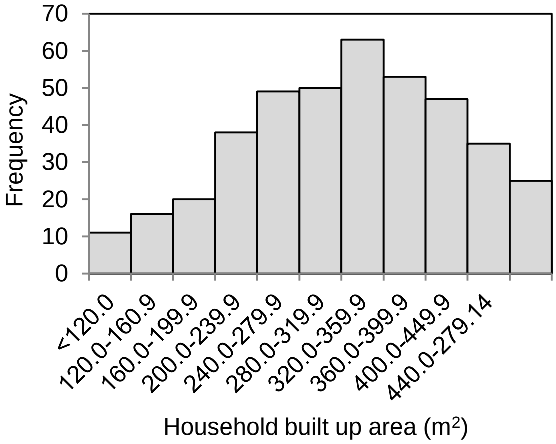

Figure B1.7 Frequency distribution of a household built up area

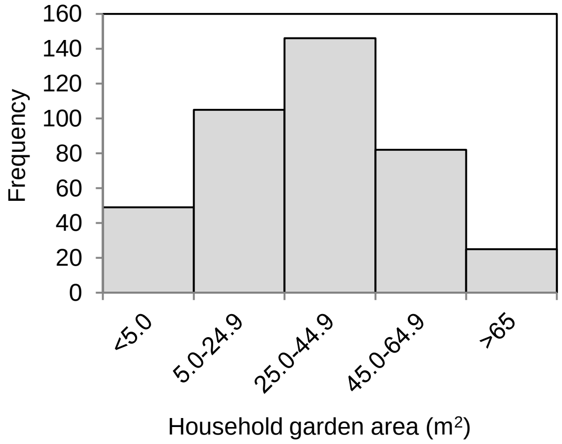

Figure B1.8 Frequency distribution of a household garden area

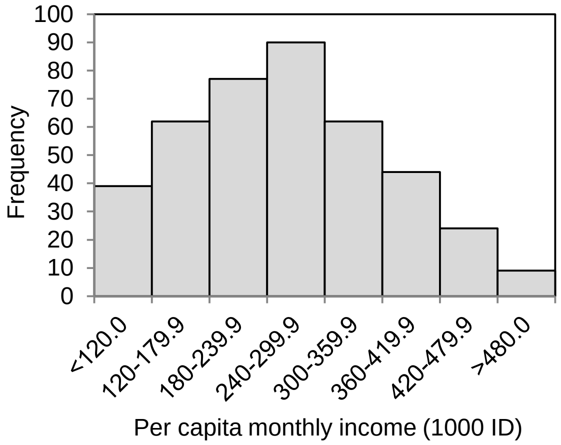

Figure B1.9 Frequency distribution of per capita monthly income

Appendix B2: Statistical Parameters of Household Characteristics in Low, Medium and High Income Groups

Table B2.1 Summary of average values for household characteristics in different income groups

Household characteristics	Unit	All surveyed households		Low income		Medium income		High income	
Gender		Male (63.1%)	Female (36.9%)	Male (63.0%)	Female (37.0%)	Male (60.8%)	Female (39.2%)	Male (66.2%)	Female (33.8%)
Household size (occupancy)	No./hh	7.04		4.82		7.10		8.45	
Number of children (<15 years)		2.22		1.45		2.63		2.22	
Number of adult females members (15-65 years)		2.33		1.25		2.37		2.99	
Number of adult males members (15-65 years)		2.27		1.93		1.94		2.90	
Number of elders (>65 years)		0.22		0.18		0.15		0.34	
No. of rooms in the household		4.19		2.60		4.09		5.37	
No. of floors in the household		1.48		1.00		1.23		2.12	
Household type		Houses (91.9%)	Apartment (8.9%)	Houses (65.2%)	Apartment (34.8%)	Houses (99.4%)	Apartment (0.6%)	Houses (100%)	Apartment (0%)
Total built up area of all floors	m^2/hh	314.56		164.95		301.70		429.86	
Garden area per household	m^2/hh	29.56		9.35		22.56		51.80	
Monthly family income per household	ID/mon	1,851,270		565,380		1,476,432		3,176,964	

Note: hh = household, ID = Iraqi Dinar (1000 ID ≈ £ 0.5)

Table B2.2 Summary of statistical parameters of household characteristics in whole survey sample

Household characteristics	Unit	Mean	Median	Std. deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Gender		Male (63.1%) , Female (36.9%)								
Household size (occupancy)	No./hh	7.04	7.00	2.35	5.53	2	13	0.24	-0.55	0.23
Number of children (< 15 years)	No./hh	2.22	2.00	1.74	3.02	0	7	0.53	-0.35	0.17
Number of adult females members (15-65 years)	No./hh	2.33	2.00	1.01	1.02	1	5	0.45	-0.72	0.09
Number of adult males members (15-65 years)	No./hh	2.27	2.00	1.07	1.15	0	5	-0.13	0.24	0.10
Number of elders (>65 years)	No./hh	0.22	0.00	0.49	0.24	0	2	2.12	3.77	0.05
Number of rooms in the household	No./hh	4.19	4.00	1.18	1.39	2	6	-0.16	-0.82	0.11
Number of floors in the household	No./hh	1.48	1.00	0.61	0.37	1	3	0.89	-0.21	0.06
Household type		Houses (91.9%) , Apartments (8.1%)								
No. of houses and apartments		Houses (374) , Apartments (33)								
Total built up area of all floors	m^2/hh	314.6	325.00	114.50	13141.9	100	500	-0.10	-1.03	11.17
Garden area per household	m^2/hh	29.56	30.00	24.38	594.4	0.0	100	1.26	1.81	2.38
Monthly per capita income	1000 ID/mon	252.50	231.00	110.17	12136.4	80.00	530.00	0.44	-0.88	10.73
Monthly family income		1851.27	1561.00	1087.63	1182935	254.00	4784.00	0.50	-0.90	105.98

Note: hh = household, ID = Iraqi Dinar (1000 ID ≈ £ 0.5)

Table B2.3 Summary of statistical parameters of household characteristics in low income group

Household characteristics	Unit	Mean	Median	Std. deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Gender		Male (63.0%) , Female (37.0%)								
Household size (occupancy)	No./hh	4.82	5.00	1.37	1.87	2	9	0.00	-0.25	0.28
Number of children (<15 years)	No./hh	1.45	1.00	1.17	1.37	0	4	0.32	-0.97	0.24
Number of adult females members (15-65 years)	No./hh	1.25	1.00	0.44	0.19	1.00	2.00	1.17	-0.64	0.09
Number of adult males members (15-65 years)	No./hh	1.93	2.00	0.25	0.06	1.00	2.00	-3.58	11.06	0.05
Number of elders (>65 years)	No./hh	0.18	0.00	0.44	0.20	0	2	2.39	5.29	0.09
Number of rooms in the household	No./hh	2.60	3.00	0.49	0.24	2	3	-0.41	-1.88	0.10
Number of floors in the household	No./hh	1.00	1.00	0.00	0.00	1	1	0	0	0
Household type		Houses (65.2%) , Apartment (34.8%)								
No. of houses and apartments		Houses (60) , Apartment (32)								
Total built up area of all floors	m^2/hh	164.95	175.00	44.17	1951.37	100	225	0.07	-1.33	9.15
Garden area per household	m^2/hh	9.35	0.00	12.03	144.62	0	30	0.94	-0.75	2.49
Monthly per capita income	1000 ID/mon	120.47	121.50	15.82	250.38	80.00	149.00	-0.04	-0.65	3.28
Monthly family income		565.38	588.00	127.03	16137.69	254.00	954.00	-0.10	0.22	26.31

Note: hh = household, ID = Iraqi Dinar (1000 ID ≈ £ 0.5)

Table B2.4 Summary of statistical parameters of household characteristics in medium income group

Household characteristics	Unit	Mean	Median	Std. deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Gender		Male (60.8%) , Female (39.2%)								
Household size (occupancy)	No./hh	7.10	7.00	2.15	4.60	4	12	0.33	-0.56	0.32
Number of children (<15 years)	No./hh	2.63	3.00	1.91	3.66	0	7	0.17	-0.90	0.28
Number of adult females members (15-65 years)	No./hh	2.37	2.00	0.90	0.82	1.00	4.00	0.80	-0.36	0.13
Number of adult males members (15-65years)	No./hh	1.94	2.00	1.03	1.07	0.00	4.00	-0.54	0.19	0.15
Number of elders (>65 years)	No./hh	0.15	0.00	0.39	0.15	0	2	2.50	5.77	0.06
Number of rooms in the household	No./hh	4.09	4.00	0.60	0.36	3	5	-0.04	-0.26	0.09
Number of floors in the household	No./hh	1.23	1.00	0.42	0.18	1	2	1.31	-0.28	0.06
Household type		Houses (99.4%) , Apartment (0.6%)								
No. of houses and apartments		Houses (175) , Apartment (1)								
Total built up area of all floors	m^2/hh	301.70	275.00	66.53	4425.65	175	425	-0.02	-0.42	9.90
Garden area per household	m^2/hh	22.56	30.00	12.82	164.28	0	50	0.48	-0.65	1.91
Monthly per capita income	1000 ID/mon	216.85	214.50	37.53	1408.62	150.00	294.00	0.13	-0.81	5.58
Monthly family income		1476.43	1441.00	306.84	94150.27	964.00	2484.00	0.58	0.04	45.65

Note: hh = household, ID = Iraqi Dinar (1000 ID ≈ £ 0.5)

Table B2.5 Summary of statistical parameters of household characteristics in high income group

Household characteristics	Unit	Mean	Median	Std. deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Gender		Male (66.2%) , Female (33.8%)								
Household size (occupancy)	No./hh	8.45	8	1.98	3.90	3	13	0.05	-0.16	0.69
Number of children (<15 years)	No./hh	2.22	2	1.65	2.72	0	7	0.66	0.21	0.59
Number of adult females members (15-65 years)	No./hh	2.99	3.00	0.79	0.63	2.00	5.00	0.28	-0.71	0.133
Number of adult males members (15-65 years)	No./hh	2.90	3.00	1.17	1.37	0.00	5.00	-0.69	-0.15	0.196
Number of elders (>65 years)	No./hh	0.34	0	0.60	0.36	0	2	1.59	1.45	0.17
Number of rooms in the household	No./hh	5.37	5	0.60	0.36	4	6	-0.37	-0.65	0.22
Number of floors in the household	No./hh	2.12	2	0.48	0.23	1	3	0.31	1.01	0.17
Household type		Houses (100%) , Apartment (0%)								
No. of houses and apartments		Houses (139) , Apartment (0)								
Total built up area of all floors	m^2/hh	429.86	425	56.94	3241.65	275	500	-0.50	-0.51	21.15
Garden area per household	m^2/hh	51.80	50	24.74	611.96	10	100	1.03	0.05	8.16
Monthly per capita income	1000 ID/mon	385.02	382.00	53.12	2821.93	300.00	530.00	0.55	-0.03	8.91
Monthly family income		3176.96	3176.00	546.32	298460.6	1470.00	4784.00	0.02	0.11	91.62

Note: hh = household, ID = Iraqi Dinar (1000 ID ≈ £ 0.5)

APPENDIX C: WATER CONSUMPTION ANALYSIS

Appendix C1 Relationships between Total Household Water Consumption and Characteristics

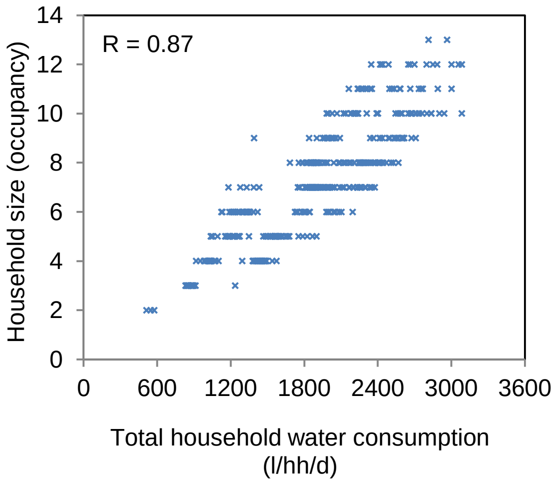

Figure C1.1 Relationship between household total average water consumption and household occupancy

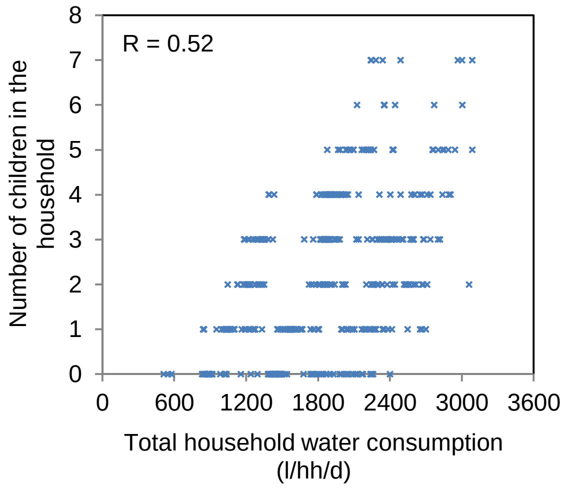

Figure C1.2 Relationship between household total average water consumption and number of children in the household

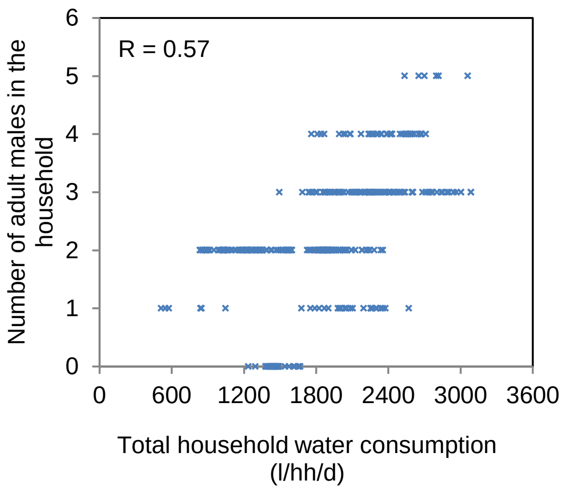

Figure C1.3 Relationship between household total average water consumption and number of adult males in the household

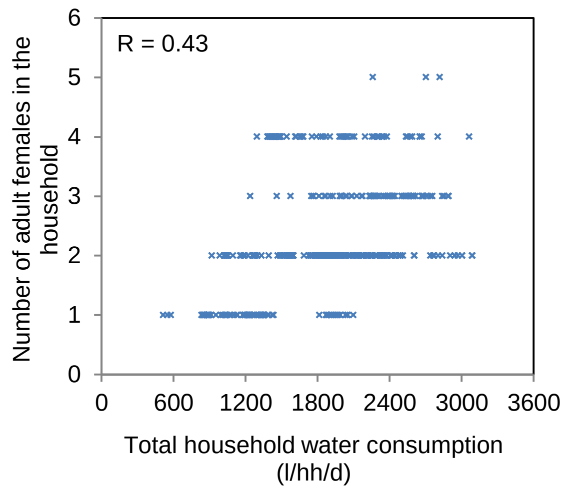

Figure C1.4 Relationship between household total average water consumption and number of adult females in the household

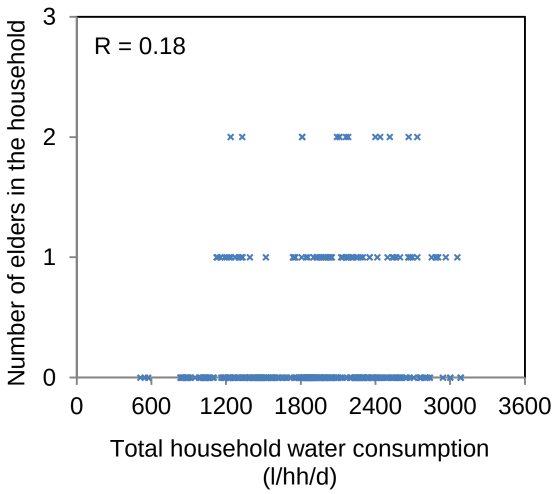

Figure C1.5 Relationship between household total average water consumption and number of elders in the household

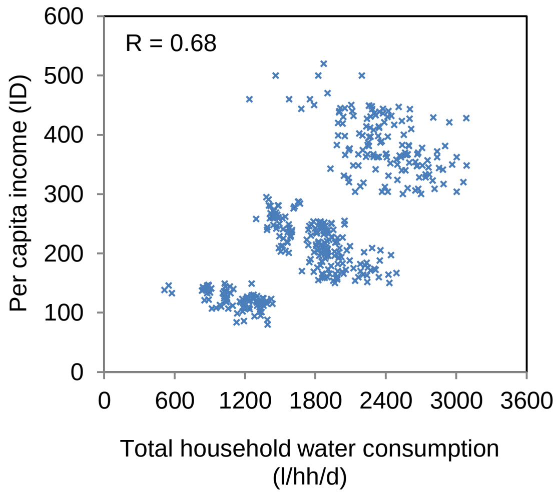

Figure C1.6 Relationship between household total average water consumption and per capita monthly income

Appendix C2 Relationships between Daily per Capita Average Water Consumption and Household Characteristics

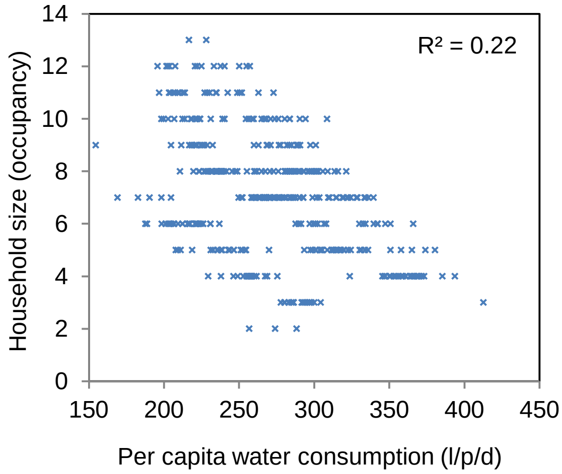

Figure C2.1 Relationship between daily per capita average water consumption and household occupancy

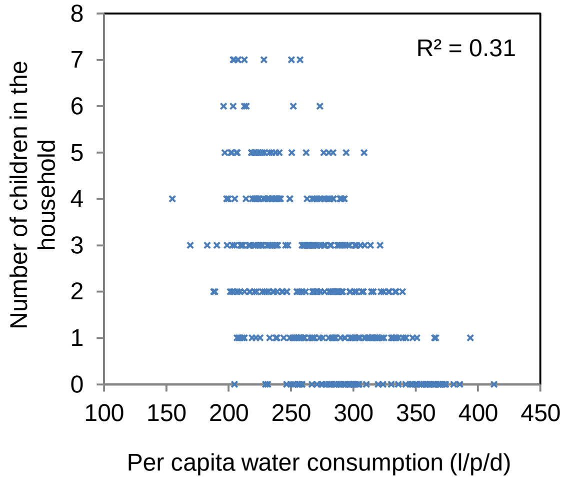

Figure C2.2 Relationship between daily per capita average water consumption and number of children in the household

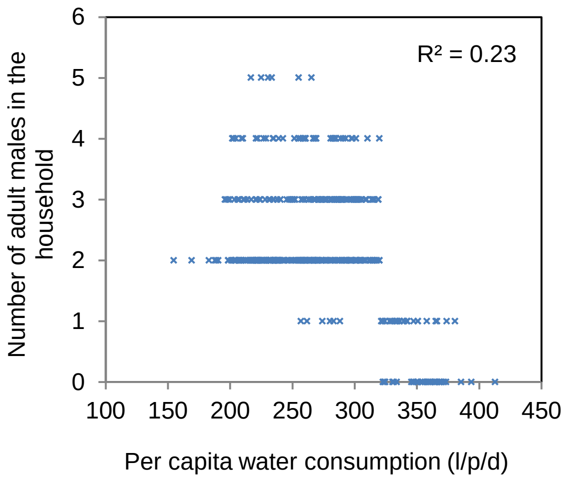

Figure C2.3 Relationship between daily per capita average water consumption and number of adult males in the household

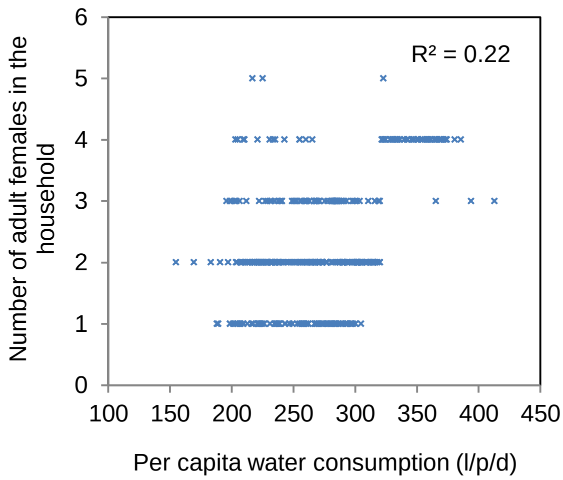

Figure C2.4 Relationship between daily per capita average water consumption and number of adult females in the household

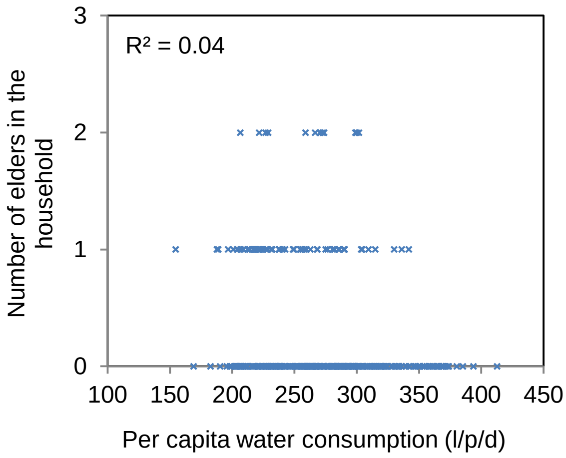

Figure C2.5 Relationship between daily per capita average water consumption and number of elders in the household

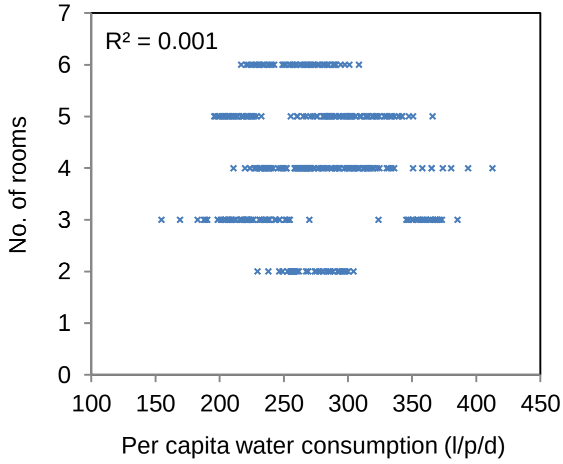

Figure C2.6 Relationship between daily per capita average water consumption and number of rooms in the household

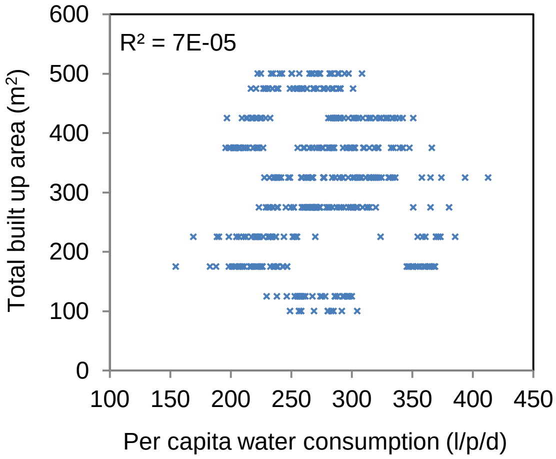

Figure C2.7 Relationship between daily per capita average water consumption and total built up area

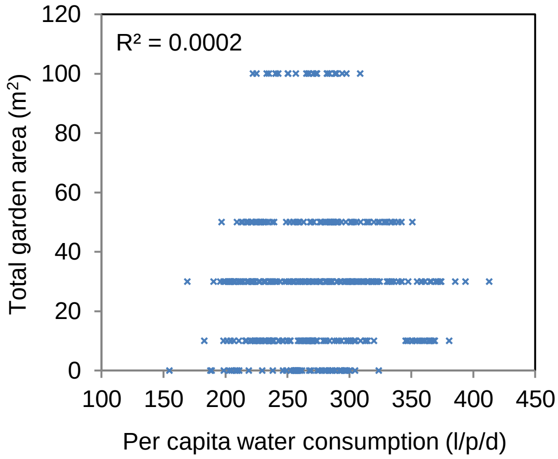

Figure C2.8 Relationship between daily per capita average water consumption and total garden area

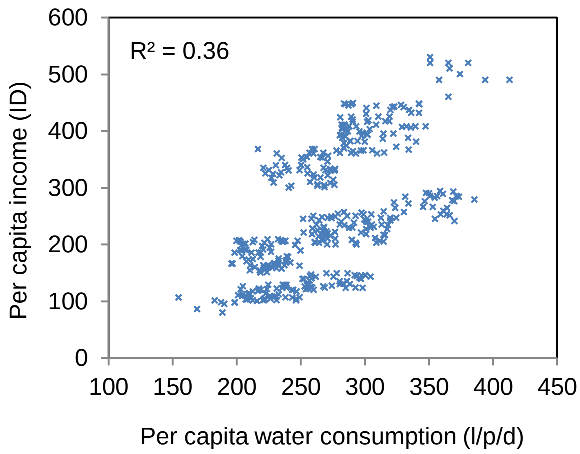

Figure C2.9 Relationship between daily per capita average water consumption and per capita income

Appendix C3 Statistical Parameters of Water End-Uses in Low, Medium and High Income Household Groups

Table C3.1 Summary of water end-uses parameters for <u>all surveyed households</u> (407 households) in <u>winter season</u>

End-use	Parameters	Unit	Mean	Median	Std. deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Bath	Frequency of taking bath per capita per day	bt/p/d	0.004	0.00	0.02	0.00	0.00	0.14	6.16	36.18	0.002
	Volume of water use in each bath	l/bt	132.00	0.00	20.80	432.81	0.00	180.00	6.48	41.52	2.03
Shower	Frequency of showering per capita per day	shw/p/d	0.488	0.428	0.158	0.025	0.29	0.86	0.468	-0.479	0.016
	Duration of each shower	min/shw	8.64	9.00	0.77	0.60	7.00	9.00	-1.66	0.75	0.08
	Flow rate	l/min	9.02	8.97	0.84	0.70	7.00	10.94	-0.07	-0.25	0.08
Hand wash basin taps	Frequency of using taps per capita per day	tpu/p/d	10.46	10.00	1.04	1.08	8.00	14.00	0.48	0.60	0.10
	Duration of tap use	min/tpu (sec/tpu)	1.01 (60.81)	1.00 (60.00)	0.06 (3.66)	0.00 (13.41)	0.88 (15)	1.13 (68)	-0.26 (-0.32)	-0.52 (-0.56)	0.006 (0.36)
	Flow rate	l/min	8.14	8.18	0.77	0.60	6.51	9.49	-0.14	-1.11	0.08
Toilet	Frequency of toilet use per capita per day	fl/p/d	4.65	5.00	0.89	0.80	3.00	6.00	-0.31	-0.62	0.09
	Water use in each flush	l/fl	5.51	5.00	1.05	1.11	5.00	9.00	1.71	1.31	0.10
Dish washing	Frequency of washing dishes per day	wsh/d	3.00	3.00	0.00	0.00	3.00	3.00	0.00	0.00	0.00
	Duration of running water in each wash	min/p/wsh	1.47	1.50	0.36	0.13	0.72	2.25	-0.05	-0.40	0.035
	Flow rate	l/min	8.36	7.87	1.50	2.25	6.27	11.58	0.78	-0.72	0.21
Laundry	Frequency of laundry per day	wsh/d	1.48	1.43	0.53	0.28	0.29	2.71	0.02	-0.48	0.05
	Volume of water per washing cycle	l/wsl	167.32	165.00	34.59	1196.31	123	387	3.52	15.01	4.10
House washing	Frequency of house washing per day	wsh/d	0.69	0.71	0.13	0.02	0.00	1.00	0.17	0.48	0.01
	Duration of each wash	min/wsh	2.13	2.00	0.44	0.20	1.11	4.67	0.70	2.00	0.064
	Flow rate	l/min	9.80	9.67	1.81	3.27	6.51	14.96	0.56	-0.03	0.22
Vehicle washing	Frequency of vehicles washing per day	wsh/d	0.07	0.00	0.08	0.01	0.00	0.00	0.40	-1.07	0.01
	Duration of each wash	min/wsh	1.39	1.25	0.67	0.44	0.45	3.75	1.59	2.83	0.085
	Flow rate	l/min	12.82	12.81	1.77	3.14	8.71	15.86	-0.52	-0.04	0.25

Note: l=liter, p=person, d=day, min=minute, sec=second, bt=bath, shw=shower, tpu=tap use, fl=flushes, wsh=washes, wsl=washing load, wtr=watering

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Table C3.1 Summary of water end-uses parameters for all surveyed households (407 households) in winter season

End-use	Parameters	Unit	Mean	Median	Std. deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Swimming pool	Frequency of filling swimming pool per day	No./d	0.001	0.00	0.01	0.00	0.00	0.00	14.21	200.98	0.005
	Volume of water provided to fill the swimming pool	m^3	36.00	36.00	5.66	32.00	32.00	40.00	0.00	0.00	50.82
Garden watering	Frequency of garden watering per day	wtr/d	0.13	0.14	0.05	0.00	0.00	0.14	-2.34	3.50	0.0010
	Duration of each watering	min/wtr	13.01	12.00	3.80	14.46	0.00	30.00	0.59	0.81	0.558
	Flow rate	l/min	11.67	11.65	1.82	3.30	8.08	14.96	-0.06	-1.01	1.76
Cooking	Daily water consumption for cooking per person	l/p/d	13.66	13.61	2.76	7.60	9.00	21.00	0.60	-0.49	0.269

Note: l=liter, p=person, d=day, min=minute, sec=second, bt=bath, shw=shower, tpu=tap use, fl=flushes, wsh=washes, wsl=washing load, wtr=watering

Table C3.2 Summary of water end-uses parameters for low income households in winter season

End-use	Parameters	Unit	Mean	Median	Std. deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Bath	Frequency of taking bath per capita per day	bt/p/d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Volume of water use in each bath	l/bt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28
Shower	Frequency of showering per capita per day	shw/p/d	0.34	0.29	0.07	0.00	0.29	0.43	0.41	-1.88	0.01
	Duration of each shower	min/shw	8.87	9.00	0.50	0.25	7.00	9.00	-3.58	11.06	0.09
	Flow rate	l/min	9.48	9.44	0.79	0.63	8.11	10.94	0.25	-0.87	0.10
Hand wash basin taps	Frequency of using taps per capita per day	tpu/p/d	9.96	10.00	0.90	0.81	8.00	11.00	-0.28	-1.00	0.00
	Duration of tap use	min/tpu (sec/tpu)	0.97 (58.31)	0.99 (59.44)	0.04 (2.73)	0.00 (7.44)	0.88 (15)	1.04 (63)	-0.60 (-0.61)	-0.48 (-0.43)	0.009 (0.56)
	Flow rate	l/min	8.13	8.08	0.66	0.44	7.00	9.41	0.18	-0.83	2.49
Toilet	Frequency of toilet use per capita per day	fl/p/d	5.39	5.00	0.51	0.26	4.00	6.00	0.20	-1.39	0.00
	Water use in each flush	l/fl	6.01	5.00	1.23	1.52	5.00	8.00	0.41	-1.88	0.00
Dish washing	Frequency of washing dishes per day	wsh/d	3.00	3.00	0.00	0.00	3.00	3.00	0.00	0.00	0.10
	Duration of running water in each wash	min/p/wsh	1.16	1.13	0.21	0.05	0.75	1.50	0.06	-0.82	0.147
	Flow rate	l/min	9.54	10.77	2.06	4.22	6.50	11.58	-0.50	-1.68	0.16
Laundry	Frequency of laundry per day	wsh/d	0.83	0.86	0.28	0.08	0.29	1.43	-0.39	-0.50	0.06
	Volume of water per washing cycle	l/wsl	190.02	170.00	63.28	4004.52	123	386	1.53	1.28	0.56
House washing	Frequency of house washing per day	wsh/d	0.51	0.57	0.07	0.00	0.43	0.57	-0.41	-1.88	0.01
	Duration of each wash	min/wsh	1.79	1.67	0.32	0.10	1.11	3.00	1.62	5.02	0.084
	Flow rate	l/min	12.20	11.93	1.47	2.15	8.18	14.96	-0.47	0.02	0.26
Vehicle washing	Frequency of vehicles washing per day	wsh/d	0.06	0.00	0.08	0.01	0.00	0.29	0.64	-0.75	0.016
	Duration of each wash	min/wsh	1.81	1.75	0.68	0.47	0.55	3.75	0.78	0.73	0.187
	Flow rate	l/min	12.79	12.76	1.82	3.32	8.97	15.86	-0.30	-0.04	0.43
Swimming pool	Frequency of filling swimming pool per day	No./d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41
	Volume of water provided to fill the swimming pool	m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.11
Garden watering	Frequency of garden watering per day	wtr/d	0.07	0.00	0.07	0.01	0.00	0.14	0.09	-2.04	0.01
	Duration of each watering	min/wtr	13.11	12.00	2.92	8.53	8.57	18.00	0.36	-1.00	1.328
	Flow rate	l/min	11.64	12.03	1.94	3.75	8.08	14.60	-0.29	-1.08	0.30
Cooking	Daily water consumption for cooking per person	l/p/d	11.20	11.33	0.82	0.67	9.00	12.00	-0.61	-0.15	0.07

Note: l=liter, p=person, d=day, min=minute, sec=second, bt=bath, shw=shower, tpu=tap use, fl=flushes, wsh=washes, wsl=washing load, wtr=watering

Table C3.3 Summary of water end-uses parameters of medium income households in winter season

End-use	Parameters	Unit	Mean	Median	Std. deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Bath	Frequency of taking bath per capita per day	bt/p/d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Volume of water use in each bath	l/bt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shower	Frequency of showering per capita per day	shw/p/d	0.47	0.43	0.14	0.02	0.29	0.71	0.39	-0.78	0.02
	Duration of each shower	min/shw	8.72	9.00	0.70	0.49	7.00	9.00	-2.07	2.30	0.10
	Flow rate	l/min	9.27	9.30	0.64	0.41	8.02	10.49	-0.09	-1.00	0.09
Hand wash basin taps	Frequency of using taps per capita per day	tpu/p/d	10.31	10.00	0.69	0.48	9.00	11.00	-0.49	-0.83	0.10
	Duration of tap use	min/tpu (sec/tpu)	1.02 (61.02)	1.04 (62.50)	0.06 (3.38)	0.00 (11.43)	0.90 (53.89)	1.09 (65.45)	-0.49 (-0.50)	-0.45 (-0.48)	0.008 (0.50)
	Flow rate	l/min	8.24	8.60	0.90	0.81	6.51	9.49	-0.51	-1.21	0.13
Toilet	Frequency of toilet use per capita per day	fl/p/d	4.66	5.00	0.84	0.70	3.00	6.00	-0.30	-0.42	0.12
	Water use in each flush	l/fl	5.36	5.00	0.88	0.77	5.00	7.50	2.07	2.30	0.13
Dish washing	Frequency of washing dishes per day	wsh/d	3.00	3.00	0.00	0.00	3.00	3.00	0.00	0.00	0.00
	Duration of running water in each wash	min/p/wsh	1.50	1.50	0.19	0.03	1.23	1.88	0.85	0.07	0.03
	Flow rate	l/min	8.39	8.07	1.22	1.49	6.27	10.47	0.28	-1.29	0.22
Laundry	Frequency of laundry per day	wsh/d	1.46	1.43	0.34	0.12	1.00	2.29	0.61	-0.16	0.05
	Volume of water per washing cycle	l/wsl	161.01	165.00	13.62	185.60	123.00	182.00	-0.49	-0.77	2.47
House washing	Frequency of house washing per day	wsh/d	0.69	0.71	0.06	0.00	0.57	0.71	-1.62	0.62	0.008
	Duration of each wash	min/wsh	2.10	2.00	0.42	0.18	1.25	2.80	0.20	-0.71	0.077
	Flow rate	l/min	9.88	9.84	0.70	0.50	7.50	10.98	-0.60	0.73	0.13
Vehicle washing	Frequency of vehicles washing per day	wsh/d	0.10	0.14	0.07	0.01	0.00	0.29	-0.26	-0.64	0.01
	Duration of each wash	min/wsh	1.34	1.13	0.65	0.42	0.58	3.75	2.05	4.87	0.11
	Flow rate	l/min	12.75	12.81	1.84	3.39	8.71	15.85	-0.54	-0.20	0.33
Swimming pool	Frequency of filling swimming pool per day	No./d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Volume of water provided to fill the swimming pool	m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Garden watering	Frequency of garden watering per day	wtr/d	0.14	0.14	0.01	0.00	0.00	0.14	-13.27	176.00	0.002
	Duration of each watering	min/wtr	11.88	11.25	3.91	15.31	7.50	22.50	1.07	0.71	0.666
	Flow rate	l/min	11.94	12.22	1.95	3.82	8.09	14.96	-0.29	-1.03	0.29
Cooking	Daily water consumption for cooking per person	l/p/d	12.85	12.16	2.07	4.28	10.35	17.07	0.48	-1.25	0.31

Note: l=liter, p=person, d=day, min=minute, sec=second, bt=bath, shw=shower, tpu=tap use, fl=flushes, wsh=washes, wsl=washing load, wtr=watering

Table C3.4 Summary of water end-uses parameters of high income households in winter season

End-use	Parameters	Unit	Mean	Median	Std. deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Bath	Frequency of taking bath per capita per day	bt/p/d	0.01	0.00	0.04	0.00	0.00	0.14	3.35	9.35	0.01
	Volume of water use in each bath	l/bt	132.00	0.00	34.84	1213.51	0.00	180	3.55	11.26	14.16
Shower	Frequency of showering per capita per day	shw/p/d	0.61	0.57	0.13	0.02	0.43	0.86	0.57	-0.35	0.02
	Duration of each shower	min/shw	8.38	9.00	0.93	0.86	7.00	9.00	-0.83	-1.32	0.33
	Flow rate	l/min	8.39	8.51	0.71	0.51	7.00	9.97	-0.07	-0.34	0.22
Hand wash basin taps	Frequency of using taps per capita per day	tpu/p/d	10.98	11.00	1.25	1.57	9.00	14.00	0.24	-0.59	0.42
	Duration of tap use	min/tpu (sec/tpu)	1.04 (62.20)	1.04 (62.5)	0.06 (3.72)	0.00 (13.85)	0.90 (53.89)	1.13 (67.50)	-0.61 (-0.70)	-0.20 (-0.14)	0.01 (1.25)
	Flow rate	l/min	8.02	7.89	0.64	0.41	7.01	9.48	0.35	-0.83	0.24
Toilet	Frequency of toilet use per capita per day	fl/p/d	4.14	4.00	0.81	0.66	3.00	6.00	-0.01	-0.97	0.27
	Water use in each flush	l/fl	5.38	5.00	1.04	1.07	5.00	9.00	2.65	5.73	0.43
Dish washing	Frequency of washing dishes per day	wsh/d	3.00	3.00	0.00	0.00	3.00	3.00	0.00	0.00	0.00
	Duration of running water in each wash	min/p/wsh	1.64	1.80	0.47	0.22	0.72	2.25	-0.84	-0.48	0.18
	Flow rate	l/min	7.54	7.53	0.58	0.33	6.60	9.46	0.35	-0.40	0.19
Laundry	Frequency of laundry per day	wsh/d	1.93	1.86	0.37	0.13	0.86	2.71	-0.04	-0.13	0.06
	Volume of water per washing cycle	l/wsl	160.28	163.00	14.12	199.44	123	183	-0.34	-0.74	4.60
House washing	Frequency of house washing per day	wsh/d	0.80	0.71	0.11	0.01	0.71	1.00	0.80	-0.88	0.02
	Duration of each wash	min/wsh	2.38	2.25	0.38	0.15	1.69	4.67	1.95	8.95	0.123
	Flow rate	l/min	8.12	7.94	0.95	0.90	6.51	10.95	0.87	0.84	0.39
Vehicle washing	Frequency of vehicles washing per day	wsh/d	0.04	0.00	0.07	0.00	0.00	0.29	1.29	0.28	0.01
	Duration of each wash	min/wsh	1.10	1.00	0.46	0.22	0.45	2.50	1.49	1.92	0.157
	Flow rate	l/min	13.08	13.15	1.49	2.23	8.99	15.73	-0.53	0.87	0.51
Swimming pool	Frequency of filling swimming pool per day	No./d	0.002	0.000	0.017	0.00	0.00	0.14	8.24	66.94	0.003
	Volume of water provided to fill the swimming pool	m^3	36.00	36.00	5.66	32.00	32.00	40.00	0.00	0.00	50.82
Garden watering	Frequency of garden watering per day	wtr/d	0.14	0.14	0.00	0.00	0.14	0.14	0.00	0.00	0.00
	Duration of each watering	min/wtr	14.49	15.00	3.24	10.49	9.23	30.00	1.02	2.46	1.081
	Flow rate	l/min	11.34	11.16	1.53	2.35	8.17	14.77	0.25	-0.78	1.76
Cooking	Daily water consumption for cooking per person	l/p/d	16.33	16.37	2.11	4.44	13.61	20.86	0.49	-0.62	23.32

Note: l=liter, p=person, d=day, min=minute, sec=second, bt=bath, shw=shower, tpu=tap use, fl=flushes, wsh=washes, wsl=washing load, wtr=watering

Table C3.5 Summary of water end-uses parameters for all surveyed households (407 households) in summer season

End-use	Parameters	Unit	Mean	Median	Std. deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Bath	Frequency of taking bath per capita per day	bt/p/d	0.003	0.000	0.022	0.00	0.00	0.14	6.16	36.18	0.003
	Volume of water use in each bath	l/bt	132.00	0.00	20.80	432.81	0.00	180	6.48	41.52	2.03
Shower	Frequency of showering per capita per day	shw/p/d	0.97	1.00	0.06	0.00	0.86	1.00	-1.27	-0.40	0.01
	Duration of each shower	min/shw	4.84	5.00	0.82	0.67	3.00	7.00	-0.58	2.54	0.12
	Flow rate	l/min	9.02	8.97	0.84	0.70	7.00	10.94	-0.07	-0.25	0.11
Hand wash basin taps	Frequency of using taps per capita per day	tpu/p/d	10.97	11.00	1.09	1.19	9.00	14.00	-0.02	-0.38	0.16
	Duration of tap use	sec/tpu	59.63	60.00	3.36	11.26	48.33	67.50	-0.29	0.43	0.49
	Flow rate	l/min	8.14	8.18	0.77	0.60	6.51	9.49	-0.14	-1.11	0.12
Toilet	Frequency of toilet use per capita per day	fl/p/d	4.78	5.00	0.92	0.84	4.00	10.00	1.46	3.37	0.11
	Water use in each flush	l/fl	5.51	5.00	1.05	1.11	5.00	9.00	1.71	1.31	0.13
Dish washing	Frequency of washing dishes per day	wsh/d	3.00	3.00	0.00	0.00	3.00	3.00	0.00	0.00	0.00
	Duration of running water in each wash	min/p/wsh	1.43	1.50	0.37	0.14	0.72	2.25	0.18	-0.63	0.05
	Flow rate	l/min	8.36	7.87	1.50	2.25	6.27	11.58	0.78	-0.72	0.19
Laundry	Frequency of laundry per day	wsh/d	1.58	1.57	0.56	0.31	0.43	3.00	0.04	-0.64	0.07
	Volume of water per washing cycle	l/wsl	167.32	165.00	34.59	1196.29	123.00	386.74	3.52	15.01	3.25
House washing	Frequency of house washing per day	wsh/d	0.79	0.86	0.11	0.01	0.57	1.00	-0.30	-0.42	0.01
	Duration of each wash	min/wsh	2.13	2.00	0.44	0.20	1.11	4.67	0.70	2.03	0.06
	Flow rate	l/min	9.80	9.67	1.81	3.27	6.51	14.96	0.56	-0.03	0.21
Vehicle washing	Frequency of vehicles washing per day	wsh/d	0.14	0.00	0.15	0.02	0.00	0.43	0.16	-1.85	0.00
	Duration of each wash	min/wsh	1.39	1.25	0.67	0.44	0.45	3.75	1.59	2.84	0.09
	Flow rate	l/min	12.82	12.81	1.77	3.14	8.71	15.86	-0.52	-0.04	0.26
Swimming pool	Frequency of filling swimming pool per day	No./d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Volume of water provided to fill the swimming pool	m^3	36.00	36.00	5.66	32.00	32.00	40.00	0.00	0.00	0.00
Garden watering	Frequency of garden watering per day	wtr/d	0.38	0.43	0.14	0.02	0.00	0.43	-2.34	3.50	0.00
	Duration of each watering	min/wtr	13.04	12.00	3.75	14.03	7.50	30.00	0.71	0.62	0.54
	Flow rate	l/min	11.67	11.65	1.82	3.30	8.08	14.96	-0.06	-1.01	0.27
Cooking	Daily water consumption for cooking per person	l/p/d	14.60	17.61	2.72	7.40	10.18	21.86	0.66	-0.34	0.27
Air cooler	Water consumption of each air-cooler per hour	l/hr	3.88	5.20	2.41	5.79	0.00	6.20	-0.82	-0.99	0.235
	Daily water consumption for air cooler per person	l/p/d	8.08	8.40	5.98	35.70	0.00	30.00	0.26	-0.09	0.58

Note: l=liter, p=person, d=day, min=minute, sec=second, bt=bath, shw=shower, tpu=tap use, fl=flushes, wsh=washes, wsl=washing load, wtr=watering

Table C3.6 Summary of water end-uses parameters of low income households in summer season

End-use	Parameters	Unit	Mean	Median	Std. deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Bath	Frequency of taking bath per capita per day	bt/p/d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Volume of water use in each bath	l/bt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shower	Frequency of showering per capita per day	shw/p/d	0.92	0.86	0.07	0.00	0.86	1.00	0.41	-1.88	0.00
	Duration of each shower	min/shw	4.41	5.00	0.92	0.84	3	5.00	-0.92	-1.18	0.44
	Flow rate	l/min	9.48	9.40	0.79	0.62	8.10	10.90	0.23	-0.88	0.31
Hand wash basin taps	Frequency of using taps per capita per day	tpu/p/d	10.46	10.00	1.02	1.04	9	12	0.18	-1.07	0.30
	Duration of tap use	sec/tpu	57.04	57.50	2.72	7.42	48	60	-1.49	2.61	1.23
	Flow rate	l/min	8.13	8.10	0.67	0.45	7.00	9.40	0.16	-0.84	0.18
Toilet	Frequency of toilet use per capita per day	fl/p/d	5.39	5.00	0.51	0.26	4	6	0.20	-1.39	0.00
	Water use in each flush	l/fl	6.01	5.00	1.23	1.52	5	8	0.41	-1.88	0.00
Dish washing	Frequency of washing dishes per day	wsh/d	3.00	3.00	0.00	0.00	3	3	0.00	0.00	0.00
	Duration of running water in each wash	min/p/wsh	1.16	1.13	0.21	0.05	1	2	0.05	-0.81	0.07
	Flow rate	l/min	9.54	10.80	2.06	4.23	6.50	11.60	-0.50	-1.67	0.96
Laundry	Frequency of laundry per day	wsh/d	0.88	0.86	0.25	0.06	0.43	1.57	-0.06	-0.38	0.06
	Volume of water per washing cycle	l/wsl	190.02	170.00	63.28	4004.19	123	387	1.53	1.28	21.05
House washing	Frequency of house washing per day	wsh/d	0.66	0.70	0.05	0.00	1	1	-0.41	-1.88	0.00
	Duration of each wash	min/wsh	1.80	1.70	0.31	0.10	1	3	1.55	5.05	0.08
	Flow rate	l/min	12.19	11.90	1.47	2.16	8.20	15.00	-0.48	0.04	0.49
Vehicle washing	Frequency of vehicles washing per day	wsh/d	0.13	0.00	0.15	0.02	0.00	0.43	0.35	-1.86	0.01
	Duration of each wash	min/wsh	1.82	1.80	0.69	0.47	1.00	4.00	0.79	0.79	0.19
	Flow rate	l/min	12.79	12.80	1.82	3.31	9.00	15.90	-0.29	-0.06	0.74
Swimming pool	Frequency of filling swimming pool per day	No./d	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Volume of water provided to fill the swimming pool	m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Garden watering	Frequency of garden watering per day	wtr/d	0.19	0.00	0.20	0.04	0.00	0.40	0.09	-2.04	0.000
	Duration of each watering	min/wtr	13.11	12.00	2.92	8.52	9.00	18.00	0.36	-1.00	1.33
	Flow rate	l/min	11.63	12.00	1.93	3.74	8.10	14.60	-0.27	-1.10	0.86
Cooking	Daily water consumption for cooking per person	l/p/d	12.18	15.30	0.81	0.66	10.00	13.00	-0.60	-0.19	0.17
Air cooler	Water consumption of each air-cooler per hour	l/hr	2.83	3.45	1.58	2.48	0.00	4.45	-0.84	-0.55	0.326
	Daily water consumption for air cooler per person	l/p/d	9.05	8.60	6.18	38.19	0.00	30.00	0.54	0.88	1.28

Note: l=liter, p=person, d=day, min=minute, sec=second, bt=bath, shw=shower, tpu=tap use, fl=flushes, wsh=washes, wsl=washing load, wtr=watering

Table C3.7 Summary of water end-uses parameters of medium income households in summer season

End-use	Parameters	Unit	Mean	Median	Std. deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Bath	Frequency of taking bath per capita per day	bt/p/d	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.000
	Volume of water use in each bath	l/bt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shower	Frequency of showering per capita per day	shw/p/d	0.97	1.00	0.06	0.00	0.86	1.00	-1.31	-0.28	0.01
	Duration of each shower	min/shw	4.72	5.00	0.70	0.49	3.00	5.00	-2.07	2.30	0.12
	Flow rate	l/min	9.27	9.30	0.64	0.41	8.02	10.49	-0.09	-1.00	0.12
Hand wash basin taps	Frequency of using taps per capita per day	tpu/p/d	10.87	11.00	0.87	0.75	9	12	-0.54	-0.25	0.16
	Duration of tap use	sec/tpu	59.73	60.00	2.66	7.06	54	64	-0.46	0.04	0.50
	Flow rate	l/min	8.24	8.60	0.90	0.81	6.51	9.49	-0.51	-1.21	0.16
Toilet	Frequency of toilet use per capita per day	fl/p/d	4.76	5.00	0.68	0.47	4.00	6.00	0.34	-0.85	0.12
	Water use in each flush	l/fl	5.36	5.00	0.88	0.77	5.00	8.00	2.07	2.30	0.15
Dish washing	Frequency of washing dishes per day	wsh/d	3.00	3.00	0.00	0.00	3.00	3.00	0.00	0.00	0.00
	Duration of running water in each wash	min/p/wsh	1.41	1.35	0.23	0.05	1.00	2.00	0.68	-0.20	0.04
	Flow rate	l/min	8.39	8.07	1.22	1.49	6.27	10.47	0.28	-1.29	0.22
Laundry	Frequency of laundry per day	wsh/d	1.58	1.57	0.37	0.14	1.00	2.43	0.29	-0.26	0.07
	Volume of water per washing cycle	l/wsl	161.01	165.00	13.62	185.60	123	182	-0.49	-0.77	2.46
House washing	Frequency of house washing per day	wsh/d	0.80	0.70	0.10	0.01	0.71	0.86	0.02	-2.02	0.02
	Duration of each wash	min/wsh	2.10	2.00	0.41	0.17	1.00	3.00	0.25	-0.71	0.08
	Flow rate	l/min	9.88	9.84	0.70	0.50	7.50	10.98	-0.60	0.73	0.13
Vehicle washing	Frequency of vehicles washing per day	wsh/d	0.21	0.30	0.14	0.02	0.00	0.43	-0.71	-1.41	0.00
	Duration of each wash	min/wsh	1.35	1.10	0.66	0.43	1.00	4.00	2.06	4.96	0.11
	Flow rate	l/min	12.75	12.80	1.84	3.37	8.70	15.80	-0.55	-0.19	0.33
Swimming pool	Frequency of filling swimming pool per day	No./d	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
	Volume of water provided to fill the swimming pool	m^3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Garden watering	Frequency of garden watering per day	wtr/d	0.43	0.43	0.03	0.00	0.00	0.43	-13.27	176.00	0.00
	Duration of each watering	min/wtr	11.88	11.25	3.91	15.31	8.00	23.00	1.07	0.71	0.67
	Flow rate	l/min	11.93	12.20	1.96	3.83	8.10	15.00	-0.28	-1.04	0.34
Cooking	Daily water consumption for cooking per person	l/p/d	13.71	16.16	1.92	3.68	11.00	18.00	0.52	-1.01	0.29
Air cooler	Water consumption of each air-cooler per hour	l/hr	4.20	5.40	2.39	5.73	0.00	6.40	-1.00	-0.60	0.356
	Daily water consumption for air cooler per person	l/p/d	8.99	10.00	5.94	35.27	0.00	21.00	-0.17	-0.73	0.88

Note: l=liter, p=person, d=day, min=minute, sec=second, bt=bath, shw=shower, tpu=tap use, fl=flushes, wsh=washes, wsl=washing load, wtr=watering

Table C3.8 Summary of water end-uses parameters of high income households in summer season

End-use	Parameters	Unit	Mean	Median	Std. deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Bath	Frequency of taking bath per capita per day	bt/p/d	0.01	0.00	0.03	0.00	0.00	0.10	3.35	9.35	0.011
	Volume of water use in each bath	l/bt	132.00	0.00	34.84	1213.51	0.00	180	3.55	11.26	14.16
Shower	Frequency of showering per capita per day	shw/p/d	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
	Duration of each shower	min/shw	5.27	5.00	0.69	0.48	5.00	7.00	2.14	2.61	0.27
	Flow rate	l/min	8.39	8.50	0.71	0.51	7.00	10.00	-0.07	-0.35	0.22
Hand wash basin taps	Frequency of using taps per capita per day	tpu/p/d	11.42	12.00	1.20	1.45	9	14	-0.26	-0.42	0.41
	Duration of tap use	sec/tpu	61.24	62.50	3.51	12.29	54	68	-0.40	-0.45	1.17
	Flow rate	l/min	8.02	7.90	0.65	0.42	7.00	9.50	0.35	-0.82	0.24
Toilet	Frequency of toilet use per capita per day	fl/p/d	4.41	4.00	1.15	1.33	4.00	10.00	2.82	7.14	0.40
	Water use in each flush	l/fl	5.38	5.00	1.04	1.07	5.00	9.00	2.65	5.75	0.43
Dish washing	Frequency of washing dishes per day	wsh/d	3.00	3.00	0.00	0.00	3.00	3.00	0.00	0.00	0.00
	Duration of running water in each wash	min/p/wsh	1.64	1.80	0.47	0.22	1.00	2.00	-0.77	-0.46	0.18
	Flow rate	l/min	7.54	7.50	0.58	0.33	6.60	9.50	0.36	-0.36	0.19
Laundry	Frequency of laundry per day	wsh/d	2.05	2.00	0.39	0.16	1.00	3.00	0.06	-0.21	0.14
	Volume of water per washing cycle	l/wsl	160.28	163.00	14.12	199.44	123	183	-0.34	-0.74	4.60
House washing	Frequency of house washing per day	wsh/d	0.92	0.90	0.04	0.00	0.86	1.00	1.69	0.85	0.01
	Duration of each wash	min/wsh	2.39	2.30	0.38	0.15	2.00	5.00	1.88	9.04	0.12
	Flow rate	l/min	8.12	7.90	0.95	0.90	6.50	10.90	0.87	0.82	0.39
Vehicle washing	Frequency of vehicles washing per day	wsh/d	0.08	0.00	0.13	0.02	0.00	0.43	1.13	-0.70	0.01
	Duration of each wash	min/wsh	1.10	1.00	0.47	0.22	1.00	3.00	1.50	1.91	0.16
	Flow rate	l/min	13.07	13.15	1.49	2.22	9.00	15.70	-0.53	0.86	0.50
Swimming pool	Frequency of filling swimming pool per day	No./d	0.002	0.000	0.017	0.00	0.00	0.14	8.24	66.94	0.003
	Volume of water provided to fill the swimming pool	m^3	36.00	36.00	5.66	32.00	32.00	40.00	0.00	0.00	50.82
Garden watering	Frequency of garden watering per day	wtr/d	0.40	0.40	0.00	0.00	0.43	0.43	0.00	0.00	0.00
	Duration of each watering	min/wtr	14.49	15.00	3.23	10.43	9.00	30.00	1.03	2.52	1.08
	Flow rate	l/min	11.34	11.20	1.54	2.36	8.20	14.80	0.27	-0.77	0.54
Cooking	Daily water consumption for cooking per person	l/p/d	17.32	20.40	2.11	4.43	15.00	22.00	0.51	-0.56	0.77
Air cooler	Water consumption of each air-cooler per hour	l/hr	5.06	6.70	3.75	14.06	0.00	8.70	-0.56	-1.58	0.629
	Daily water consumption for air cooler per person	l/p/d	6.28	7.10	5.50	30.22	0.00	28.00	0.59	0.70	1.95

Note: l=liter, p=person, d=day, min=minute, sec=second, bt=bath, shw=shower, tpu=tap use, fl=flushes, wsh=washes, wsl=washing load, wtr=watering

Appendix C4 Comparison between Water End-Uses in Winter and Summer Season

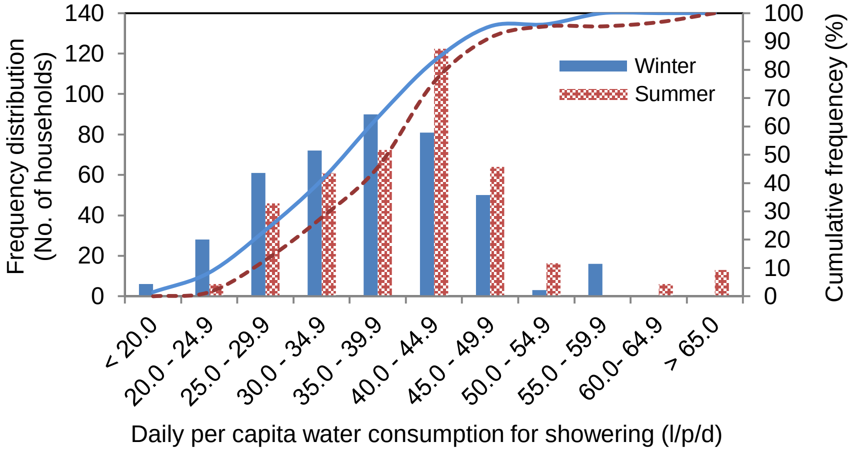


Figure C4.1 Comparison between per capita water consumption for showing in winter and summer

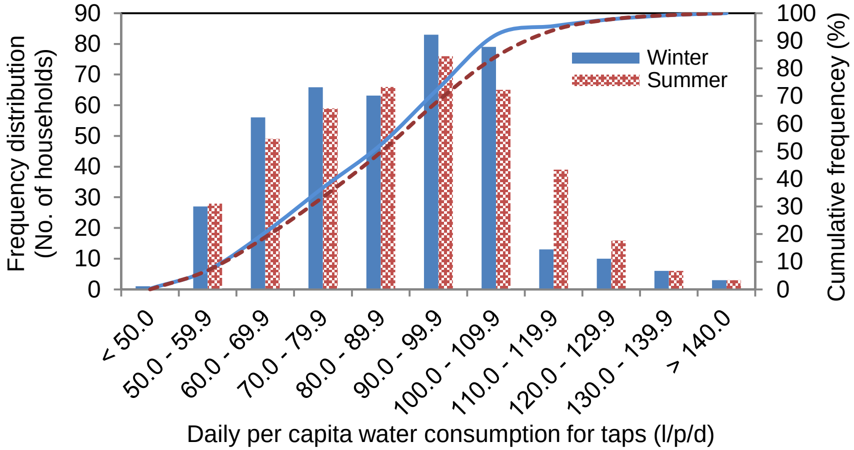


Figure C4.2 Comparison between per capita water consumption for hand wash basin taps uses in winter and summer

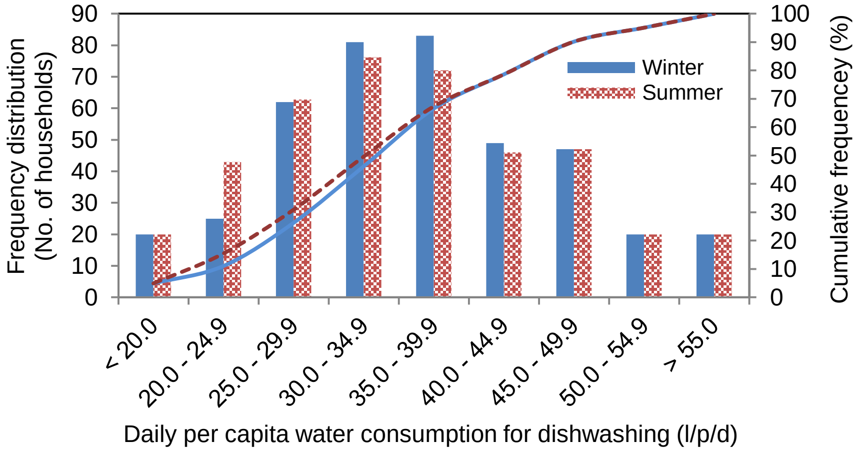


Figure C4.3 Comparison between per capita water consumption for dishwashing in winter and summer

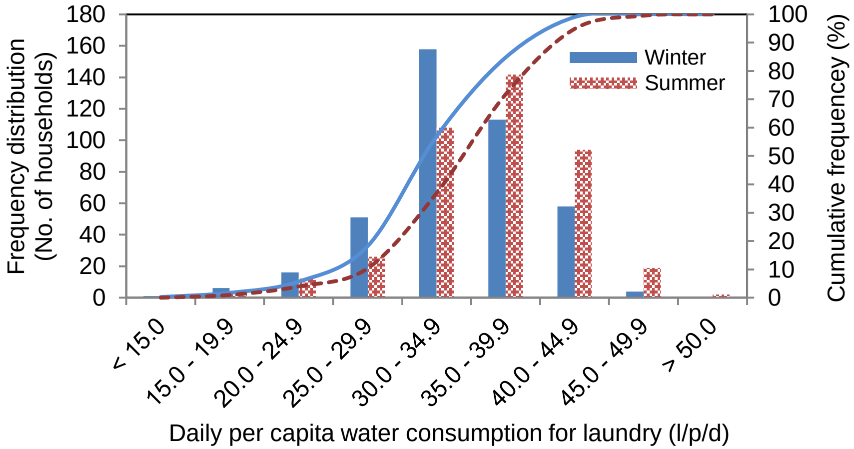


Figure C4.4 Comparison between per capita water consumption for laundry in winter and summer

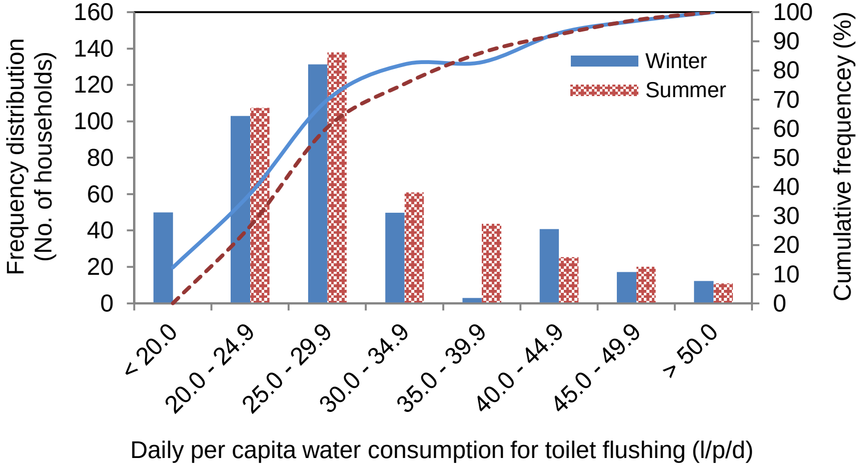


Figure C4.5 Comparison between per capita water consumption for toilet flushing in winter and summer

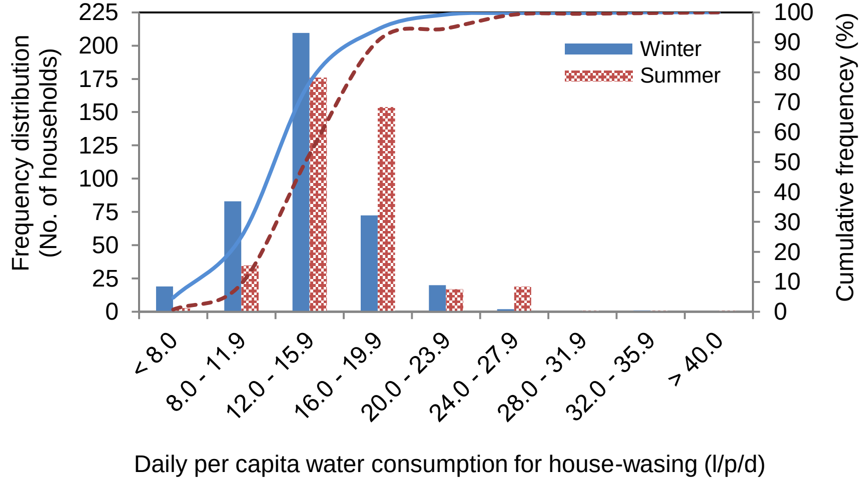


Figure C4.6 Comparison between per capita water consumption for house-washing in winter and summer

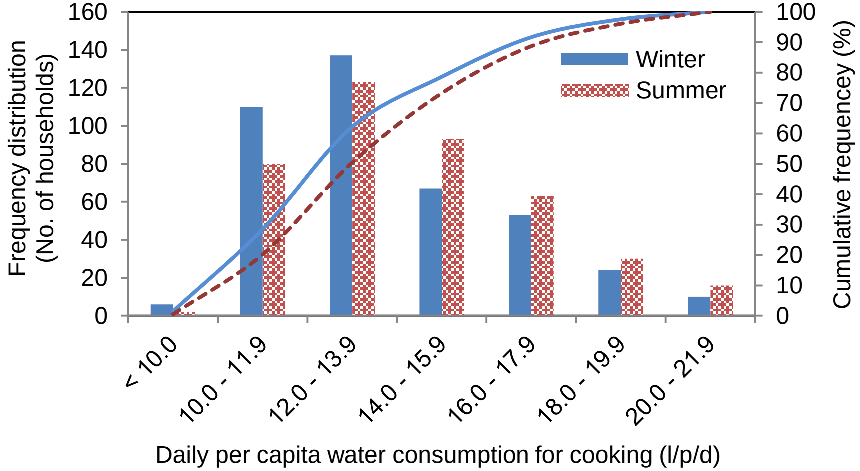


Figure C4.7 Comparison between per capita water consumption for cooking in winter and summer

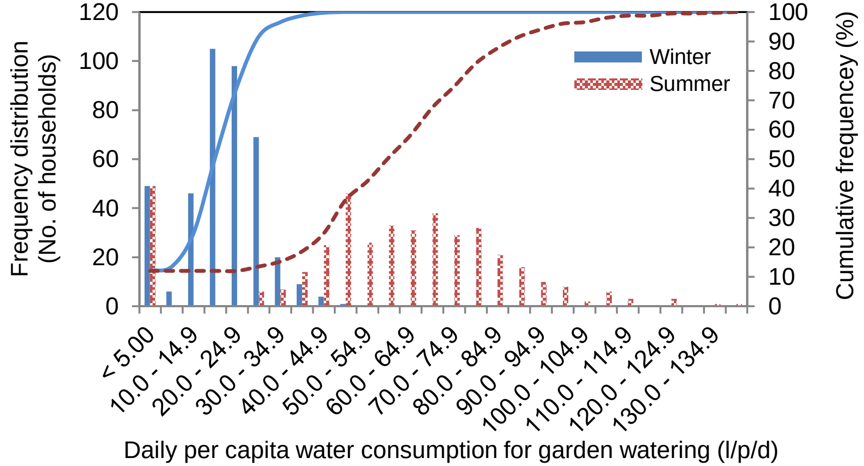


Figure C4.8 Comparison between per capita water consumption for garden watering in winter and summer

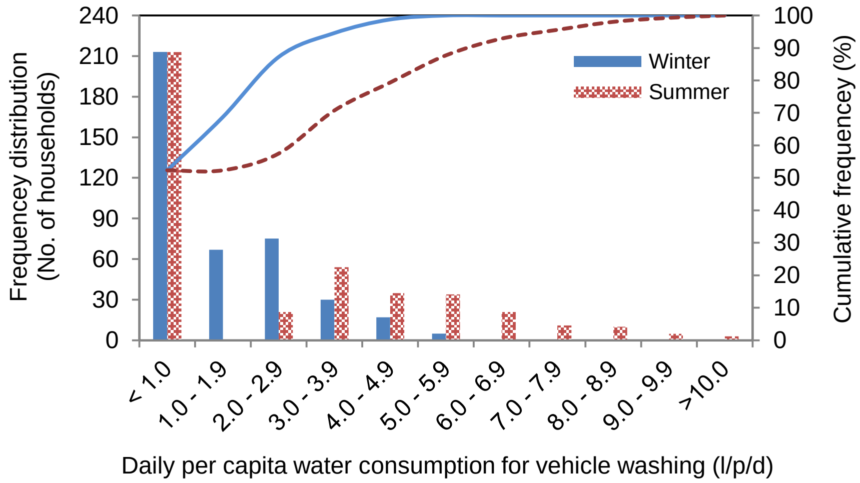


Figure C4.9 Comparison between per capita water consumption for vehicle washing in winter and summer

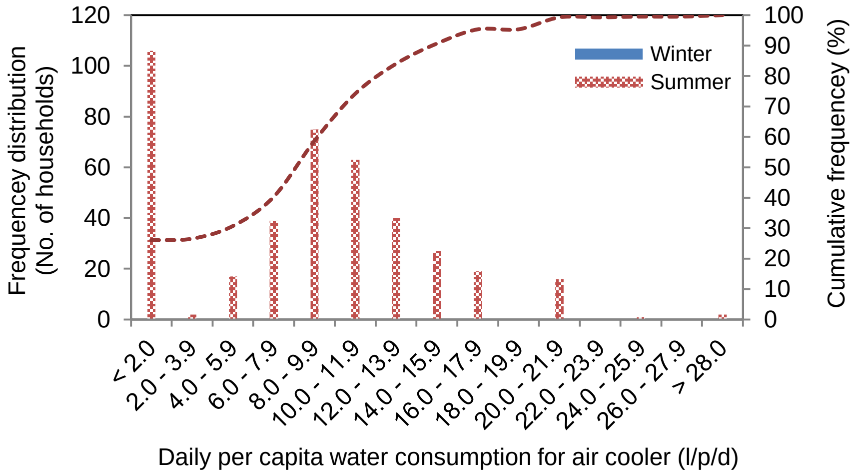


Figure C4.10 Comparison between per capita water consumption for air-cooler in winter and summer

APPENDIX D: ENERGY CONSUMPTION ANALYSIS

Appendix D1 Relationships between Total Household Energy Consumption and Characteristics

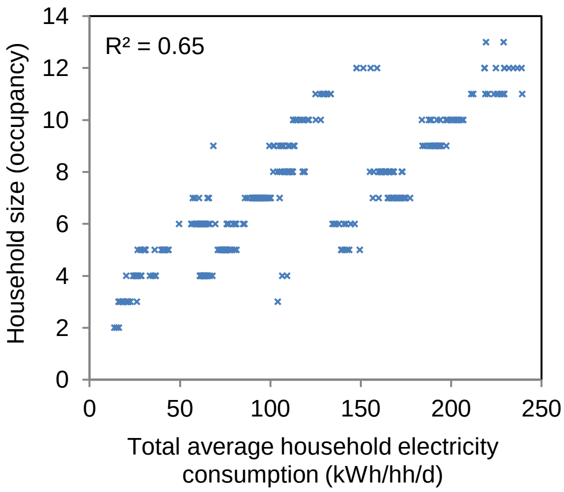


Figure D1.1 Relationship between household total average electricity consumption and household occupancy

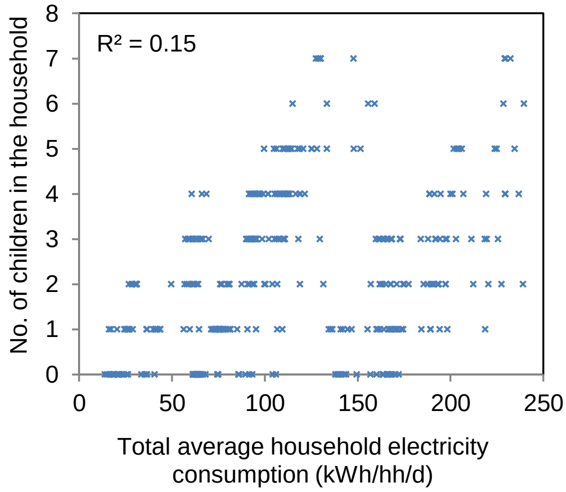


Figure D1.2 Relationship between household total average electricity consumption and number of children in the household

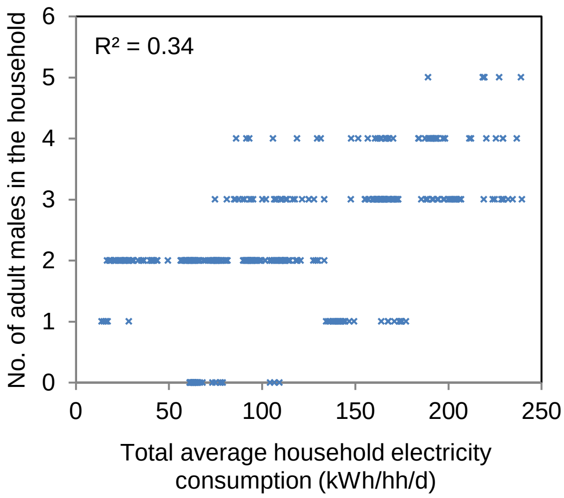


Figure D1.3 Relationship between household total average electricity consumption and number of adult males in the household

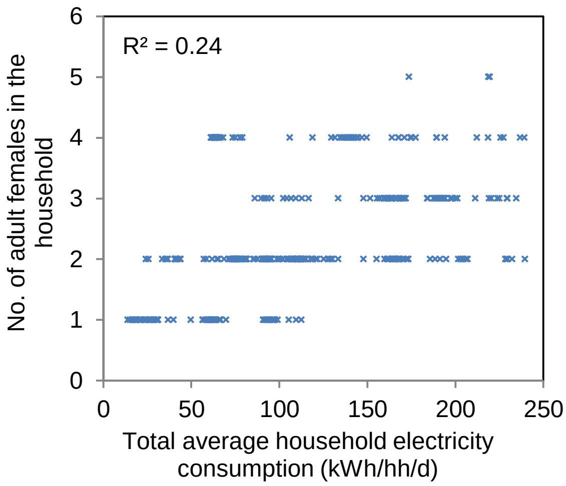


Figure D1.4 Relationship between household total average electricity consumption and number of adult females in the household

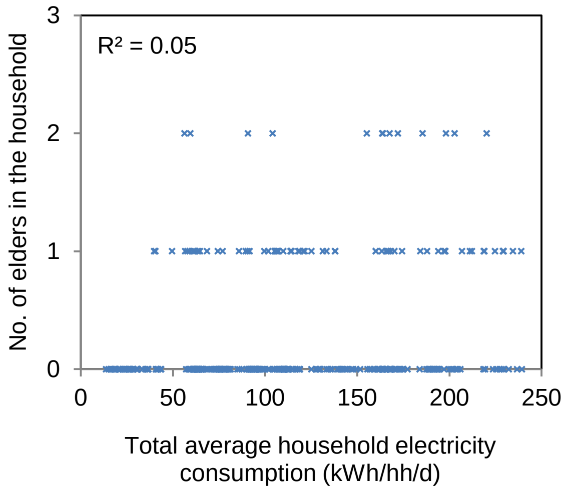


Figure D1.5 Relationship between household total average electricity consumption and number of elders in the household

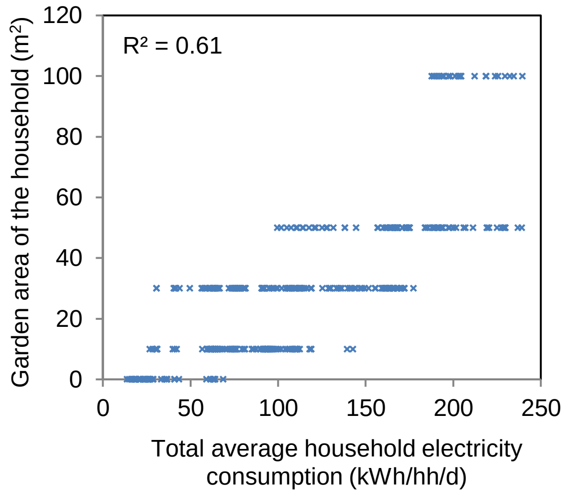


Figure D1.6 Relationship between household total average electricity consumption and garden area of the household

Appendix D2 Relationships between Daily per Capita Average Energy Consumption and Household Characteristics

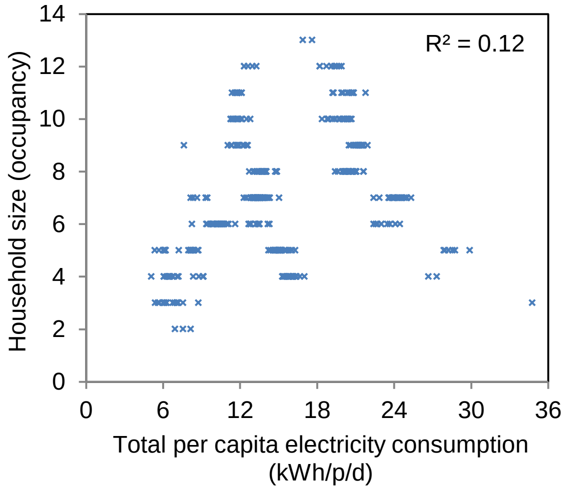


Figure D2.1 Relationship between daily per capita average electricity consumption and household occupancy

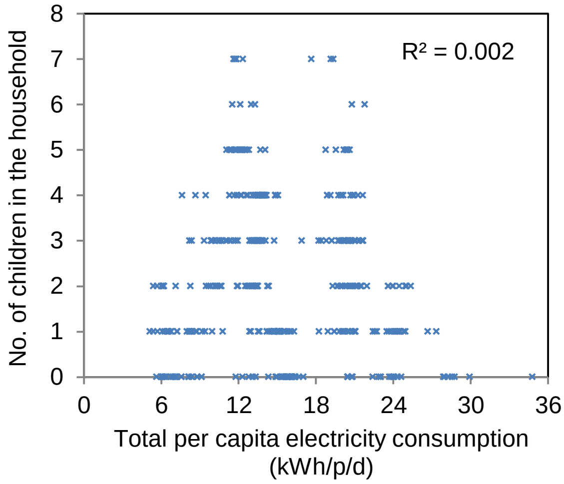


Figure D2.2 Relationship between daily per capita average electricity consumption and number of children in the household

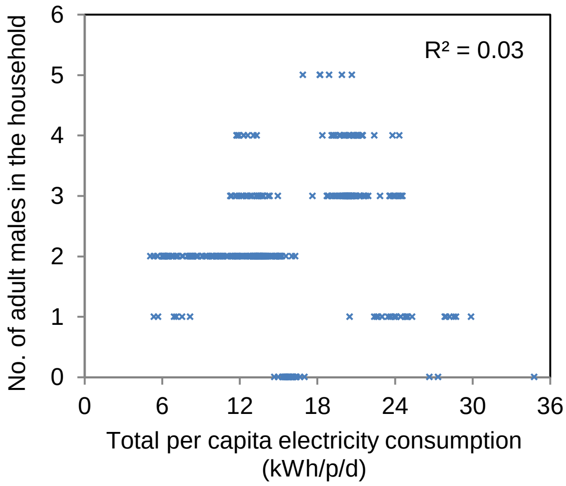


Figure D2.3 Relationship between daily per capita average electricity consumption and number of adult males in the household

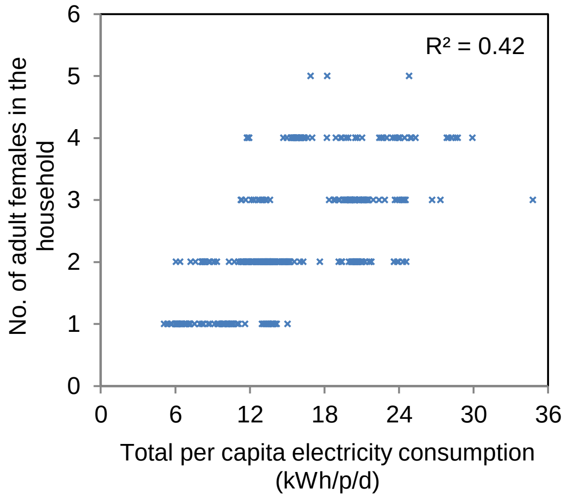


Figure D2.4 Relationship between daily per capita average electricity consumption and number of adult females in the household

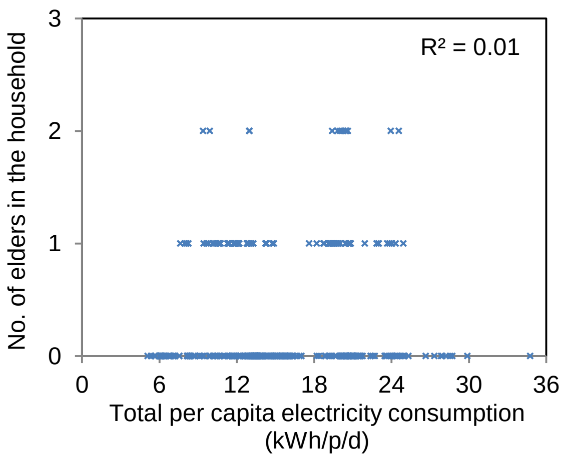


Figure D2.5 Relationship between daily per capita average electricity consumption and number of elders in the household

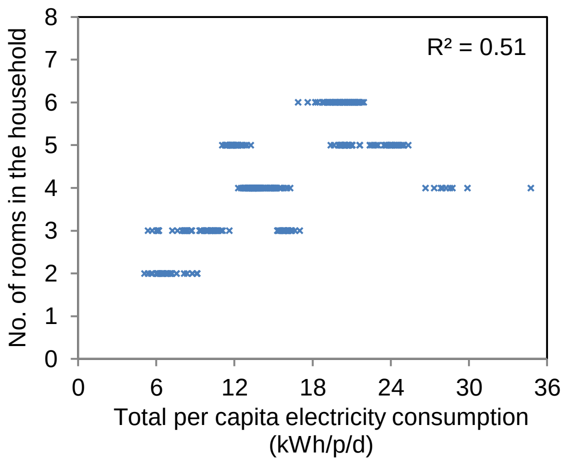


Figure D2.6 Relationship between daily per capita average electricity consumption and number of rooms in the household

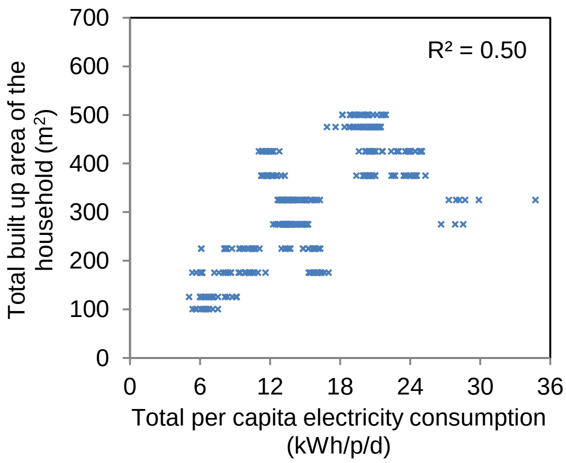


Figure D2.7 Relationship between daily per capita average electricity consumption and total built up area

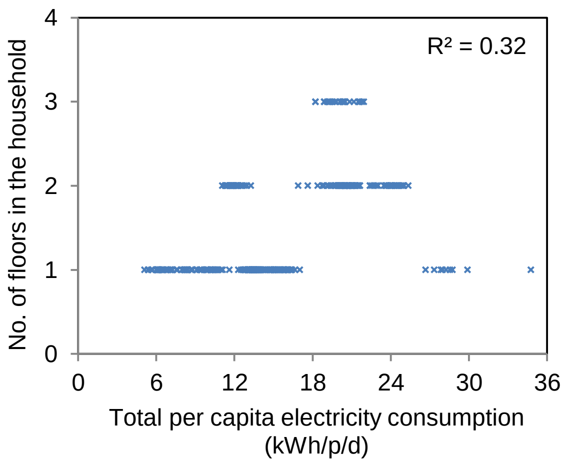


Figure D2.8 Relationship between daily per capita average electricity consumption and number of floors in the household

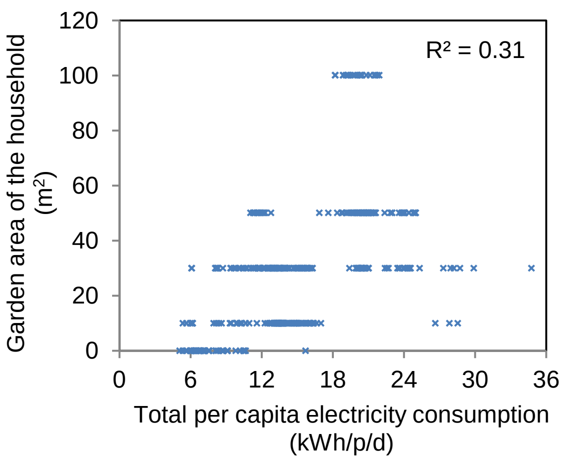


Figure D2.9 Relationship between daily per capita average electricity consumption and total garden area

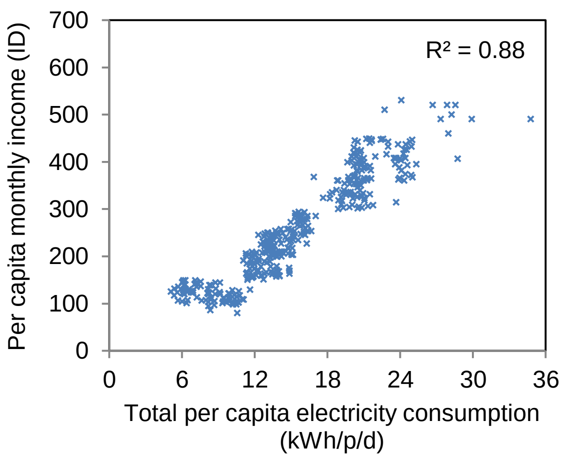


Figure D2.10 Relationship between daily per capita average electricity consumption and per capita monthly income

Appendix D3 Statistical Parameters of Energy End-Uses in Low, Medium and High Income Household Groups

Table D3.1 Summary of energy end-uses parameters for all surveyed households (407 households) in winter season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Space heating	Electrical heater	Number of electrical heaters in use in a household	No.	0.87	1.00	0.34	0.11	0.00	1.00	-2.21	2.88	0.033
		Duration of use of each electrical heater per capita per day	hr/p/d	0.98	0.90	0.51	0.26	0.000	2.00	0.07	-0.33	0.057
		Wattage of each electrical heater	Watt	1101.72	1050.00	332.64	110647.9	800.00	1450.00	-1.86	3.75	32.413
	Kerosene heater	Number of kerosene heaters in use in a household	No.	2.69	3.00	0.59	0.35	1.00	4.00	-1.11	1.10	0.058
		Duration of use of each kerosene heater per capita per day	hr/p/d	2.44	2.14	1.18	1.38	1.17	8.50	2.12	6.12	0.115
		Volume of kerosene use by each heater per hour	l/htr/hr	0.28	0.28	0.03	0.00	0.22	0.35	-0.01	-0.93	0.003
		Volume of kerosene use by each heater per day	l/htr/d	4.13	4.00	0.65	0.42	3.00	5.50	0.08	-0.77	0.063
	Gas heaters	Number of gas heaters in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Number of days each gas bottle is last for gas heater	d									
	Air conditioners	Number of air conditioners in use in a household	No.	1.36	1.00	0.99	0.98	0.00	3.00	0.14	-1.01	0.096
		Duration of use of each air conditioner per capita per day	hr/p/d	1.17	1.13	0.39	0.15	0.500	3.00	0.82	1.96	0.058
		Wattage of each air conditioner	W	3118.2	3050.00	1310.88	1718393	2150.00	3450.00	-1.28	-0.29	127.735
Lighting	Spot lights	Number of spot lights in use per day in a household	No.	9.04	9.00	3.59	12.92	2.00	18.00	0.27	-0.65	0.350
		Duration of use of each spot light per capita per day	hr/p/d	1.48	1.43	0.42	0.18	0.77	3.50	0.94	2.43	0.041
	Tube lights	Number of tube lights in use per day in a household	No.	4.03	4.00	1.29	1.66	2.00	7.00	0.12	-0.53	0.126
		Duration of use of each tube light per capita per day	hr/p/d	1.48	1.43	0.48	0.23	0.70	3.50	1.03	1.51	0.060
Wet appliances	Water pumps	Number of water pumps in use in a household	No.	0.50	0.00	0.50	0.25	0.00	1.00	0.00	-2.01	0.062
		Duration of use of each water pump per capita per week	hr/p/w	0.76	0.78	0.11	0.01	0.60	1.00	0.09	-0.55	0.015
		Wattage of each water pump	Watt	381.48	0.00	192.04	36879.98	340.00	430.00	0.04	-1.96	3.969
	Dishwasher	Number of dishwashing machines in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each dishwasher per capita per week	hr/p/w									
		Wattage of each dishwasher	Watt									
	Clothes washer	Number of clothes washing machines in use in a household	No.	0.94	1.00	0.23	0.05	0.00	1.00	-3.86	12.93	0.025
		Energy consumption per washing cycle	kWh/wsl	0.51	0.55	0.19	0.04	0.00	0.73	-1.02	0.29	0.019

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.1 Summary of energy end-uses parameters for all surveyed households (407 households) in winter season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Water heating	Electrical water heater	Total consumption of heated water per capita per day	l/p/d	85.85	87.00	19.20	368.60	29.73	133.43	-0.24	-0.24	1.871
		Total energy consumption for water heating per capita per day	kWh/p/d	4.99	5.06	1.12	1.25	1.73	7.76	-0.24	-0.24	0.109
Refrigeration appliances	Chest-freezer	Number of chest-freezers in a household	No.	1.08	1.00	0.60	0.36	0.00	2.00	-0.03	-0.21	0.173
		Wattage of each chest-freezer	Watt	384.18	380.00	28.20	795.32	340.00	430.00	0.10	-1.17	11.830
	Fridge-freezer	No. of fridge-freezers in a household	No.	1.44	1.00	0.50	0.25	1.00	2.00	0.22	-1.96	0.173
		Wattage of each fridge-freezer	Watt	294.20	300.00	28.99	840.68	250.00	340.00	0.00	-1.25	9.177
Electronic appliances	TV	Number of TVs in use in a household	No.	2.04	2.00	0.69	0.48	1.00	3.00	-0.05	-0.90	0.206
		Duration of use of each TV per capita per day	hr/p/d	1.51	1.33	0.62	0.38	0.54	3.50	1.00	0.60	0.183
		Wattage of each TV	Watt	175.10	175.00	45.83	2100.61	70.00	250.00	-0.25	-0.63	16.205
	Radio	Number of radios in use in a household	No.	0.15	0.00	0.36	0.13	0.00	1.00	1.92	1.68	0.133
		Duration of use of each radio per capita per day	hr/p/d	0.40	0.38	0.13	0.02	0.23	0.71	0.97	0.17	0.030
		Wattage of each radio	Watt	92.46	95.00	26.97	727.32	40.00	135.00	-0.41	-0.93	11.302
	Computer	Number of computers in use in a household	No.	1.11	1.00	0.55	0.31	0.00	3.00	0.57	1.66	0.229
		Duration of use of each computer per capita per day	hr/p/d	0.43	0.43	0.24	0.06	0.00	1.00	0.22	-0.21	0.045
		Wattage of each computer	Watt	134.03	135.00	43.11	1858.36	65.00	205.00	0.05	-1.25	16.892
	Video record	Number of video records in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each video record per capita per day	hr/p/d									
		Wattage of each video record	Watt									
	CD player	Number of CD players in use in a household	No.	0.18	0.00	0.39	0.15	0.00	1.00	1.66	0.75	0.201
		Duration of use of each CD player per capita per day	hr/p/d	0.11	0.11	0.02	0.00	0.080	0.14	0.10	-1.26	0.019
		Wattage of each CD player	Watt	32.54	33.00	4.85	23.53	25.00	40.00	-0.01	-1.25	1.745
	Play station	Number of play stations in use in a household	No.	0.38	0.00	0.48	0.24	0.00	1.00	0.51	-1.74	0.037
		Duration of use of each play station per capita per day	hr/p/d	0.16	0.13	0.08	0.01	0.08	0.46	1.63	1.82	0.035
		Wattage of each play station	Watt	168.50	168.00	5.57	31.07	160.00	178.00	0.18	-1.06	1.926
Cooking appliances	Electrical hob	Number of electrical hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each electrical hob per capita per day	hr/p/d									
		Wattage of each electrical hob	Watt									

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.1 Summary of energy end-uses parameters for all surveyed households (407 households) in winter season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cooking appliances	Electrical oven	Number of electrical ovens in use in a household	No.	0.94	1.00	0.23	0.05	0.00	1.00	-3.86	12.93	0.055
		Duration of use of each electrical oven per capita per week	hr/p/w	0.49	0.50	0.11	0.01	0.29	0.80	0.21	-0.68	0.014
		Wattage of each electrical oven	Watt	2827.34	2800.00	295.85	87527.13	2400.00	3300.00	0.14	-1.30	39.183
	Electrical kettle	Number of electrical kettles in use in a household	No.	0.59	1.00	0.49	0.24	0.00	1.00	-0.38	-1.87	0.032
		Duration of use of each electrical kettles per capita per day	min/p/d	0.88	0.83	0.28	0.08	0.39	1.50	0.46	-0.85	0.039
		Wattage of each electrical kettle	Watt	2467.63	2500.00	276.04	76198.13	2000.00	2900.00	-0.02	-1.15	36.415
	Microwave oven	Number of microwave ovens in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each microwave oven per capita per day	min/p/d									
		Wattage of each microwave oven	Watt									
	Toaster	Number of toasters in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each toaster per capita per day	min/p/d									
		Wattage of each toaster	Watt									
	Gas hob	Number of gas hobs in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Number of days each gas bottle is last for cooking	d	16.11	15.00	6.41	41.13	8.00	30.00	0.72	-0.31	0.514
	Kerosene hob	Number of kerosene hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		The amount of kerosene use for cooking per day	l/p/d									
Miscellaneous appliances	Hair dryer	Number of hair dryers in use in a household	No.	1.42	1.00	0.49	0.24	1.00	2.00	0.35	-1.89	0.051
		Duration of use of each hair dryer per capita per week	min/p/w	1.56	1.36	0.77	0.59	0.71	3.57	1.14	0.67	0.082
		Wattage of each hair dryer	Watt	1372.48	1400.00	375.58	141063.5	800.00	2000.00	0.09	-1.13	38.908
	Vacuum cleaner	Number of vacuum cleaners in use in a household	No.	0.95	1.00	0.21	0.04	0.00	1.00	-4.31	16.69	0.059
		Duration of use of each vacuum cleaner per capita per week	hr/p/w	0.18	0.19	0.06	0.00	0.07	0.28	-0.17	-1.17	0.006
		Wattage of each vacuum cleaner	Watt	1087.24	1100.00	221.13	48900.13	700.00	1450.00	-0.11	-1.18	22.634
	Sewing machine	Number of sewing machines in use in a household	No.	0.90	1.00	0.30	0.09	0.00	1.00	-2.62	4.88	0.047
		Duration of use of each sewing machine per capita per week	hr/p/w	0.26	0.25	0.04	0.00	0.20	0.33	0.18	-0.61	0.004
		Wattage of each sewing machine	Watt	100.05	100.00	11.44	130.84	80.00	119.00	-0.08	-1.12	1.177
	Iron	Number of irons in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each iron per capita per week	hr/p/w	0.21	0.19	0.09	0.01	0.06	0.38	0.25	-0.83	0.009
		Wattage of each iron	Watt	1276.90	1250.00	142.27	20241.13	1050.00	1500.00	0.05	-1.21	13.863

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Table D3.2 Summary of energy end-uses parameters for low income households (92 households) in winter season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Space heating	Electrical heater	Number of electrical heaters in use in a household	No.	0.79	1.00	0.41	0.17	0.00	1.00	-1.47	0.18	0.084
		Duration of use of each electrical heater per capita per day	hr/p/d	1.36	1.00	0.55	0.31	0.56	2.00	0.14	-1.85	0.154
		Wattage of each electrical heater	Watt	1023.03	1000.00	235.17	55304.29	800.00	1250.00	-2.30	8.32	48.702
	Kerosene heater	Number of kerosene heaters in use in a household	No.	1.79	2.00	0.41	0.17	1.00	2.00	-1.47	0.18	0.084
		Duration of use of each kerosene heater per capita per day	hr/p/d	3.59	3.00	1.52	2.31	1.33	8.50	1.71	2.07	0.315
		Volume of kerosene use by each heater per hour	l/htr/hr	0.27	0.28	0.03	0.00	0.22	0.33	0.00	-0.98	0.006
		Volume of kerosene use by each heater per day	l/htr/d	4.27	4.50	0.70	0.50	3.00	5.50	0.02	-0.92	0.146
	Gas heaters	Number of gas heaters in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Number of days each gas bottle is last for gas heater	d									
	Air conditioners	Number of air conditioners in use in a household	No.	0.01	0.00	0.10	0.01	0.00	1.00	9.59	92.00	0.022
		Duration of use of each air conditioner per capita per day	hr/p/d	0.56	0.56	0.06	0.00	0.00	0.56	9.59	92.00	0.012
		Wattage of each air conditioner	Watt	2150.00	0.00	224.15	50244.57	2150.00	2150.00	9.59	92.00	46.421
Lighting	Spot lights	Number of spot lights in use per day in a household	No.	5.10	5.00	1.64	2.68	2.00	7.00	-0.07	-1.38	0.339
		Duration of use of each spot light per capita per day	hr/p/d	1.92	1.75	0.40	0.16	1.11	3.50	2.02	6.20	0.083
	Tube lights	Number of tube lights in use per day in a household	No.	2.60	3.00	0.49	0.24	2.00	3.00	-0.41	-1.88	0.102
		Duration of use of each tube light per capita per day	hr/p/d	1.92	1.75	0.40	0.16	1.11	3.50	2.02	6.20	0.093
Wet appliances	Water pumps	Number of water pumps in use in a household	No.	0.28	0.00	0.45	0.20	0.00	1.00	0.98	-1.06	0.036
		Duration of use of each water pump per capita per week	hr/p/w	0.62	0.60	0.05	0.00	0.60	0.71	1.66	0.81	0.019
		Wattage of each water pump	Watt	381.54	0.00	173.46	30089.73	340.00	430.00	1.01	-0.96	12.235
	Dishwasher	Number of dishwashing machines in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each dishwasher per capita per week	hr/p/w									
		Wattage of each dishwasher	Watt									
	Clothes washer	Number of clothes washing machines in use in a household	No.	0.75	1.00	0.44	0.19	0.00	1.00	-1.17	-0.64	0.077
		Energy consumption per washing cycle	kWh/wsl	0.23	0.31	0.14	0.02	0.00	0.35	-1.12	-0.68	0.029
Water heating	Electrical water heater	Total consumption of heated water per capita per day	l/p/d	65.80	67.09	15.79	249.37	29.73	97.02	-0.16	-0.82	3.270
		Total energy consumption for water heating per capita per day	kWh/p/d	3.83	3.90	0.92	0.84	1.73	5.64	-0.16	-0.82	0.190

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.2 Summary of energy end-uses parameters for low income households (92 households) in winter season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Refrigeration appliances	Chest-freezer	Number of chest-freezers in a household	No.	0.37	0.00	0.49	0.24	0.00	1.00	0.55	-1.74	0.114
		Wattage of each chest-freezer	Watt	381.20	380.00	29.38	863.39	340.00	430.00	0.22	-1.17	7.309
	Fridge-freezer	No. of fridge-freezers in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Wattage of each fridge-freezer	Watt	293.04	290.00	29.94	896.13	250.00	340.00	-0.01	-1.39	7.142
Electronic appliances	TV	Number of TVs in use in a household	No.	1.30	1.00	0.46	0.21	1.00	2.00	0.86	-1.28	0.106
		Duration of use of each TV per capita per day	hr/p/d	2.09	2.00	0.34	0.12	1.33	3.50	2.13	7.70	0.082
		Wattage of each TV	Watt	125.11	125.00	37.14	1379.66	70.00	190.00	0.15	-1.37	9.079
	Radio	Number of radios in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each radio per capita per day	hr/p/d									
		Wattage of each radio	Watt									
	Computer	Number of computers in use in a household	No.	0.93	1.00	0.25	0.06	0.00	1.00	-3.58	11.06	0.057
		Duration of use of each computer per capita per day	hr/p/d	0.61	0.60	0.24	0.06	0.00	1.00	-0.42	0.98	0.057
		Wattage of each computer	Watt	131.47	130.00	40.33	1626.67	65.00	205.00	0.19	-1.06	9.656
	Video record	Number of video records in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each video record per capita per day	hr/p/d									
		Wattage of each video record	Watt									
	CD player	Number of CD players in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each CD player per capita per day	hr/p/d									
		Wattage of each CD player	Watt									
	Play station	Number of play stations in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each play station per capita per day	hr/p/d									
		Wattage of each play station	Watt									
Cooking appliance	Electrical hob	Number of electrical hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each electrical hob per capita per day	hr/p/d									
		Wattage of each electrical hob	Watt									

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.2 Summary of energy end-uses parameters for low income households (92 households) in winter season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cooking appliances	Electrical oven	Number of electrical ovens in use in a household	No.	0.75	1.00	0.44	0.19	0.00	1.00	-1.17	-0.64	0.081
		Duration of use of each electrical oven per capita per week	hr/p/w	0.39	0.33	0.08	0.01	0.29	0.50	0.56	-1.35	0.009
		Wattage of each electrical oven	Watt	2802.90	2800.00	280.22	78520.89	2400.00	3300.00	0.20	-1.12	142.708
	Electrical kettle	Number of electrical kettles in use in a household	No.	0.45	0.00	0.50	0.25	0.00	1.00	0.22	-1.99	0.027
		Duration of use of each electrical kettles per capita per day	min/p/d	0.91	0.83	0.16	0.03	0.71	1.43	1.96	4.19	0.023
		Wattage of each electrical kettle	Watt	2465.85	2500.00	299.67	89804.88	2000.00	2900.00	0.01	-1.39	134.546
	Microwave oven	Number of microwave ovens in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each microwave oven per capita per day	min/p/d									
		Wattage of each microwave oven	Watt									
	Toaster	Number of toasters in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each toaster per capita per day	min/p/d									
		Wattage of each toaster	Watt									
	Gas hob	Number of gas hobs in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Number of days each gas bottle is last for cooking	d	25.12	23.00	4.25	18.06	17.00	30.00	0.01	-1.30	0.954
	Kerosene hob	Number of kerosene hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		The amount of kerosene use for cooking per day	l/p/d									
Miscellaneous appliances	Hair dryer	Number of hair dryers in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each hair dryer per capita per week	min/p/w	1.15	1.00	0.40	0.16	0.71	2.50	1.45	2.28	0.023
		Wattage of each hair dryer	Watt	1335.87	1300.00	384.19	147600.3	800.00	2000.00	0.25	-1.17	199.989
	Vacuum cleaner	Number of vacuum cleaners in use in a household	No.	0.79	1.00	0.41	0.17	0.00	1.00	-1.47	0.18	0.042
		Duration of use of each vacuum cleaner per capita per week	hr/p/w	0.10	0.10	0.02	0.00	0.07	0.17	0.84	0.43	0.002
		Wattage of each vacuum cleaner	Watt	1093.15	1100.00	220.69	48702.44	700.00	1450.00	-0.19	-1.05	111.024
	Sewing machine	Number of sewing machines in use in a household	No.	0.79	1.00	0.41	0.17	0.00	1.00	-1.47	0.18	0.050
		Duration of use of each sewing machine per capita per week	hr/p/w	0.27	0.25	0.06	0.00	0.20	0.33	-0.01	-1.65	0.009
		Wattage of each sewing machine	Watt	99.78	100.00	11.54	133.15	80.00	119.00	-0.01	-1.00	5.136
	Iron	Number of irons in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each iron per capita per week	hr/p/w	0.11	0.10	0.04	0.00	0.06	0.25	1.47	2.42	0.002
		Wattage of each iron	Watt	1290.22	1300.00	145.87	21276.88	1050.00	1500.00	0.01	-1.19	72.867

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Table D3.3 Summary of energy end-uses parameters for medium income households (176 households) in winter season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Space heating	Electrical heater	Number of electrical heaters in use in a household	No.	0.86	1.00	0.35	0.12	0.00	1.00	-2.07	2.30	0.052
		Duration of use of each electrical heater per capita per day	hr/p/d	0.97	1.20	0.52	0.27	0.00	1.50	-0.88	-0.53	0.087
		Wattage of each electrical heater	Watt	1017.88	1000.00	378.11	142968.5	800.00	1250.00	-1.60	1.31	56.250
	Kerosene heater	Number of kerosene heaters in use in a household	No.	2.86	3.00	0.35	0.12	2.00	3.00	-2.07	2.30	0.052
		Duration of use of each kerosene heater per capita per day	hr/p/d	2.25	2.14	0.83	0.69	1.18	4.00	1.00	0.25	0.124
		Volume of kerosene use by each heater per hour	l/htr/hr	0.28	0.28	0.03	0.00	0.22	0.35	0.03	-0.83	0.005
		Volume of kerosene use by each heater per day	l/htr/d	4.01	4.00	0.58	0.33	3.00	5.00	0.00	-0.85	0.086
	Gas heaters	Number of gas heaters in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Number of days each gas bottle is last for gas heater	d									
	Air conditioners	Number of air conditioners in use in a household	No.	1.23	1.00	0.42	0.18	1.00	2.00	1.31	-0.28	0.063
		Duration of use of each air conditioner per capita per day	hr/p/d	1.01	1.00	0.29	0.08	0.50	1.40	-0.42	-0.92	0.043
		Wattage of each air conditioner	Watt	3034.09	3050.00	146.10	21345.45	2800.00	3250.00	-0.12	-1.22	21.735
Lighting	Spot lights	Number of spot lights in use per day in a household	No.	7.97	8.00	1.88	3.54	5.00	11.00	-0.07	-0.82	0.280
		Duration of use of each spot light per capita per day	hr/p/d	1.45	1.43	0.34	0.12	0.83	2.00	0.13	-0.95	0.051
	Tube lights	Number of tube lights in use per day in a household	No.	4.02	4.00	1.02	1.04	2.00	6.00	-0.41	0.54	0.152
		Duration of use of each tube light per capita per day	hr/p/d	1.44	1.40	0.49	0.24	0.70	2.50	1.03	0.63	0.071
Wet appliances	Water pumps	Number of water pumps in use in a household	No.	0.73	1.00	0.44	0.20	0.00	1.00	-1.06	-0.88	0.018
		Duration of use of each water pump per capita per week	hr/p/w	0.76	0.75	0.09	0.01	0.60	0.88	-0.37	-0.94	0.016
		Wattage of each water pump	Watt	379.92	360.00	170.45	29053.06	340.00	430.00	-0.99	-0.93	5.151
	Dishwasher	Number of dishwashing machines in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each dishwasher per capita per week	hr/p/w									
		Wattage of each dishwasher	Watt									
	Clothes washer	Number of clothes washing machines in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Energy consumption per washing cycle	kWh/wsl	0.61	0.63	0.07	0.01	0.50	0.73	-0.01	-1.12	0.011
Water heating	Electrical water heater	Total consumption of heated water per capita per day	l/p/d	89.35	89.06	17.06	291.03	59.84	133.43	0.08	-0.90	2.538
		Total energy consumption for water heating per capita per day	kWh/p/d	5.19	5.18	0.99	0.98	3.48	7.76	0.08	-0.90	0.148

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.3 Summary of energy end-uses parameters for medium income households (176 households) in winter season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Refrigeration appliances	Chest-freezer	Number of chest-freezers in a household	No.	1.03	1.00	0.17	0.03	1.00	2.00	5.73	31.14	0.136
		Wattage of each chest-freezer	Watt	383.01	380.00	27.37	749.17	340.00	430.00	0.11	-1.09	10.996
	Fridge-freezer	No. of fridge-freezers in a household	No.	1.39	1.00	0.49	0.24	1.00	2.00	0.45	-1.82	0.196
		Wattage of each fridge-freezer	Watt	294.32	300.00	28.94	837.25	250.00	340.00	-0.01	-1.22	11.857
Electronic appliances	TV	Number of TVs in use in a household	No.	2.01	2.00	0.54	0.30	1.00	3.00	0.01	0.43	0.203
		Duration of use of each TV per capita per day	hr/p/d	1.43	1.29	0.66	0.44	0.82	3.00	1.80	1.76	0.073
		Wattage of each TV	Watt	191.05	187.50	37.16	1380.75	130.00	250.00	0.02	-1.24	16.039
	Radio	Number of radios in use in a household	No.	0.14	0.00	0.35	0.12	0.00	1.00	2.07	2.30	0.048
		Duration of use of each radio per capita per day	hr/p/d	0.39	0.33	0.12	0.01	0.27	0.71	1.37	1.36	0.042
		Wattage of each radio	Watt	94.40	100.00	26.11	681.92	50.00	130.00	-0.31	-1.20	11.027
	Computer	Number of computers in use in a household	No.	0.85	1.00	0.42	0.18	0.00	2.00	-0.95	1.34	0.151
		Duration of use of each computer per capita per day	hr/p/d	0.46	0.43	0.19	0.04	0.00	0.75	-0.32	0.21	0.050
		Wattage of each computer	Watt	135.00	135.00	42.41	1798.69	65.00	205.00	0.00	-1.16	15.674
	Video record	Number of video records in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each video record per capita per day	hr/p/d									
		Wattage of each video record	Watt									
	CD player	Number of CD players in use in a household	No.	0.02	0.00	0.15	0.02	0.00	1.00	6.46	40.19	0.008
		Duration of use of each CD player per capita per day	hr/p/d	0.10	0.10	0.01	0.00	0.09	0.11	0.85	-1.29	0.042
		Wattage of each CD player	Watt	32.88	33.00	4.85	23.55	25.00	40.00	-0.04	-1.25	1.364
	Play station	Number of play stations in use in a household	No.	0.38	0.00	0.49	0.24	0.00	1.00	0.50	-1.77	0.048
		Duration of use of each play station per capita per day	hr/p/d	0.14	0.13	0.05	0.00	0.08	0.30	1.84	2.28	0.018
		Wattage of each play station	Watt	169.10	170.00	5.54	30.70	160.00	178.00	0.06	-1.15	1.574
Cooking appliances	Electrical hob	Number of electrical hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each electrical hob per capita per day	hr/p/d									
		Wattage of each electrical hob	Watt									

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.3 Summary of energy end-uses parameters for medium income households (176 households) in winter season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cooking appliances	Electrical oven	Number of electrical ovens in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each electrical oven per capita per week	hr/p/w	0.44	0.43	0.08	0.01	0.33	0.60	0.65	-0.60	0.007
		Wattage of each electrical oven	Watt	2841.48	2850.00	306.01	93641.23	2400.00	3300.00	0.01	-1.44	88.571
	Electrical kettle	Number of electrical kettles in use in a household	No.	0.65	1.00	0.48	0.23	0.00	1.00	-0.62	-1.63	0.041
		Duration of use of each electrical kettles per capita per day	min/p/d	1.00	1.00	0.30	0.09	0.45	1.50	0.03	-1.39	0.040
		Wattage of each electrical kettle	Watt	2468.42	2500.00	277.57	77047.04	2000.00	2900.00	-0.03	-1.11	79.681
	Microwave oven	Number of microwave ovens in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each microwave oven per capita per day	min/p/d									
		Wattage of each microwave oven	Watt									
	Toaster	Number of toasters in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each toaster per capita per day	min/p/d									
		Wattage of each toaster	Watt									
	Gas hob	Number of gas hobs in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Number of days each gas bottle is last for cooking	d	15.81	15.00	3.70	13.67	10.00	23.00	0.48	0.05	0.722
	Kerosene hob	Number of kerosene hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		The amount of kerosene use for cooking per day	l/p/d									
Miscellaneous appliances	Hair dryer	Number of hair dryers in use in a household	No.	1.44	1.00	0.50	0.25	1.00	2.00	0.23	-1.97	0.141
		Duration of use of each hair dryer per capita per week	min/p/w	1.34	1.25	0.64	0.41	0.71	2.92	1.10	0.39	0.158
		Wattage of each hair dryer	Watt	1378.98	1400.00	369.96	136869.81	800.00	2000.00	0.04	-1.05	110.746
	Vacuum cleaner	Number of vacuum cleaners in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each vacuum cleaner per capita per week	hr/p/w	0.17	0.19	0.05	0.00	0.10	0.25	-0.29	-1.20	0.007
		Wattage of each vacuum cleaner	Watt	1106.25	1150.00	227.57	51789.29	700.00	1450.00	-0.28	-1.25	34.667
	Sewing machine	Number of sewing machines in use in a household	No.	0.93	1.00	0.26	0.07	0.00	1.00	-3.29	8.90	0.037
		Duration of use of each sewing machine per capita per week	hr/p/w	0.26	0.25	0.04	0.00	0.20	0.33	0.12	-0.30	0.006
		Wattage of each sewing machine	Watt	99.72	100.00	11.38	129.46	80.00	119.00	-0.07	-1.13	1.760
	Iron	Number of irons in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each iron per capita per week	hr/p/w	0.22	0.21	0.09	0.01	0.06	0.38	0.19	-0.74	0.014
		Wattage of each iron	Watt	1269.03	1250.00	142.00	20164.20	1050.00	1500.00	0.08	-1.22	21.761

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Table D3.4 Summary of energy end-uses parameters for high income households (139 households) in winter season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Space heating	Electrical heater	Number of electrical heaters in use in a household	No.	0.94	1.00	0.25	0.06	0.00	1.00	-3.58	10.95	0.071
		Duration of use of each electrical heater per capita per day	hr/p/d	0.78	0.78	0.33	0.11	0.38	1.29	0.25	-1.26	0.076
		Wattage of each electrical heater	Watt	1244.2	1250.00	181.82	33059.90	1000.00	1450.00	-2.36	13.83	43.020
	Kerosene heater	Number of kerosene heaters in use in a household	No.	3.06	3.00	0.25	0.06	3.00	4.00	3.58	10.95	0.115
		Duration of use of each kerosene heater per capita per day	hr/p/d	1.92	1.86	0.69	0.48	1.17	5.33	1.99	4.96	0.187
		Volume of kerosene use by each heater per hour	l/htr/hr	0.28	0.28	0.03	0.00	0.22	0.33	-0.08	-1.09	0.005
		Volume of kerosene use by each heater per day	l/htr/d	4.18	4.00	0.68	0.46	3.00	5.50	0.00	-0.83	0.219
	Gas heaters	Number of gas heaters in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Number of days each gas bottle is last for gas heater	d									
	Air conditioners	Number of air conditioners in use in a household	No.	2.43	2.00	0.50	0.25	2.00	3.00	0.28	-1.95	0.109
		Duration of use of each air conditioner per capita per day	hr/p/d	1.37	1.50	0.41	0.17	0.90	3.00	0.96	1.31	0.109
		Wattage of each air conditioner	Watt	3231.65	3250.00	147.09	21635.65	3000.00	3450.00	-0.06	-1.29	44.114
Lighting	Spot lights	Number of spot lights in use per day in a household	No.	13.01	12.00	2.02	4.09	7.00	18.00	0.39	0.30	0.559
		Duration of use of each spot light per capita per day	hr/p/d	1.24	1.25	0.30	0.09	0.77	2.33	0.95	1.05	0.091
	Tube lights	Number of tube lights in use per day in a household	No.	5.00	5.00	1.04	1.09	2.00	7.00	-0.04	-0.18	0.333
		Duration of use of each tube light per capita per day	hr/p/d	1.24	1.25	0.30	0.09	0.77	2.33	0.95	1.05	0.091
Wet appliances	Water pumps	Number of water pumps in use in a household	No.	0.35	0.00	0.48	0.23	0.00	1.00	0.66	-1.59	0.029
		Duration of use of each water pump per capita per week	hr/p/w	0.82	0.80	0.11	0.01	0.60	1.00	0.28	0.11	0.031
		Wattage of each water pump	Watt	385.63	0.00	184.61	34081.21	340.00	430.00	0.68	-1.53	7.358
	Dishwasher	Number of dishwashing machines in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each dishwasher per capita per week	hr/p/w									
		Wattage of each dishwasher	Watt									
	Clothes washer	Number of clothes washing machines in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Energy consumption per washing cycle	kWh/wsl	0.53	0.58	0.17	0.03	0.22	0.73	-0.89	-0.55	0.028
Water heating	Electrical water heater	Total consumption of heated water per capita per day	l/p/d	94.69	94.13	13.74	188.70	63.01	129.95	0.19	-0.10	2.304
		Total energy consumption for water heating per capita per day	kWh/p/d	5.51	5.47	0.80	0.64	3.66	7.56	0.19	-0.10	0.134

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.4 Summary of energy end-uses parameters for high income households (139 households) in winter season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Refrigeration appliances	Chest-freezer	Number of chest-freezers in a household	No.	1.60	2.00	0.49	0.24	1.00	2.00	-0.43	-1.84	0.173
		Wattage of each chest-freezer	Watt	387.63	390.00	28.30	800.84	340.00	430.00	0.01	-1.26	11.855
	Fridge-freezer	No. of fridge-freezers in a household	No.	1.81	2.00	0.40	0.16	1.00	2.00	-1.56	0.45	0.190
		Wattage of each fridge-freezer	Watt	294.82	290.00	28.62	819.35	250.00	340.00	0.04	-1.19	14.886
Electronic appliances	TV	Number of TVs in use in a household	No.	2.55	3.00	0.51	0.26	1.00	3.00	-0.38	-1.48	0.171
		Duration of use of each TV per capita per day	hr/p/d	1.24	1.13	0.44	0.19	0.54	3.00	0.56	0.61	0.129
		Wattage of each TV	Watt	187.99	185.00	36.90	1361.49	130.00	250.00	0.01	-1.22	22.123
	Radio	Number of radios in use in a household	No.	0.27	0.00	0.45	0.20	0.00	1.00	1.03	-0.96	0.051
		Duration of use of each radio per capita per day	hr/p/d	0.40	0.38	0.14	0.02	0.23	0.71	0.82	-0.17	0.049
		Wattage of each radio	Watt	91.18	95.00	27.79	772.21	40.00	135.00	-0.46	-0.84	15.151
	Computer	Number of computers in use in a household	No.	1.55	2.00	0.58	0.34	1.00	3.00	0.49	-0.69	0.272
		Duration of use of each computer per capita per day	hr/p/d	0.28	0.30	0.18	0.03	0.08	1.00	0.80	0.57	0.057
		Wattage of each computer	Watt	134.64	135.00	45.81	2098.42	65.00	205.00	0.01	-1.43	21.737
	Video record	Number of video records in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each video record per capita per day	hr/p/d									
		Wattage of each video record	Watt									
	CD player	Number of CD players in use in a household	No.	0.50	1.00	0.50	0.25	0.00	1.00	-0.01	-2.03	0.225
		Duration of use of each CD player per capita per day	hr/p/d	0.11	0.11	0.02	0.00	0.08	0.14	0.03	-1.29	0.021
		Wattage of each CD player	Watt	32.11	32.00	4.76	22.66	25.00	40.00	0.04	-1.24	2.590
	Play station	Number of play stations in use in a household	No.	0.62	1.00	0.49	0.24	0.00	1.00	-0.49	-1.78	0.192
		Duration of use of each play station per capita per day	hr/p/d	0.18	0.13	0.10	0.01	0.08	0.45	1.22	0.34	0.051
		Wattage of each play station	Watt	168.02	168.00	5.59	31.20	160.00	178.00	0.28	-0.94	2.568
Cooking appliances	Electrical hob	Number of electrical hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each electrical hob per capita per day	hr/p/d									
		Wattage of each electrical hob	Watt									

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.4 Summary of energy end-uses parameters for high income households (139 households) in winter season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cooking appliances	Electrical oven	Number of electrical ovens in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each electrical oven per capita per week	hr/p/w	0.60	0.60	0.06	0.00	0.46	0.80	1.15	2.57	0.009
		Wattage of each electrical oven	Watt	2821.58	2800.00	291.36	84893.13	2400.00	3300.00	0.26	-1.15	60.973
	Electrical kettle	Number of electrical kettles in use in a household	No.	0.62	1.00	0.49	0.24	0.00	1.00	-0.49	-1.78	0.012
		Duration of use of each electrical kettles per capita per day	min/p/d	0.72	0.63	0.23	0.05	0.38	1.36	1.01	0.25	0.050
		Wattage of each electrical kettle	Watt	2467.44	2500.00	265.44	70456.91	2000.00	2900.00	-0.03	-1.07	56.910
	Microwave oven	Number of microwave ovens in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each microwave oven per capita per day	min/p/d									
		Wattage of each microwave oven	Watt									
	Toaster	Number of toasters in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each toaster per capita per day	min/p/d									
		Wattage of each toaster	Watt									
	Gas hob	Number of gas hobs in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Number of days each gas bottle is last for cooking	d	10.51	12.00	2.44	5.96	8.00	19.00	0.69	1.02	0.417
	Kerosene hob	Number of kerosene hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		The amount of kerosene use for cooking per day	l/p/d									
Miscellaneous appliances	Hair dryer	Number of hair dryers in use in a household	No.	1.65	2.00	0.48	0.23	1.00	2.00	-0.66	-1.59	0.089
		Duration of use of each hair dryer per capita per week	min/p/w	2.12	1.88	0.80	0.63	1.00	3.57	0.83	-0.65	0.148
		Wattage of each hair dryer	Watt	1388.49	1400.00	378.03	142906.68	800.00	2000.00	0.04	-1.14	83.526
	Vacuum cleaner	Number of vacuum cleaners in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each vacuum cleaner per capita per week	hr/p/w	0.22	0.21	0.04	0.00	0.10	0.28	-0.78	1.04	0.007
		Wattage of each vacuum cleaner	Watt	1060.07	1050.00	211.72	44825.36	700.00	1450.00	0.14	-1.00	44.807
	Sewing machine	Number of sewing machines in use in a household	No.	0.93	1.00	0.26	0.07	0.00	1.00	-3.35	9.35	0.052
		Duration of use of each sewing machine per capita per week	hr/p/w	0.26	0.25	0.03	0.00	0.20	0.33	-0.13	-0.71	0.006
		Wattage of each sewing machine	Watt	100.62	101.00	11.53	132.83	81.00	119.00	-0.13	-1.16	2.410
	Iron	Number of irons in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each iron per capita per week	hr/p/w	0.24	0.25	0.06	0.00	0.12	0.36	0.04	-0.78	0.011
		Wattage of each iron	Watt	1278.06	1250.00	140.54	19750.55	1050.00	1500.00	0.03	-1.23	31.381

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Table D3.5 Summary of energy end-uses parameters for all surveyed households (407 households) in summer season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Space cooling	Fan	Number of fans in use in a household	No.	3.60	4.00	0.59	0.35	2.00	5.00	-0.88	0.17	0.076
		Duration of use of each fan per capita per day	hr/p/d	2.66	2.33	1.17	1.37	1.08	9.00	1.71	4.67	0.113
		Wattage of each fan	Watt	104.78	100.00	8.97	80.46	90.00	120.00	0.15	-1.09	1.081
	Air-cooler	Number of air-coolers in use in a household	No.	0.83	1.00	0.43	0.18	0.00	2.00	-0.90	0.97	0.023
		Duration of use of each air-cooler per capita per day	hr/p/d	2.51	2.25	1.27	1.60	0.77	9.00	2.15	6.56	0.086
		Wattage of each air-cooler	Watt	303.39	300.00	28.57	816.41	260.00	350.00	0.07	-1.21	3.415
	Air conditioners	Number of air conditioners in use in a household	No.	1.36	1.00	0.99	0.98	0.00	3.00	0.14	-1.01	0.079
		Duration of use of each air conditioner per capita per day	hr/p/d	1.42	1.50	0.39	0.15	0.70	4.00	0.87	5.34	0.050
		Wattage of each air conditioner	Watt	3118.20	3100.00	184.24	33945.62	2150.00	3450.00	-0.42	1.35	22.759
Lighting	Spot lights	Number of spot lights in use per day in a household	No.	9.04	9.00	3.59	12.92	2.00	18.00	0.27	-0.65	0.334
		Duration of use of each spot light per capita per day	hr/p/d	1.22	1.13	0.46	0.21	0.54	3.50	1.52	3.86	0.044
	Tube lights	Number of tube lights in use per day in a household	No.	4.03	4.00	1.29	1.66	2.00	7.00	0.12	-0.53	0.135
		Duration of use of each tube light per capita per day	hr/p/d	1.22	1.00	0.45	0.20	0.64	3.50	1.51	4.09	0.044
Wet appliances	Water pumps	Number of water pumps in use in a household	No.	0.50	0.00	0.50	0.25	0.00	1.00	0.00	-2.01	0.062
		Duration of use of each water pump per capita per week	hr/p/w	1.06	1.00	0.08	0.01	0.92	1.25	0.84	-0.50	0.012
		Wattage of each water pump	Watt	381.48	380.00	28.68	822.56	340.00	430.00	0.09	-1.19	4.002
	Dishwasher	Number of dishwashing machines in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each dishwasher per capita per week	hr/p/w									
		Wattage of each dishwasher	Watt									
	Clothes washer	Number of clothes washing machines in use in a household	No.	0.94	1.00	0.23	0.05	0.00	1.00	-3.86	12.93	0.025
		Energy consumption per washing cycle	kWh/wsl	0.51	0.55	0.19	0.04	0.00	0.73	-1.02	0.29	0.019
Water heating	Electrical water heater	Total consumption of heated water per capita per day	l/p/d	0.00	0.00	0.00	0.00	0.00	0.00			
		Total energy consumption for water heating per capita per day	kWh/p/d	0.00	0.00	0.00	0.00	0.00	0.00			

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.5 Summary of energy end-uses parameters for <u>all surveyed households</u> (407 households) in <u>summer season</u>

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Refrigeration appliances	Chest-freezer	Number of chest-freezers in a household	No.	1.08	1.00	0.60	0.36	0.00	2.00	-0.03	-0.21	0.076
		Wattage of each chest-freezer	Watt	384.38	380.00	28.21	795.96	340.00	430.00	0.08	-1.18	6.783
	Fridge-freezer	No. of fridge-freezers in a household	No.	1.44	1.00	0.50	0.25	1.00	2.00	0.22	-1.96	0.109
		Wattage of each fridge-freezer	Watt	294.20	300.00	28.99	840.68	250.00	340.00	0.00	-1.25	7.438
Electronic appliances	TV	Number of TVs in use in a household	No.	2.04	2.00	0.69	0.48	1.00	3.00	-0.05	-0.90	0.129
		Duration of use of each TV per capita per day	hr/p/d	1.53	1.33	0.65	0.42	0.54	4.50	1.33	2.68	0.098
		Wattage of each TV	Watt	175.10	175.00	45.83	2100.61	70.00	250.00	-0.25	-0.63	9.832
	Radio	Number of radios in use in a household	No.	0.15	0.00	0.36	0.13	0.00	1.00	1.92	1.68	0.133
		Duration of use of each radio per capita per day	hr/p/d	0.40	0.38	0.13	0.02	0.23	0.71	0.94	0.08	0.032
		Wattage of each radio	Watt	92.46	95.00	26.97	727.32	40.00	135.00	-0.41	-0.93	6.845
	Computer	Number of computers in use in a household	No.	1.11	1.00	0.55	0.31	0.00	3.00	0.57	1.66	0.145
		Duration of use of each computer per capita per day	hr/p/d	0.49	0.43	0.18	0.03	0.23	1.00	1.08	0.83	0.021
		Wattage of each computer	Watt	134.38	135.00	43.08	1855.57	65.00	205.00	0.04	-1.25	10.769
	Video record	Number of video records in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each video record per capita per day	hr/p/d									
		Wattage of each video record	Watt									
	CD player	Number of CD players in use in a household	No.	0.18	0.00	0.39	0.15	0.00	1.00	1.66	0.75	0.201
		Duration of use of each CD player per capita per day	hr/p/d	0.11	0.11	0.02	0.00	0.08	0.14	0.10	-1.26	0.004
		Wattage of each CD player	Watt	32.15	31.50	4.60	21.14	25.00	40.00	0.11	-1.07	1.411
	Play station	Number of play stations in use in a household	No.	0.38	0.00	0.48	0.24	0.00	1.00	0.51	-1.74	0.037
		Duration of use of each play station per capita per day	hr/p/d	0.39	0.38	0.08	0.01	0.23	0.64	0.63	0.61	0.024
		Wattage of each play station	Watt	168.50	168.00	5.57	31.07	160.00	178.00	0.18	-1.06	1.806
Cooking appliances	Electrical hob	Number of electrical hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each electrical hob per capita per day	hr/p/d									
		Wattage of each electrical hob	Watt									

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.5 Summary of energy end-uses parameters for all surveyed households (407 households) in summer season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cooking appliances	Electrical oven	Number of electrical ovens in use in a household	No.	0.94	1.00	0.23	0.05	0.00	1.00	-3.86	12.93	0.055
		Duration of use of each electrical oven per capita per week	hr/p/w	0.62	0.56	0.28	0.08	0.33	1.67	2.47	6.57	0.016
		Wattage of each electrical oven	Watt	2827.34	2800.00	295.85	87527.13	2400.00	3300.00	0.14	-1.30	40.783
	Electrical kettle	Number of electrical kettles in use in a household	No.	0.59	1.00	0.49	0.24	0.00	1.00	-0.38	-1.87	0.032
		Duration of use of each electrical kettles per capita per day	min/p/d	1.10	1.11	0.31	0.10	0.42	1.67	-0.16	-0.69	0.044
		Wattage of each electrical kettle	Watt	2467.63	2500.00	276.04	76198.13	2000.00	2900.00	-0.02	-1.15	37.685
	Microwave oven	Number of microwave ovens in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each microwave oven per capita per day	min/p/d									
		Wattage of each microwave oven	Watt									
	Toaster	Number of toasters in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each toaster per capita per day	min/p/d									
		Wattage of each toaster	Watt									
	Gas hob	Number of gas hobs in use in a household	No.	1	1	0	0	1	1	0.00	0.00	0.00
		Number of days each gas bottle is last for cooking	d	15.64	14	6.53	42.66	8	30	0.85	-0.25	0.636
	Kerosene hob	Number of kerosene hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		The amount of kerosene use for cooking per day	l/p/d									
Miscellaneous appliances	Hair dryer	Number of hair dryers in use in a household	No.	1.42	1.00	0.49	0.24	1.00	2.00	0.35	-1.89	0.068
		Duration of use of each hair dryer per capita per week	min/p/w	1.56	1.36	0.77	0.60	0.71	3.57	1.13	0.64	0.109
		Wattage of each hair dryer	Watt	1372.48	1400.00	375.58	141063.5	800.00	2000.00	0.09	-1.13	52.162
	Vacuum cleaner	Number of vacuum cleaners in use in a household	No.	0.95	1.00	0.21	0.04	0.00	1.00	-4.31	16.69	0.059
		Duration of use of each vacuum cleaner per capita per week	hr/p/w	0.23	0.21	0.06	0.00	0.13	0.38	0.56	0.34	0.004
		Wattage of each vacuum cleaner	Watt	1087.24	1100.00	221.13	48900.13	700.00	1450.00	-0.11	-1.18	29.704
	Sewing machine	Number of sewing machines in use in a household	No.	0.90	1.00	0.30	0.09	0.00	1.00	-2.62	4.88	0.047
		Duration of use of each sewing machine per capita per week	hr/p/w	0.26	0.25	0.04	0.00	0.20	0.33	0.10	-0.80	0.004
		Wattage of each sewing machine	Watt	100.05	100.00	11.44	130.84	80.00	119.00	-0.08	-1.12	1.575
	Iron	Number of irons in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each iron per capita per week	hr/p/w	0.21	0.21	0.09	0.01	0.06	0.50	0.34	-0.45	0.007
		Wattage of each iron	Watt	1276.90	1250.00	142.27	20241.13	1050.00	1500.00	0.05	-1.21	19.681

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Table D3.6 Summary of energy end-uses parameters for low income households (92 households) in summer season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Space cooling	Fan	Number of fans in use in a household	No.	3.68	4.00	0.55	0.31	3.00	5.00	0.01	-0.63	0.131
		Duration of use of each fan per capita per day	hr/p/d	3.71	3.50	1.38	1.91	2.00	9.00	1.71	3.65	0.353
		Wattage of each fan	Watt	106.28	105.00	9.01	81.19	90.00	120.00	0.14	-1.24	2.074
	Air-cooler	Number of air-coolers in use in a household	No.	0.80	1.00	0.40	0.16	0.00	1.00	-1.56	0.44	0.029
		Duration of use of each air-cooler per capita per day	hr/p/d	4.02	3.60	1.59	2.53	2.00	9.00	1.54	1.90	0.368
		Wattage of each air-cooler	Watt	309.73	310.00	30.65	939.65	260.00	350.00	-0.22	-1.27	7.102
	Air conditioners	Number of air conditioners in use in a household	No.	0.01	0.00	0.10	0.01	0.00	1.00	9.59	92.00	0.022
		Duration of use of each air conditioner per capita per day	hr/p/d	1.78	1.78	0.024	0.00	1.23	1.78	9.59	92.00	0.012
		Wattage of each air conditioner	Watt	2150.00	2150.00	224.15	50244.57	2150.00	2150.00	9.59	92.00	46.421
Lighting	Spot lights	Number of spot lights in use per day in a household	No.	5.10	5.00	1.64	2.68	2.00	7.00	-0.07	-1.38	0.339
		Duration of use of each spot light per capita per day	hr/p/d	1.71	1.75	0.53	0.28	0.78	3.50	1.16	2.22	0.110
	Tube lights	Number of tube lights in use per day in a household	No.	2.60	3.00	0.49	0.24	2.00	3.00	-0.41	-1.88	0.102
		Duration of use of each tube light per capita per day	hr/p/d	1.70	1.50	0.50	0.25	0.78	3.50	1.67	3.88	0.103
Wet appliances	Water pumps	Number of water pumps in use in a household	No.	0.28	0.00	0.45	0.20	0.00	1.00	0.98	-1.06	0.036
		Duration of use of each water pump per capita per week	hr/p/w	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Wattage of each water pump	Watt	381.54	380.00	30.29	917.54	340.00	430.00	0.11	-1.34	12.235
	Dishwasher	Number of dishwashing machines in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each dishwasher per capita per week	hr/p/w									
		Wattage of each dishwasher	Watt									
	Clothes washer	Number of clothes washing machines in use in a household	No.	0.75	1.00	0.44	0.19	0.00	1.00	-1.17	-0.64	0.077
		Energy consumption per washing cycle	kWh/wsl	0.23	0.31	0.14	0.02	0.00	0.35	-1.12	-0.68	0.029
Water heating	Electrical water heater	Total consumption of heated water per capita per day	l/p/d	0.00	0.00	0.00	0.00	0.00	0.00			
		Total energy consumption for water heating per capita per day	kWh/p/d	0.00	0.00	0.00	0.00	0.00	0.00			

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.6 Summary of energy end-uses parameters for low income households (92 households) in summer season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Refrigeration appliances	Chest-freezer	Number of chest-freezers in a household	No.	0.37	0.00	0.49	0.24	0.00	1.00	0.55	-1.74	0.114
		Wattage of each chest-freezer	Watt	378.24	380.00	31.28	978.61	340.00	430.00	0.29	-1.29	10.915
	Fridge-freezer	No. of fridge-freezers in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Wattage of each fridge-freezer	Watt	293.04	290.00	29.94	896.13	250.00	340.00	-0.01	-1.39	11.436
Electronic appliances	TV	Number of TVs in use in a household	No.	1.30	1.00	0.46	0.21	1.00	2.00	0.86	-1.28	0.135
		Duration of use of each TV per capita per day	hr/p/d	2.12	2.00	0.49	0.24	1.33	4.50	3.69	16.38	0.052
		Wattage of each TV	Watt	125.11	125.00	37.14	1379.66	70.00	190.00	0.15	-1.37	12.646
	Radio	Number of radios in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each radio per capita per day	hr/p/d									
		Wattage of each radio	Watt									
	Computer	Number of computers in use in a household	No.	0.93	1.00	0.25	0.06	0.00	1.00	-3.58	11.06	0.057
		Duration of use of each computer per capita per day	hr/p/d	0.65	0.60	0.19	0.03	0.33	1.00	0.84	-0.42	0.013
		Wattage of each computer	Watt	131.22	130.00	40.20	1616.43	65.00	205.00	0.17	-1.05	13.412
	Video record	Number of video records in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each video record per capita per day	hr/p/d									
		Wattage of each video record	Watt									
	CD player	Number of CD players in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each CD player per capita per day	hr/p/d									
		Wattage of each CD player	Watt									
	Play station	Number of play stations in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each play station per capita per day	hr/p/d									
		Wattage of each play station	Watt									
Cooking appliances	Electrical hob	Number of electrical hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each electrical hob per capita per day	hr/p/d									
		Wattage of each electrical hob	Watt									

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.6 Summary of energy end-uses parameters for low income households (92 households) in summer season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cooking appliances	Electrical oven	Number of electrical ovens in use in a household	No.	0.75	1.00	0.44	0.19	0.00	1.00	-1.17	-0.64	0.081
		Duration of use of each electrical oven per capita per week	hr/p/w	0.92	1.00	0.50	0.25	0.40	1.67	0.49	-1.38	0.013
		Wattage of each electrical oven	Watt	2802.90	2800.00	280.22	78520.89	2400.00	3300.00	0.20	-1.12	142.708
	Electrical kettle	Number of electrical kettles in use in a household	No.	0.45	0.00	0.50	0.25	0.00	1.00	0.22	-1.99	0.027
		Duration of use of each electrical kettles per capita per day	min/p/d	1.26	1.25	0.36	0.13	0.83	1.67	0.02	-1.82	0.046
		Wattage of each electrical kettle	Watt	2465.85	2500.00	299.67	89804.88	2000.00	2900.00	0.01	-1.39	134.546
	Microwave oven	Number of microwave ovens in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each microwave oven per capita per day	min/p/d									
		Wattage of each microwave oven	Watt									
	Toaster	Number of toasters in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each toaster per capita per day	min/p/d									
		Wattage of each toaster	Watt									
	Gas hob	Number of gas hobs in use in a household	No.	1	1	0	0	1	1	0.00	0.00	0.00
		Number of days each gas bottle is last for cooking	d	24.59	22	4.61	21.21	17	30	0.18	-1.61	0.954
	Kerosene hob	Number of kerosene hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		The amount of kerosene use for cooking per day	l/p/d									
Miscellaneous appliances	Hair dryer	Number of hair dryers in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each hair dryer per capita per week	min/p/w	1.15	1.00	0.40	0.16	0.71	2.50	1.44	2.21	0.046
		Wattage of each hair dryer	Watt	1335.87	1300.00	384.19	147600.3	800.00	2000.00	0.25	-1.17	92.360
	Vacuum cleaner	Number of vacuum cleaners in use in a household	No.	0.79	1.00	0.41	0.17	0.00	1.00	-1.47	0.18	0.042
		Duration of use of each vacuum cleaner per capita per week	hr/p/w	0.29	0.30	0.06	0.00	0.21	0.38	0.50	-1.04	0.013
		Wattage of each vacuum cleaner	Watt	1093.15	1100.00	220.69	48702.44	700.00	1450.00	-0.19	-1.05	51.490
	Sewing machine	Number of sewing machines in use in a household	No.	0.79	1.00	0.41	0.17	0.00	1.00	-1.47	0.18	0.050
		Duration of use of each sewing machine per capita per week	hr/p/w	0.27	0.25	0.05	0.00	0.20	0.33	-0.04	-1.66	0.013
		Wattage of each sewing machine	Watt	99.78	100.00	11.54	133.15	80.00	119.00	-0.01	-1.00	2.692
	Iron	Number of irons in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each iron per capita per week	hr/p/w	0.11	0.10	0.04	0.00	0.06	0.25	1.28	1.59	0.005
		Wattage of each iron	Watt	1290.22	1300.00	145.87	21276.88	1050.00	1500.00	0.01	-1.19	33.817

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Table D3.7 Summary of energy end-uses parameters for medium income households (176 households) in summer season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Space cooling	Fan	Number of fans in use in a household	No.	3.49	4.00	0.64	0.41	2.00	4.00	-0.88	-0.29	0.121
		Duration of use of each fan per capita per day	hr/p/d	2.58	2.25	0.93	0.87	1.17	5.50	0.81	-0.10	0.164
		Wattage of each fan	Watt	104.94	105.00	8.77	76.95	90.00	120.00	0.16	-1.01	1.588
	Air-cooler	Number of air-coolers in use in a household	No.	0.99	1.00	0.34	0.11	0.00	2.00	-0.20	5.99	0.049
		Duration of use of each air-cooler per capita per day	hr/p/d	2.16	2.00	0.72	0.52	1.17	3.50	0.72	-0.70	0.122
		Wattage of each air-cooler	Watt	301.33	300.00	27.66	765.28	260.00	350.00	0.21	-1.10	5.082
	Air conditioners	Number of air conditioners in use in a household	No.	1.23	1.00	0.42	0.18	1.00	2.00	1.31	-0.28	0.071
		Duration of use of each air conditioner per capita per day	hr/p/d	1.34	1.29	0.37	0.14	0.70	1.80	-0.38	-1.06	0.063
		Wattage of each air conditioner	Watt	3034.09	3050.00	146.10	21345.45	2800.00	3250.00	-0.12	-1.22	27.060
Lighting	Spot lights	Number of spot lights in use per day in a household	No.	7.97	8.00	1.88	3.54	5.00	11.00	-0.07	-0.82	0.328
		Duration of use of each spot light per capita per day	hr/p/d	1.15	1.13	0.31	0.10	0.58	1.75	0.66	0.05	-0.339
	Tube lights	Number of tube lights in use per day in a household	No.	4.02	4.00	1.02	1.04	2.00	6.00	-0.41	0.54	0.173
		Duration of use of each tube light per capita per day	hr/p/d	1.15	1.13	0.34	0.12	0.64	1.75	0.36	0.05	-0.908
Wet appliances	Water pumps	Number of water pumps in use in a household	No.	0.73	1.00	0.44	0.20	0.00	1.00	-1.06	-0.88	0.018
		Duration of use of each water pump per capita per week	hr/p/w	1.08	1.00	0.09	0.01	1.00	1.25	0.64	-0.89	0.016
		Wattage of each water pump	Watt	379.92	380.00	29.57	874.21	340.00	430.00	0.16	-1.21	5.377
	Dishwasher	Number of dishwashing machines in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each dishwasher per capita per week	hr/p/w									
		Wattage of each dishwasher	Watt									
	Clothes washer	Number of clothes washing machines in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Energy consumption per washing cycle	kWh/wsl	0.61	0.63	0.07	0.01	0.50	0.73	-0.01	-1.12	0.011
Water heating	Electrical water heater	Total consumption of heated water per capita per day	l/p/d	0.00	0.00	0.00	0.00	0.00	0.00			
		Total energy consumption for water heating per capita per day	kWh/p/d	0.00	0.00	0.00	0.00	0.00	0.00			

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.7 Summary of energy end-uses parameters for medium income households (176 households) in summer season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Refrigeration appliances	Chest-freezer	Number of chest-freezers in a household	No.	1.03	1.00	0.17	0.03	1.00	2.00	5.73	31.14	0.136
		Wattage of each chest-freezer	Watt	383.01	380.00	27.37	749.17	340.00	430.00	0.11	-1.09	11.502
	Fridge-freezer	No. of fridge-freezers in a household	No.	1.39	1.00	0.49	0.24	1.00	2.00	0.45	-1.82	0.194
		Wattage of each fridge-freezer	Watt	294.32	300.00	28.94	837.25	250.00	340.00	-0.01	-1.22	12.411
Electronic appliances	TV	Number of TVs in use in a household	No.	2.01	2.00	0.54	0.30	1.00	3.00	0.01	0.43	0.211
		Duration of use of each TV per capita per day	hr/p/d	1.45	1.29	0.66	0.43	0.82	3.00	1.74	1.62	0.092
		Wattage of each TV	Watt	191.05	187.50	37.16	1380.75	130.00	250.00	0.02	-1.24	16.542
	Radio	Number of radios in use in a household	No.	0.14	0.00	0.35	0.12	0.00	1.00	2.07	2.30	0.048
		Duration of use of each radio per capita per day	hr/p/d	0.39	0.33	0.12	0.01	0.27	0.71	1.32	1.21	0.044
		Wattage of each radio	Watt	94.40	100.00	26.11	681.92	50.00	130.00	-0.31	-1.20	11.017
	Computer	Number of computers in use in a household	No.	0.85	1.00	0.42	0.18	0.00	2.00	-0.95	1.34	0.125
		Duration of use of each computer per capita per day	hr/p/d	0.49	0.43	0.15	0.02	0.25	0.75	0.48	-0.99	0.040
		Wattage of each computer	Watt	136.00	135.00	42.20	1781.11	65.00	205.00	-0.01	-1.16	16.015
	Video record	Number of video records in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each video record per capita per day	hr/p/d									
		Wattage of each video record	Watt									
	CD player	Number of CD players in use in a household	No.	0.02	0.00	0.15	0.02	0.00	1.00	6.46	40.19	0.008
		Duration of use of each CD player per capita per day	hr/p/d	0.10	0.10	0.01	0.00	0.09	0.11	0.85	-1.29	0.015
		Wattage of each CD player	Watt	33.25	33.00	4.79	22.92	28.00	39.00	0.24	-1.52	7.617
	Play station	Number of play stations in use in a household	No.	0.38	0.00	0.49	0.24	0.00	1.00	0.50	-1.77	0.048
		Duration of use of each play station per capita per day	hr/p/d	0.37	0.38	0.06	0.00	0.25	0.50	-0.21	-0.89	0.014
		Wattage of each play station	Watt	169.10	170.00	5.54	30.70	160.00	178.00	0.06	-1.15	1.352
Cooking appliances	Electrical hob	Number of electrical hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each electrical hob per capita per day	hr/p/d									
		Wattage of each electrical hob	Watt									

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.7 Summary of energy end-uses parameters for <u>medium income households</u> (176 households) in <u>summer season</u>

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cooking appliances	Electrical oven	Number of electrical ovens in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each electrical oven per capita per week	hr/p/w	0.49	0.50	0.10	0.01	0.33	0.60	-0.35	-1.56	0.018
		Wattage of each electrical oven	Watt	2841.48	2850.00	306.01	93641.23	2400.00	3300.00	0.01	-1.44	56.250
	Electrical kettle	Number of electrical kettles in use in a household	No.	0.65	1.00	0.48	0.23	0.00	1.00	-0.62	-1.63	0.041
		Duration of use of each electrical kettles per capita per day	min/p/d	1.17	1.25	0.25	0.06	0.45	1.50	-0.81	-0.26	0.047
		Wattage of each electrical kettle	Watt	2468.42	2500.00	277.57	77047.04	2000.00	2900.00	-0.03	-1.11	51.505
	Microwave oven	Number of microwave ovens in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each microwave oven per capita per day	min/p/d									
		Wattage of each microwave oven	Watt									
	Toaster	Number of toasters in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each toaster per capita per day	min/p/d									
		Wattage of each toaster	Watt									
	Gas hob	Number of gas hobs in use in a household	No.	1	1	0	0	1	1	0.00	0.00	0.00
		Number of days each gas bottle is last for cooking	d	15.40	14	4.14	17.17	10	24	0.96	0.19	0.616
	Kerosene hob	Number of kerosene hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		The amount of kerosene use for cooking per day	l/p/d									
Miscellaneous appliances	Hair dryer	Number of hair dryers in use in a household	No.	1.44	1.00	0.50	0.25	1.00	2.00	0.23	-1.97	0.076
		Duration of use of each hair dryer per capita per week	min/p/w	1.34	1.25	0.64	0.41	0.71	2.92	1.09	0.37	0.103
		Wattage of each hair dryer	Watt	1378.98	1400.00	369.96	136869.8	800.00	2000.00	0.04	-1.05	56.985
	Vacuum cleaner	Number of vacuum cleaners in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each vacuum cleaner per capita per week	hr/p/w	0.20	0.21	0.05	0.00	0.13	0.30	0.44	-0.46	0.008
		Wattage of each vacuum cleaner	Watt	1106.25	1150.00	227.57	51789.29	700.00	1450.00	-0.28	-1.25	34.667
	Sewing machine	Number of sewing machines in use in a household	No.	0.93	1.00	0.26	0.07	0.00	1.00	-3.29	8.90	0.037
		Duration of use of each sewing machine per capita per week	hr/p/w	0.26	0.25	0.04	0.00	0.20	0.33	0.04	-0.62	0.006
		Wattage of each sewing machine	Watt	99.72	100.00	11.38	129.46	80.00	119.00	-0.07	-1.13	1.760
	Iron	Number of irons in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each iron per capita per week	hr/p/w	0.24	0.21	0.08	0.01	0.13	0.38	0.71	-0.68	0.012
		Wattage of each iron	Watt	1269.03	1250.00	142.00	20164.20	1050.00	1500.00	0.08	-1.22	21.761

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Table D3.8 Summary of energy end-uses parameters for high income households (139 households) in summer season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Space cooling	Fan	Number of fans in use in a household	No.	3.68	4.00	0.53	0.28	2.00	4.00	-1.35	0.88	0.433
		Duration of use of each fan per capita per day	hr/p/d	2.08	2.00	0.75	0.57	1.08	6.00	2.33	8.11	0.848
		Wattage of each fan	Watt	103.60	100.00	9.09	82.65	90.00	120.00	0.18	-1.14	7.411
	Air-cooler	Number of air-coolers in use in a household	No.	0.65	1.00	0.48	0.23	0.00	1.00	-0.66	-1.59	0.036
		Duration of use of each air-cooler per capita per day	hr/p/d	1.90	1.43	0.62	0.39	0.77	4.67	1.27	3.34	0.743
		Wattage of each air-cooler	Watt	301.98	300.00	28.02	784.93	260.00	350.00	0.03	-1.22	21.778
	Air conditioners	Number of air conditioners in use in a household	No.	2.43	2.00	0.50	0.25	2.00	3.00	0.28	-1.95	0.387
		Duration of use of each air conditioner per capita per day	hr/p/d	1.51	1.50	0.40	0.16	0.92	4.00	2.30	10.58	0.514
		Wattage of each air conditioner	Watt	3231.65	3250.00	147.09	21635.65	3000.00	3450.00	-0.06	-1.29	148.211
Lighting	Spot lights	Number of spot lights in use per day in a household	No.	13.01	12.00	2.02	4.09	7.00	18.00	0.39	0.30	2.545
		Duration of use of each spot light per capita per day	hr/p/d	0.97	0.88	0.28	0.08	0.54	2.33	1.21	2.99	0.047
	Tube lights	Number of tube lights in use per day in a household	No.	5.00	5.00	1.04	1.09	2.00	7.00	-0.04	-0.18	1.409
		Duration of use of each tube light per capita per day	hr/p/d	0.98	0.90	0.26	0.07	0.64	2.33	1.97	5.72	0.043
Wet appliances	Water pumps	Number of water pumps in use in a household	No.	0.35	0.00	0.48	0.23	0.00	1.00	0.66	-1.59	0.029
		Duration of use of each water pump per capita per week	hr/p/w	1.06	1.00	0.08	0.01	0.92	1.17	0.38	-1.13	0.031
		Wattage of each water pump	Watt	385.63	390.00	25.34	642.15	340.00	430.00	-0.06	-1.01	24.881
	Dishwasher	Number of dishwashing machines in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each dishwasher per capita per week	hr/p/w									
		Wattage of each dishwasher	Watt									
	Clothes washer	Number of clothes washing machines in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Energy consumption per washing cycle	kWh/wsl	0.53	0.58	0.17	0.03	0.22	0.73	-0.89	-0.55	0.028
Water heating	Electrical water heater	Total consumption of heated water per capita per day	l/p/d	0.00	0.00	0.00	0.00	0.00	0.00			
		Total energy consumption for water heating per capita per day	kWh/p/d	0.00	0.00	0.00	0.00	0.00	0.00			

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.8 Summary of energy end-uses parameters for high income households (139 households) in summer season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Refrigeration appliances	Chest-freezer	Number of chest-freezers in a household	No.	1.60	2.00	0.49	0.24	1.00	2.00	-0.43	-1.84	13.373
		Wattage of each chest-freezer	Watt	387.63	390.00	28.30	800.84	340.00	430.00	0.01	-1.26	11.855
	Fridge-freezer	No. of fridge-freezers in a household	No.	1.81	2.00	0.40	0.16	1.00	2.00	-1.56	0.45	0.190
		Wattage of each fridge-freezer	Watt	294.82	290.00	28.62	819.35	250.00	340.00	0.04	-1.19	16.620
Electronic appliances	TV	Number of TVs in use in a household	No.	2.55	3.00	0.51	0.26	1.00	3.00	-0.38	-1.48	0.168
		Duration of use of each TV per capita per day	hr/p/d	1.24	1.13	0.44	0.19	0.54	3.00	0.56	0.64	0.133
		Wattage of each TV	Watt	187.99	185.00	36.90	1361.49	130.00	250.00	0.01	-1.22	25.791
	Radio	Number of radios in use in a household	No.	0.27	0.00	0.45	0.20	0.00	1.00	1.03	-0.96	0.051
		Duration of use of each radio per capita per day	hr/p/d	0.40	0.38	0.14	0.02	0.23	0.71	0.79	-0.24	0.033
		Wattage of each radio	Watt	91.18	95.00	27.79	772.21	40.00	135.00	-0.46	-0.84	18.729
	Computer	Number of computers in use in a household	No.	1.55	2.00	0.58	0.34	1.00	3.00	0.49	-0.69	0.168
		Duration of use of each computer per capita per day	hr/p/d	0.39	0.38	0.11	0.01	0.23	1.00	2.11	8.25	0.028
		Wattage of each computer	Watt	134.64	135.00	45.81	2098.42	65.00	205.00	0.01	-1.43	24.501
	Video record	Number of video records in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each video record per capita per day	hr/p/d									
		Wattage of each video record	Watt									
	CD player	Number of CD players in use in a household	No.	0.50	1.00	0.50	0.25	0.00	1.00	-0.01	-2.03	0.225
		Duration of use of each CD player per capita per day	hr/p/d	0.11	0.11	0.02	0.00	0.08	0.14	0.03	-1.29	0.006
		Wattage of each CD player	Watt	32.09	31.50	4.61	21.30	25.00	40.00	0.11	-1.07	3.013
	Play station	Number of play stations in use in a household	No.	0.62	1.00	0.49	0.24	0.00	1.00	-0.49	-1.78	0.192
		Duration of use of each play station per capita per day	hr/p/d	0.40	0.38	0.09	0.01	0.23	0.64	0.57	0.02	0.046
		Wattage of each play station	Watt	168.02	168.00	5.59	31.20	160.00	178.00	0.28	-0.94	3.293
Cooking appliances	Electrical hob	Number of electrical hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each electrical hob per capita per day	hr/p/d									
		Wattage of each electrical hob	Watt									

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Continue

Table D3.8 Summary of energy end-uses parameters for high income households (139 households) in summer season

End-use	Appliances	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cooking appliances	Electrical oven	Number of electrical ovens in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each electrical oven per capita per week	hr/p/w	0.63	0.57	0.12	0.01	0.46	0.83	0.39	-1.49	0.022
		Wattage of each electrical oven	Watt	2821.58	2800.00	291.36	84893.13	2400.00	3300.00	0.26	-1.15	60.973
	Electrical kettle	Number of electrical kettles in use in a household	No.	0.62	1.00	0.49	0.24	0.00	1.00	-0.49	-1.78	0.012
		Duration of use of each electrical kettles per capita per day	min/p/d	0.93	1.00	0.27	0.07	0.42	1.36	-0.22	-1.22	0.058
		Wattage of each electrical kettle	Watt	2467.44	2500.00	265.44	70456.91	2000.00	2900.00	-0.03	-1.07	56.910
	Microwave oven	Number of microwave ovens in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each microwave oven per capita per day	min/p/d									
		Wattage of each microwave oven	Watt									
	Toaster	Number of toasters in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		Duration of use of each toaster per capita per day	min/p/d									
		Wattage of each toaster	Watt									
	Gas hob	Number of gas hobs in use in a household	No.	1	1	0	0	1	1	0.00	0.00	0.00
		Number of days each gas bottle is last for cooking	d	10.04	11	2.16	4.69	8	19	1.38	3.68	0.363
	Kerosene hob	Number of kerosene hobs in use in a household	No.	0.00	0.00	0.00	0.00	0.00	0.00			
		The amount of kerosene use for cooking per day	l/p/d									
Miscellaneous appliances	Hair dryer	Number of hair dryers in use in a household	No.	1.65	2.00	0.48	0.23	1.00	2.00	-0.66	-1.59	0.089
		Duration of use of each hair dryer per capita per week	min/p/w	2.12	1.88	0.80	0.63	1.00	3.57	0.82	-0.66	0.148
		Wattage of each hair dryer	Watt	1388.49	1400.00	378.03	142910.0	800.00	2000.00	0.04	-1.14	83.526
	Vacuum cleaner	Number of vacuum cleaners in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each vacuum cleaner per capita per week	hr/p/w	0.23	0.21	0.04	0.00	0.13	0.30	0.20	-0.56	0.007
		Wattage of each vacuum cleaner	Watt	1060.07	1050.00	211.72	44825.36	700.00	1450.00	0.14	-1.00	44.807
	Sewing machine	Number of sewing machines in use in a household	No.	0.93	1.00	0.26	0.07	0.00	1.00	-3.35	9.35	0.052
		Duration of use of each sewing machine per capita per week	hr/p/w	0.26	0.25	0.03	0.00	0.20	0.33	-0.15	-0.88	0.006
		Wattage of each sewing machine	Watt	100.62	101.00	11.53	132.83	81.00	119.00	-0.13	-1.16	2.410
	Iron	Number of irons in use in a household	No.	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
		Duration of use of each iron per capita per week	hr/p/w	0.25	0.25	0.07	0.00	0.12	0.50	0.46	0.44	0.011
		Wattage of each iron	Watt	1278.06	1250.00	140.54	19750.55	1050.00	1500.00	0.03	-1.23	31.381

Note: hr=hour, p=person, d=day, w=week, l=litters, htr=heater, kWh=kiloWatt hour, wsl=clothes washing load, min=minute

Appendix D4 Comparison between Energy End-Uses in Winter and Summer Season

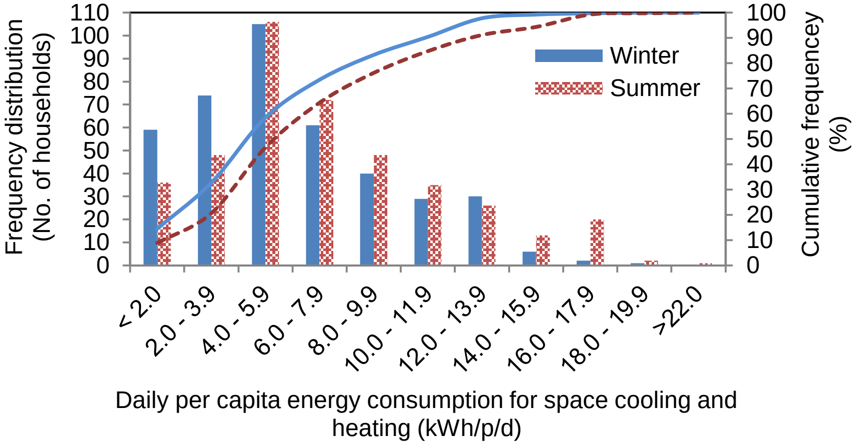


Figure D4.1 Comparison between per capita energy consumption for space cooling and heating in winter and summer

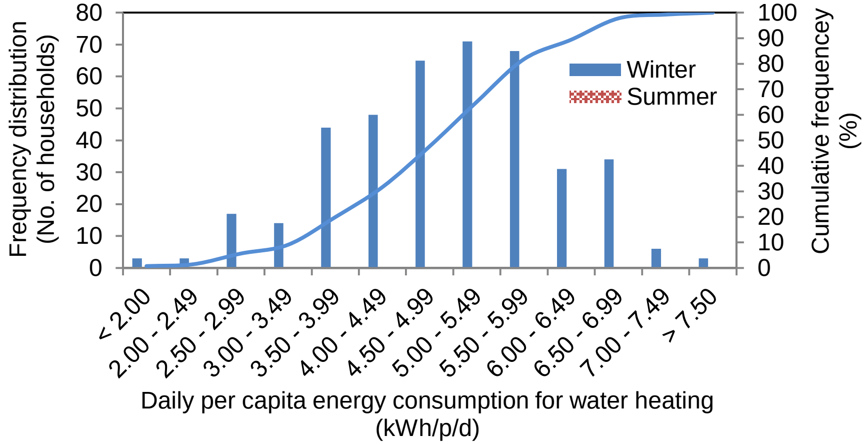


Figure D4.2 Comparison between per capita energy consumption for water heating in winter and summer

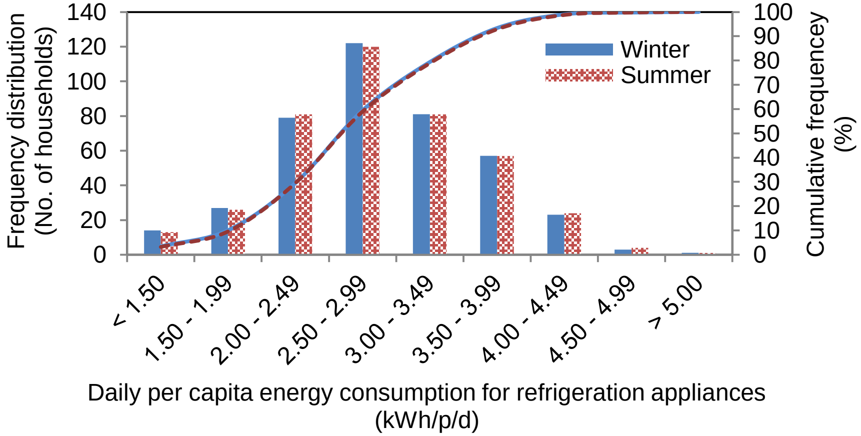


Figure D4.3 Comparison between per capita energy consumption for refrigeration appliances in winter and summer

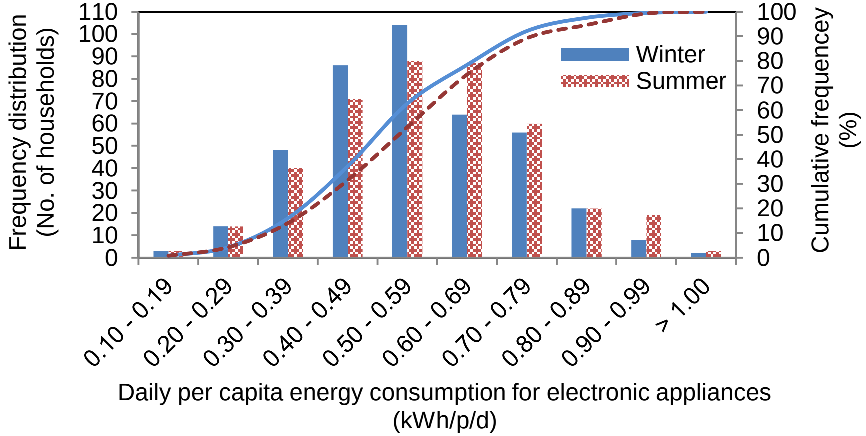


Figure D4.4 Comparison between per capita energy consumption for electronic appliances in winter and summer

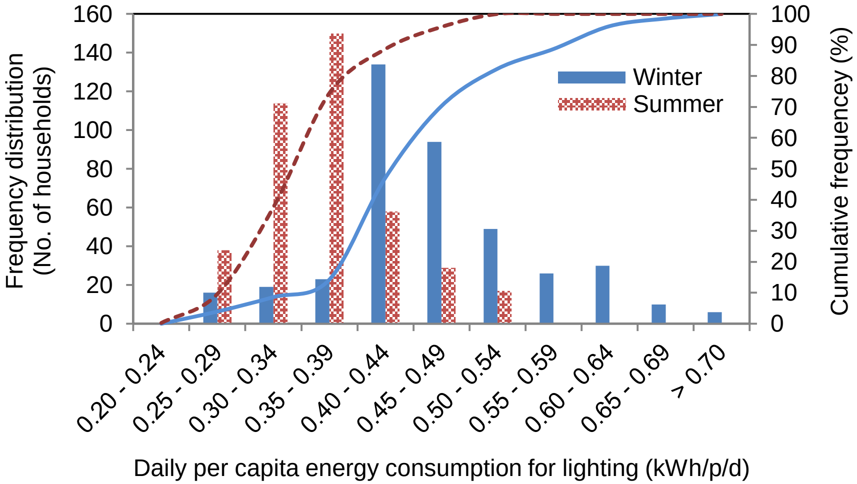


Figure D4.5 Comparison between per capita energy consumption for lighting in winter and summer

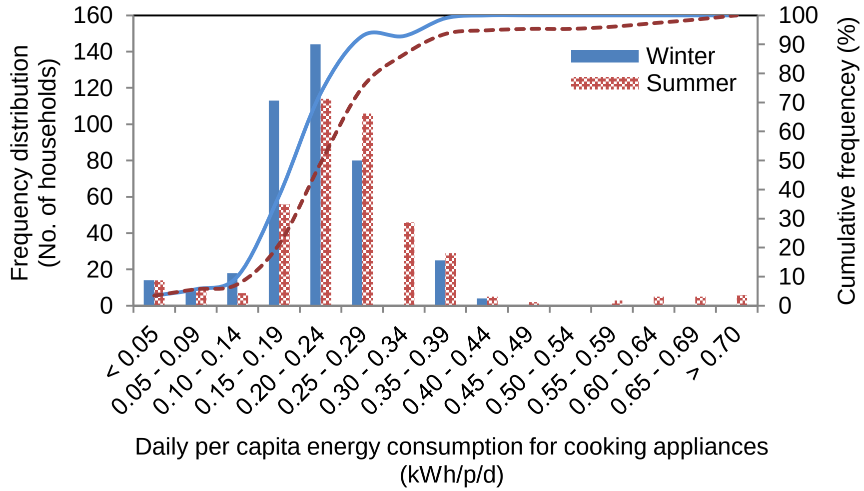


Figure D4.6 Comparison between per capita energy consumption for cooking appliances in winter and summer

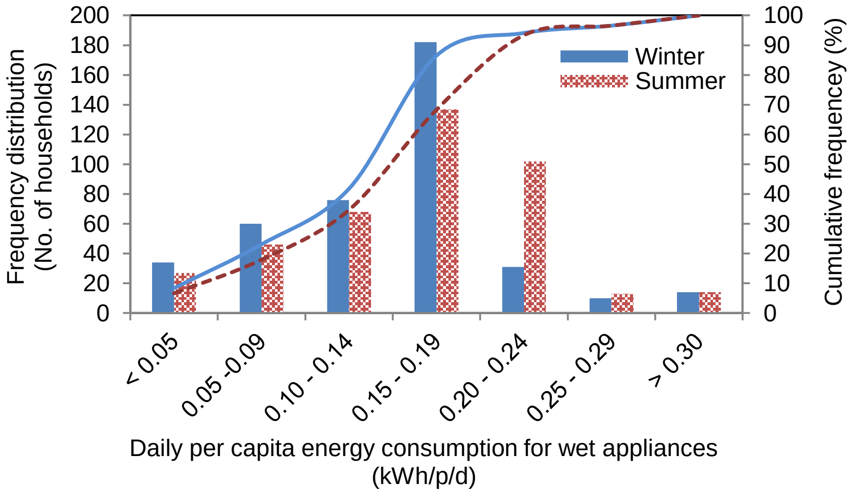


Figure D4.7 Comparison between per capita energy consumption for wet appliances in winter and summer

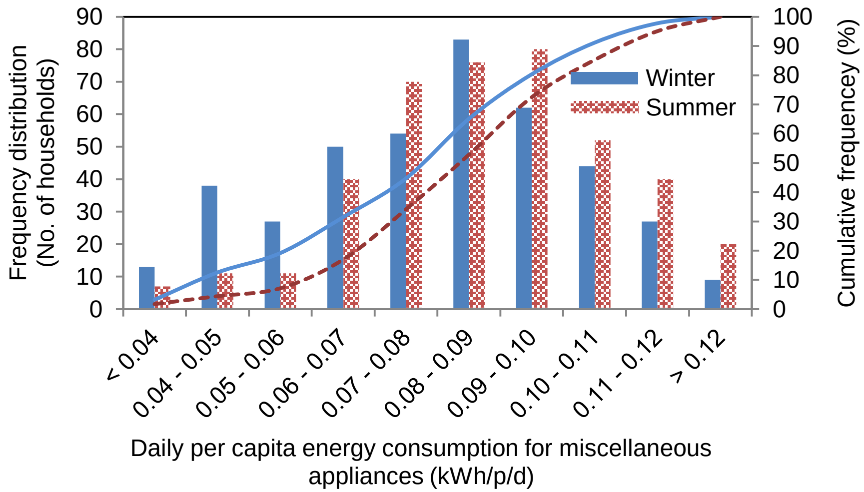


Figure D4.8 Comparison between per capita energy consumption for miscellaneous appliances in winter and summer

APPENDIX E: FOOD CONSUMPTION ANALYSIS

Appendix E1 Relationships between Total Household Food Consumption and Characteristics

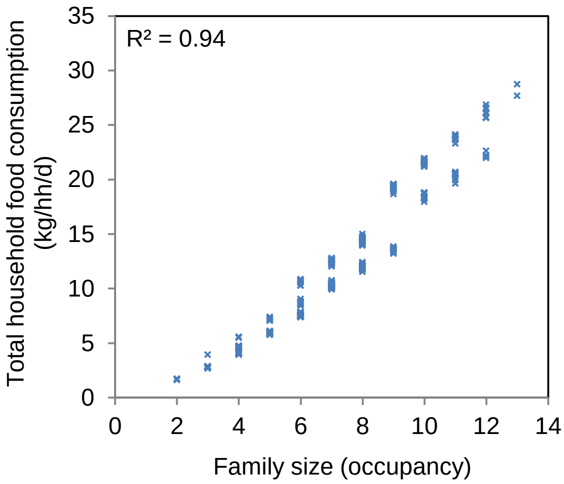


Figure E1.1 Relationship between household total average food consumption and number of occupants in the household

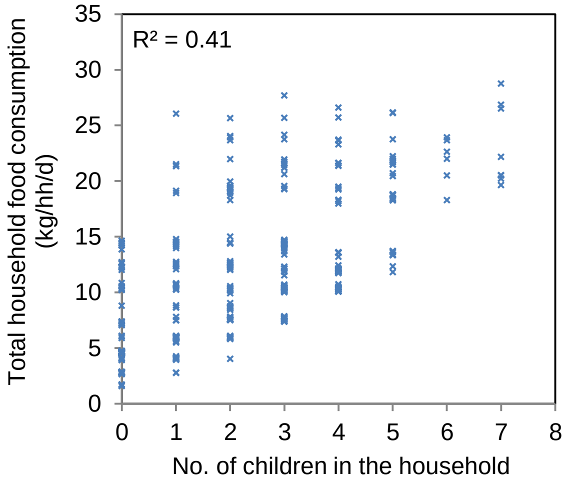


Figure E1.2 Relationship between household total average food consumption and number of children in the household

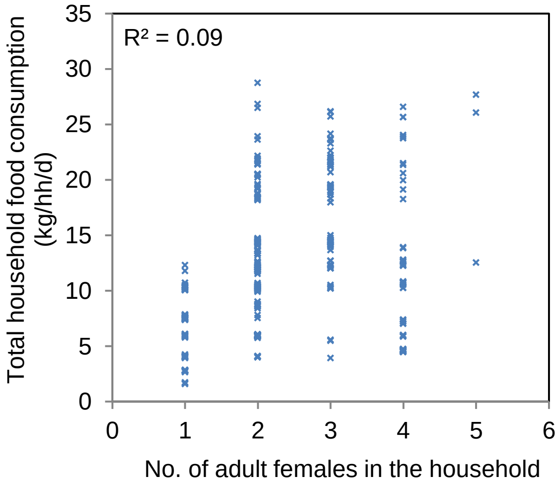


Figure E1.3 Relationship between household total average food consumption and number of adult females in the household

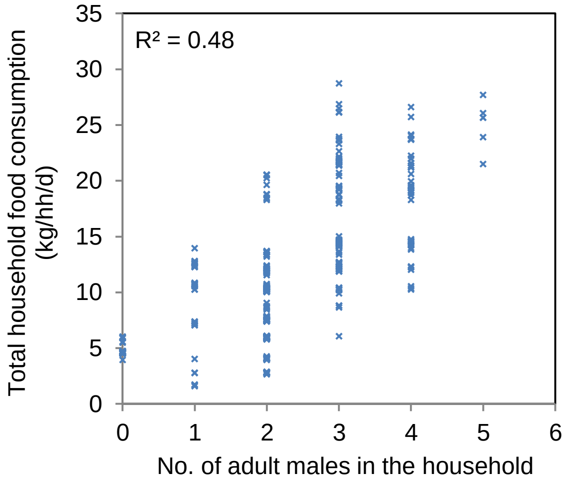


Figure E1.4 Relationship between household total average food consumption and number of adult males in the household

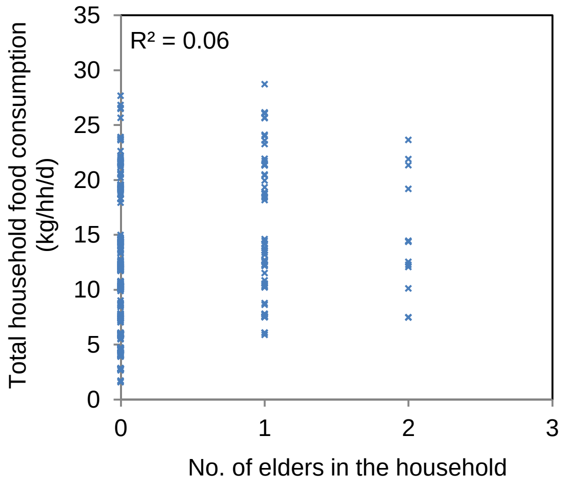


Figure E1.5 Relationship between household total average food consumption and number of elders in the household

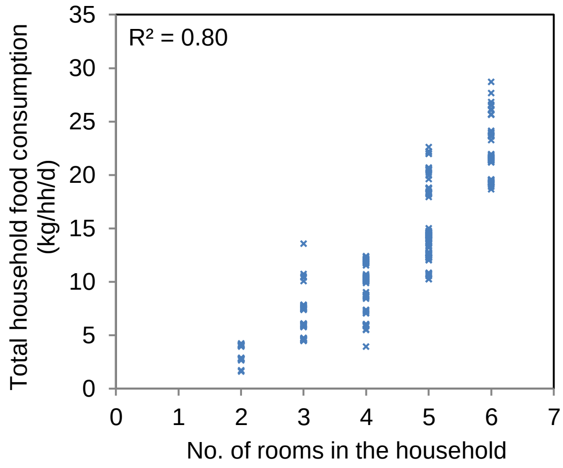


Figure E1.6 Relationship between household total average food consumption and number of rooms in the household

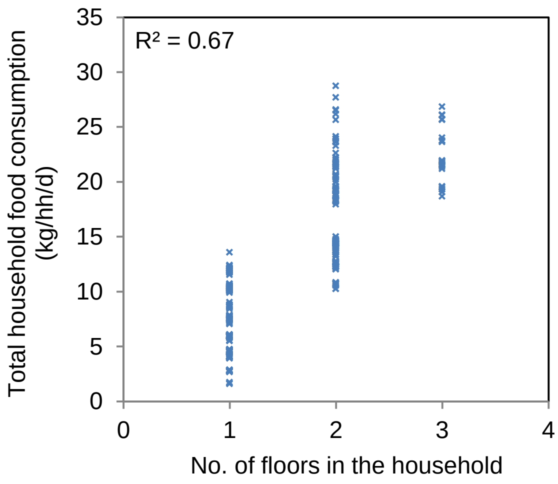


Figure E1.7 Relationship between household total average food consumption and number of floors in the household

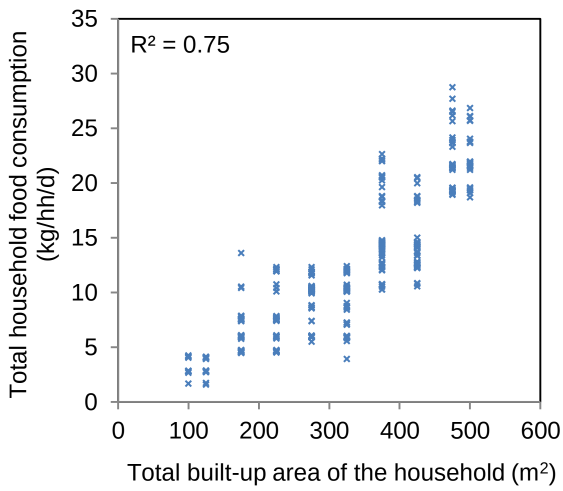
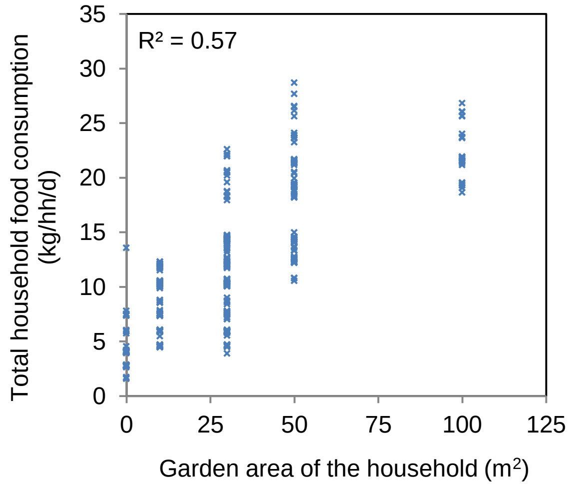


Figure E1.8 Relationship between household total average food consumption and total built-up area of the household



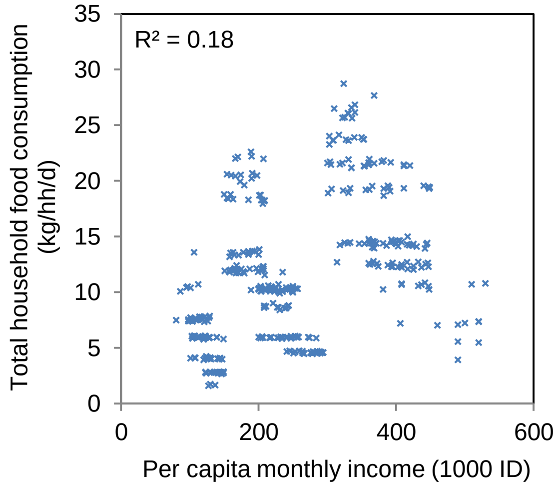


Figure E1.9 Relationship between household total average food consumption and garden area of the household

Figure E1.10 Relationship between household total average food consumption and per capita monthly income

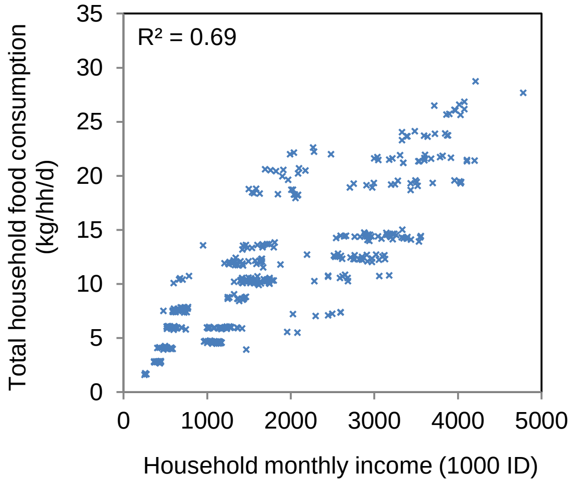


Figure E1.11 Relationship between household total average food consumption and household monthly income

Appendix E2 Relationships between Daily per Capita Average Food Consumption and Household Characteristics

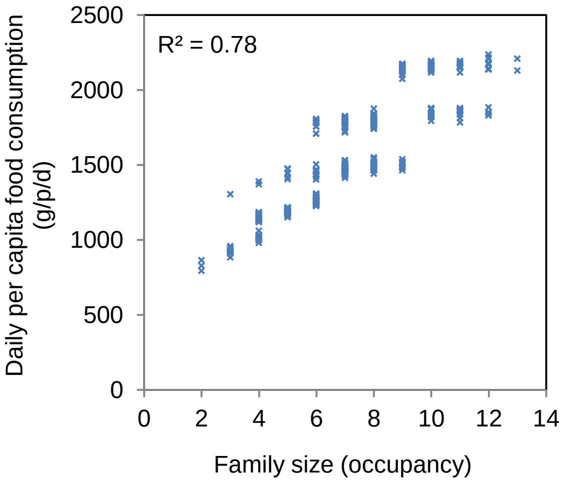


Figure E2.1 Relationship between daily per capita average food consumption and household occupancy

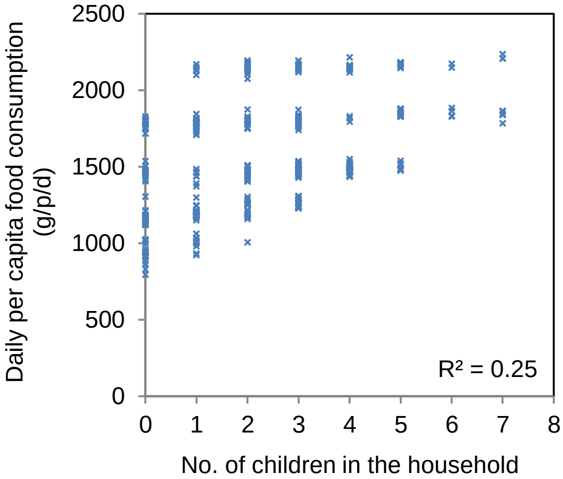


Figure E2.2 Relationship between daily per capita average food consumption and number of children in the household

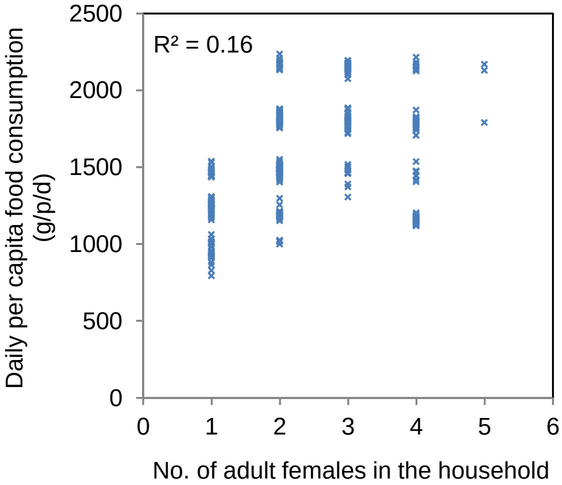


Figure E2.3 Relationship between daily per capita average food consumption and number of adult females in the household

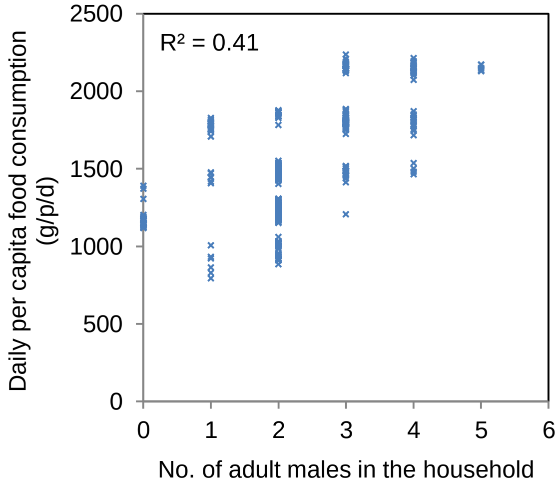


Figure E2.4 Relationship between daily per capita average food consumption and number of adult males in the household

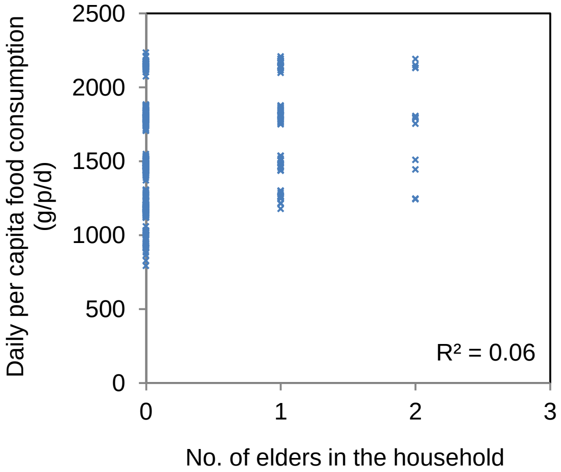


Figure E2.5 Relationship between daily per capita average food consumption and number of elders in the household

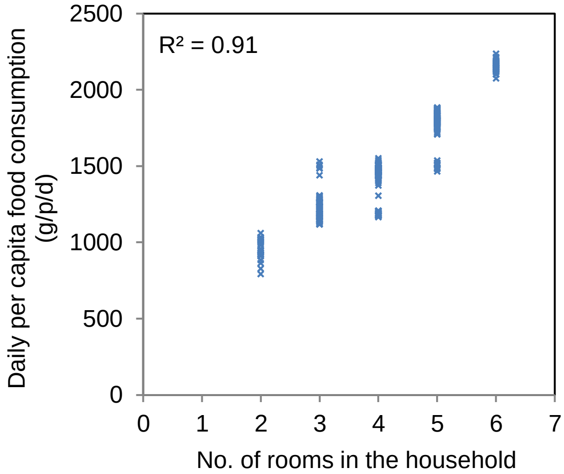


Figure E2.6 Relationship between daily per capita average food consumption and number of rooms in the household

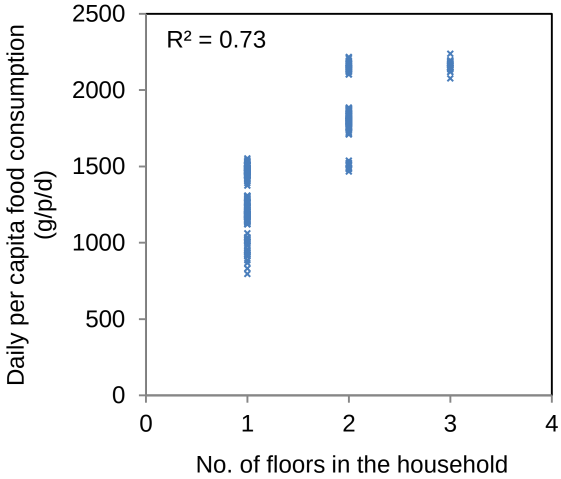


Figure E2.7 Relationship between daily per capita average food consumption and number of floors in the household

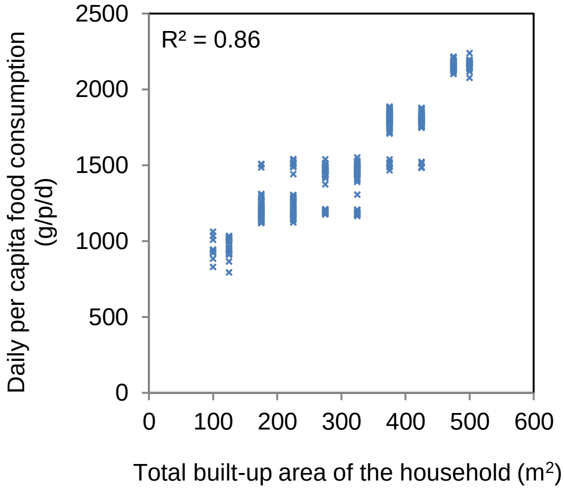


Figure E2.8 Relationship between daily per capita average food consumption and total built-up area of the household

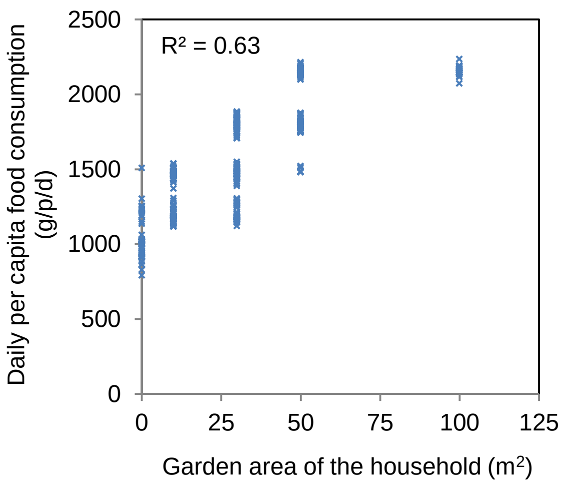


Figure E2.9 Relationship between daily per capita average food consumption and total garden area of the household

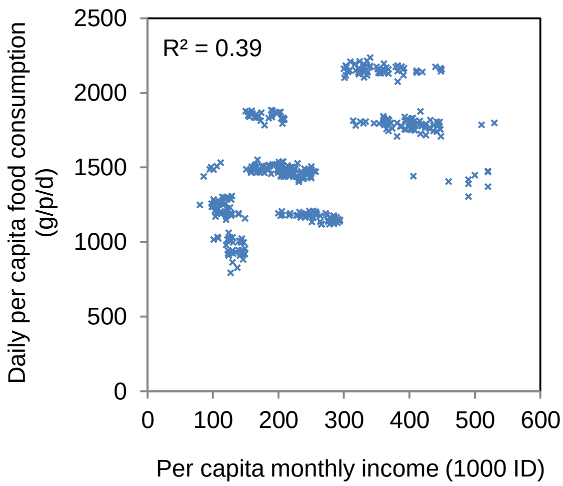


Figure E2.10 Relationship between daily per capita average food consumption and per capita monthly income

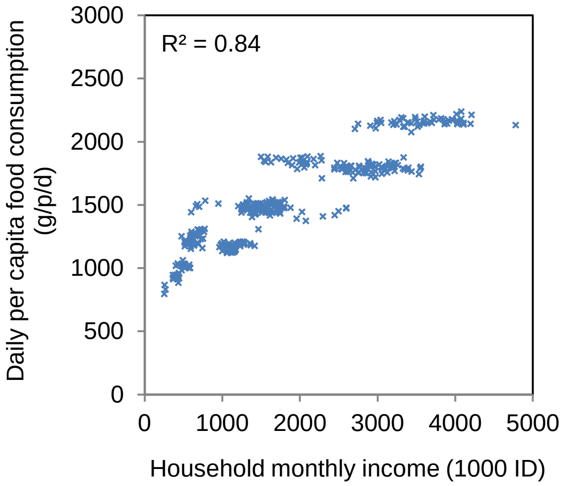


Figure E2.11 Relationship between daily per capita average food consumption and household monthly income

Appendix E3 Statistical Parameters of Food end-uses in Low, Medium and High Income Household Groups

Table E3.1 Summary of food commodity parameters for <u>all surveyed households</u> (407 households) in <u>winter</u>

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cereal grains	Wheat	Daily per capita wheat flour consumption	g/p/d	257.95	262.00	17.56	308.51	202	292.00	-0.93	0.81	1.712
		Water consumption per capita per cooking session	l/p/cs	1.68	1.40	0.50	0.25	1.1	2.50	0.45	-1.57	0.048
		No. of cooking sessions per day	cs/d	0.14	0.14	0.00	0.00	0.14	0.14	0.00	0.00	0.00
		LPG consumption per capita per cooking session	ml/p/cs	24.97	23.70	7.05	49.76	16.5	76.10	3.30	18.73	0.687
	Rice	Daily per capita rice consumption	g/p/d	86.03	87.00	7.45	55.47	71	98.00	-0.56	-0.63	0.726
		Water consumption per capita per cooking session	l/p/cs	2.58	2.30	0.53	0.28	2	3.50	0.50	-1.37	0.051
		No. of cooking sessions per day	cs/d	1.15	1.10	0.16	0.03	0.9	1.40	0.16	-1.36	0.016
		LPG consumption per capita per cooking session	ml/p/cs	14.95	13.30	5.25	27.60	8.6	50.70	2.91	14.49	0.512
	Burgul and jareesh	Daily per capita burgul and jareesh consumption	g/p/d	5.67	6.00	0.58	0.34	4	7.00	-0.34	-0.03	0.056
		Water consumption per capita per cooking session	l/p/cs	1.51	1.40	0.29	0.08	1.1	2.00	0.47	-1.25	0.028
		No. of cooking sessions per day	cs/d	0.13	0.10	0.07	0.01	0.1	0.30	2.00	2.00	0.007
		LPG consumption per capita per cooking session	ml/p/cs	14.95	13.30	5.25	27.60	8.6	50.70	2.91	14.49	0.512
	Macaroni and vermicelli	Daily per capita macaroni and vermicelli consumpt.	g/p/d	7.54	8.00	1.20	1.45	4	10.00	-0.72	0.41	0.117
		Water consumption per capita per cooking session	l/p/cs	1.05	0.90	0.26	0.07	0.7	1.50	0.43	-1.37	0.025
		No. of cooking sessions per day	cs/d	0.18	0.10	0.10	0.01	0.1	0.30	0.47	-1.79	0.009
		LPG consumption per capita per cooking session	ml/p/cs	8.75	8.00	2.36	5.58	5.7	25.40	2.99	16.25	0.230
	Buns, cake and biscuits	Daily per capita buns, cake and biscuits consumpt.	g/p/d	48.99	50.00	6.23	38.78	36	61.00	-0.45	-0.47	0.607
		Water consumption per capita per cooking session	l/p/cs	0.58	0.40	0.25	0.06	0.3	1.00	0.52	-1.38	0.024
		No. of cooking sessions per day	cs/d	1.02	1.00	0.28	0.08	0.6	1.40	-0.19	-1.12	0.027
		LPG consumption per capita per cooking session	ml/p/cs	18.44	15.90	6.48	42.05	11.4	63.40	3.13	15.84	0.632
Meat	Sheep and goat	Daily per capita sheep and goat meat consumption	g/p/d	35.03	31.00	11.68	136.49	12	61.00	0.32	-0.84	1.138
		Water consumption per capita per cooking session	l/p/cs	2.58	2.30	0.53	0.28	2	3.50	0.50	-1.37	0.051
		No. of cooking sessions per day	cs/d	1.01	1.00	0.28	0.08	0.6	1.40	-0.12	-1.11	0.027
		LPG consumption per capita per cooking session	ml/p/cs	89.71	79.60	31.55	995.59	51.4	304.40	2.90	14.46	3.075
	Bovine	Daily per capita bovine meat consumption	g/p/d	4.50	0.00	5.50	30.23	0	20.00	0.92	-0.41	0.536
		Water consumption per capita per cooking session	l/p/cs	1.37	2.00	1.34	1.80	0	3.50	0.14	-1.62	0.131
		No. of cooking sessions per day	cs/d	0.08	0.10	0.10	0.01	0	0.30	1.20	0.34	0.010
		LPG consumption per capita per cooking session	ml/p/cs	43.72	58.30	43.64	1904.30	0	147.90	0.24	-1.47	4.252

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.1 Summary of food commodity parameters for all surveyed households (407 households) in winter

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Meat	Chicken and turkey	Daily per capita chicken and turkey consumption	g/p/d	52.30	49.00	17.91	320.95	18	91.00	0.29	-0.84	1.746
		Water consumption per capita per cooking session	l/p/cs	2.58	2.30	0.53	0.28	2	3.50	0.50	-1.37	0.051
		No. of cooking sessions per day	cs/d	0.89	0.90	0.27	0.07	0.4	1.30	-0.17	-0.85	0.026
		LPG consumption per capita per cooking session	ml/p/cs	52.55	47.80	14.16	200.62	34.2	152.20	2.95	16.04	1.380
	Fish and seafood	Daily per capita fish and seafood consumption	g/p/d	16.03	15.00	6.75	45.51	0	30.00	0.04	-0.24	0.657
		Water consumption per capita per cooking session	l/p/cs	2.98	2.80	0.67	0.45	0	4.00	-1.07	4.62	0.066
		No. of cooking sessions per day	cs/d	0.13	0.10	0.07	0.01	0	0.30	1.82	1.84	0.007
		LPG consumption per capita per cooking session	ml/p/cs	16.85	15.90	4.23	17.92	0	28.70	-0.31	3.67	0.412
Dairy	Yogurt	Daily per capita yogurt consumption	g/p/d	43.90	42.00	14.46	209.21	12	75.00	0.25	-0.65	1.409
		No. of cooking sessions per day	cs/d	0.02	0.00	0.04	0.00	0	0.10	1.30	-0.32	0.004
		LPG consumption per capita per cooking session	ml/p/cs	9.36	0.00	18.49	341.99	0	74.00	1.71	1.37	1.802
	Cheese	Daily per capita cheese consumption	g/p/d	9.17	9.00	3.15	9.95	0	17.00	0.32	0.07	0.307
	Egg	Daily per capita egg consumption	egg/p/d	0.49	0.47	0.15	0.02	0.21	0.83	0.43	-0.61	0.015
		Water consumption per capita per cooking session	l/p/cs	0.58	0.40	0.25	0.06	0.3	1.00	0.52	-1.38	0.024
		No. of cooking sessions per day	cs/d	0.91	0.90	0.24	0.06	0.6	1.30	0.17	-1.12	0.023
		LPG consumption per capita per cooking session	ml/p/cs	8.37	8.00	2.69	7.21	4.3	25.40	2.11	10.11	0.262
	Milk	Daily per capita milk consumption	g/p/d	29.22	27.80	10.18	103.69	0	51.90	0.25	-0.54	0.992
		No. of cooking sessions per day	cs/d	0.24	0.30	0.11	0.01	0	0.40	-0.31	-1.40	0.011
		LPG consumption per capita per cooking session	ml/p/cs	11.75	10.60	3.60	12.98	0	37.60	2.47	12.96	0.351
	Butter	Daily per capita butter consumption	g/p/d	3.81	4.00	1.31	1.71	0	7.00	-0.20	0.59	0.127
Roots and tubers	Potato	Daily per capita potato consumption	g/p/d	88.85	83.00	21.90	479.59	36	143.00	0.50	-0.27	2.134
		Water consumption per capita per cooking session	l/p/cs	1.05	0.90	0.26	0.07	0.7	1.50	0.43	-1.37	0.025
		No. of cooking sessions per day	cs/d	0.72	0.70	0.16	0.03	0.4	0.90	-0.36	-0.82	0.016
		LPG consumption per capita per cooking session	ml/p/cs	26.27	23.90	7.09	50.29	17.1	76.10	2.95	16.00	0.691
	Onion	Daily per capita onion consumption	g/p/d	56.44	54.00	15.16	229.80	24	93.00	0.30	-0.29	1.477
	Carrots	Daily per capita carrot consumption	g/p/d	0.71	0.00	1.44	2.09	0	4.00	1.62	0.73	0.141
		Water consumption per capita per cooking session	l/p/cs	0.06	0.00	0.12	0.01	0	0.40	1.55	0.47	0.012
		No. of cooking sessions per day	cs/d	0.02	0.00	0.04	0.00	0	0.10	1.53	0.35	0.004
		LPG consumption per capita per cooking session	ml/p/cs	1.43	0.00	2.91	8.47	0	8.20	1.58	0.56	0.284

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

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Table E3.1 Summary of food commodity parameters for all surveyed households (407 households) in winter

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Roots & tubers	Garlic	Daily per capita garlic consumption	g/p/d	1.27	0.00	1.38	1.91	0	4.00	0.44	-1.29	0.135
	Radish	Daily per capita radish consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
Vegetables and fruits	Tomato	Daily per capita tomato consumption	g/p/d	221.53	214.00	63.10	3981.77	107	357.00	0.41	-0.90	6.149
		Water consumption per capita per cooking session	l/p/cs	0.72	0.70	0.14	0.02	0.5	1.00	0.79	-0.50	0.014
		No. of cooking sessions per day	cs/d	1.08	1.10	0.11	0.01	0.9	1.30	0.60	0.05	0.011
	Cucumber	Daily per capita cucumber consumption	g/p/d	82.09	80.00	25.86	669.00	36	137.00	0.38	-0.97	2.520
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
	Aubergine	Daily per capita aubergine consumption	g/p/d	56.84	54.00	18.28	334.06	24	95.00	0.33	-0.82	1.781
		Water consumption per capita per cooking session	l/p/cs	0.64	0.60	0.11	0.01	0.5	0.80	0.30	-1.20	0.011
		No. of cooking sessions per day	cs/d	0.42	0.40	0.10	0.01	0.3	0.60	0.80	-0.51	0.010
		LPG consumption per capita per cooking session	ml/p/cs	29.04	23.90	12.70	161.33	17.1	114.10	3.10	14.19	1.238
	Courgette	Daily per capita courgette consumption	g/p/d	29.76	30.00	9.57	91.64	12	52.00	0.24	-0.75	0.933
		Water consumption per capita per cooking session	l/p/cs	0.64	0.60	0.11	0.01	0.5	0.80	0.30	-1.20	0.011
		No. of cooking sessions per day	cs/d	0.19	0.10	0.12	0.01	0.1	0.40	0.61	-1.36	0.012
		LPG consumption per capita per cooking session	ml/p/cs	30.37	23.90	13.26	175.72	17.1	114.10	2.52	10.51	1.292
	Okra	Daily per capita okra consumption	g/p/d	14.34	15.00	6.20	38.42	0	27.00	-0.15	-0.39	0.604
		Water consumption per capita per cooking session	l/p/cs	0.61	0.60	0.17	0.03	0	0.80	-1.80	5.02	0.017
		No. of cooking sessions per day	cs/d	0.14	0.10	0.09	0.01	0	0.30	1.14	-0.09	0.008
		LPG consumption per capita per cooking session	ml/p/cs	27.16	23.90	10.58	112.02	0	60.70	0.02	0.52	1.031
	Lettuce	Daily per capita lettuce consumption	g/p/d	7.33	8.00	4.24	17.99	0	16.00	-0.42	-0.74	0.413
		Water consumption per capita per cooking session	l/p/cs	0.47	0.50	0.26	0.07	0	1.00	-0.43	-0.41	0.026
		No. of cooking sessions per day	cs/d	0.13	0.10	0.10	0.01	0	0.30	0.83	-0.39	0.010
	Sweet pepper	Daily per capita sweet pepper consumption	g/p/d	7.42	7.00	4.23	17.88	0	15.00	-0.40	-0.68	0.412
		Water consumption per capita per cooking session	l/p/cs	0.16	0.10	0.12	0.02	0	0.40	0.54	-0.69	0.012
		No. of cooking sessions per day	cs/d	0.13	0.10	0.10	0.01	0	0.30	0.84	-0.37	0.010
	Celery	Daily per capita celery consumption	g/p/d	7.16	7.00	4.24	17.94	0	15.00	-0.37	-0.76	0.413
		Water consumption per capita per cooking session	l/p/cs	0.26	0.30	0.13	0.02	0	0.40	-1.35	0.41	0.012
		No. of cooking sessions per day	cs/d	0.12	0.10	0.10	0.01	0	0.30	0.83	-0.41	0.010

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

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Table E3.1 Summary of food commodity parameters for all surveyed households (407 households) in winter

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Vegetables and fruits	Water melon	Daily per capita water melon consumption	g/p/d	86.49	82.00	27.31	745.98	36	143.00	0.42	-0.83	2.661
	Orange	Daily per capita orange consumption	g/p/d	28.86	27.00	11.31	127.82	12	54.00	0.29	-0.99	1.102
	Apple	Daily per capita apple consumption	g/p/d	28.53	27.00	10.86	117.84	12	52.00	0.23	-0.99	1.058
		Water consumption per capita per cooking	l/p/cs	0.33	0.30	0.06	0.00	0.3	0.50	1.70	1.59	0.006
		No. of cooking sessions per day	cs/d	0.43	0.40	0.17	0.03	0.1	0.70	0.06	-0.73	0.017
	Melon	Daily per capita melon consumption	g/p/d	19.62	18.00	8.07	65.13	0	36.00	0.13	-0.51	0.786
	Grape	Daily per capita grape consumption	g/p/d	11.67	12.00	8.02	64.36	0	29.00	-0.08	-0.99	0.782
		Water consumption per capita per cooking	l/p/cs	0.24	0.30	0.13	0.02	0	0.50	-1.02	-0.39	0.013
		No. of cooking sessions per day	cs/d	0.27	0.30	0.20	0.04	0	0.60	0.12	-1.02	0.019
	Pumpkin	Daily per capita pumpkin consumption	g/p/d	11.75	12.00	7.89	62.29	0	29.00	-0.16	-1.02	0.769
		Water consumption per capita per cooking	l/p/cs	0.24	0.30	0.13	0.02	0	0.50	-1.05	-0.32	0.013
		No. of cooking sessions per day	cs/d	0.08	0.10	0.04	0.00	0	0.10	-1.30	-0.32	0.004
		LPG consumption per capita per cooking session	ml/p/cs	23.14	27.70	14.19	201.43	0	62.60	-0.51	-0.60	1.383
	Banana	Daily per capita banana consumption	g/p/d	12.56	12.00	5.70	32.48	0	24.00	0.03	-0.51	0.555
Oilseeds and pulses	Bean	Daily per capita bean consumption	g/p/d	18.19	18.00	5.51	30.36	0	32.00	0.06	0.13	0.537
		Water consumption per capita per cooking	l/p/cs	1.49	1.40	0.31	0.10	0	2.00	-0.34	2.13	0.031
		No. of cooking sessions per day	cs/d	0.24	0.30	0.11	0.01	0	0.40	-0.30	-1.39	0.011
		LPG consumption per capita per cooking session	ml/p/cs	49.10	47.80	14.23	202.52	0	87.30	0.30	0.72	1.387
	Chickpea	Daily per capita chickpea consumption	g/p/d	18.22	18.00	5.48	30.00	0	32.00	0.15	0.28	0.534
		Water consumption per capita per cooking	l/p/cs	1.49	1.40	0.31	0.10	0	2.00	-0.34	2.13	0.031
		No. of cooking sessions per day	cs/d	0.24	0.30	0.11	0.01	0	0.40	-0.30	-1.39	0.011
		LPG consumption per capita per cooking session	ml/p/cs	49.10	47.80	14.23	202.52	0	87.30	0.30	0.72	1.387
	Lentils	Daily per capita lentils consumption	g/p/d	18.12	18.00	5.25	27.60	0	30.00	0.07	0.37	0.512
		Water consumption per capita per cooking	l/p/cs	1.93	1.80	0.33	0.11	0	2.50	-1.00	6.53	0.032
		No. of cooking sessions per day	cs/d	0.24	0.30	0.11	0.01	0	0.40	-0.30	-1.39	0.011
		LPG consumption per capita per cooking session	ml/p/cs	49.10	47.80	14.23	202.52	0	87.30	0.30	0.72	1.387
Oils & fats	Vegetable oil	Daily per capita vegetable oil consumption	g/p/d	35.67	36.00	6.28	39.44	18	49.00	-0.16	-0.53	0.612
	Animal fats	Daily per capita animal fats consumption	g/p/d	0.19	0.00	0.49	0.24	0	2.00	2.59	5.83	0.048
	Sugar	Daily per capita sugar consumption	g/p/d	75.36	76.00	9.88	97.60	36	97.00	-0.16	1.08	0.963

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Table E3.2 Summary of food commodity parameters for <u>low income households</u> (92 households) in <u>winter</u>

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cereal grains	Wheat	Daily per capita wheat flour consumption	g/p/d	235.65	238.00	16.34	266.84	202	270.00	-0.34	-0.63	3.383
		Water consumption per capita per cooking session	l/p/cs	2.13	2.20	0.29	0.08	1.1	2.50	-1.94	4.64	0.060
		No. of cooking sessions per day	cs/d	0.14	0.14	0.00	0.00	0.14	0.14	0.00	0.00	0.00
		LPG consumption per capita per cooking session	ml/p/cs	31.67	29.70	10.41	108.37	16.9	76.10	2.59	8.39	2.156
	Rice	Daily per capita rice consumption	g/p/d	76.62	77.00	5.29	28.00	71	87.00	0.35	-1.06	1.096
		Water consumption per capita per cooking session	l/p/cs	3.00	3.00	0.34	0.11	2	3.50	-1.08	1.94	0.070
		No. of cooking sessions per day	cs/d	0.98	1.00	0.10	0.01	0.9	1.30	2.16	5.22	0.020
		LPG consumption per capita per cooking session	ml/p/cs	20.42	18.50	7.27	52.78	10.5	50.70	2.44	7.44	1.505
	Burgul and jareesh	Daily per capita burgul and jareesh consumption	g/p/d	5.47	6.00	0.64	0.41	4	6.00	-0.79	-0.38	0.132
		Water consumption per capita per cooking session	l/p/cs	1.75	1.70	0.20	0.04	1.1	2.00	-1.03	2.00	0.041
		No. of cooking sessions per day	cs/d	0.10	0.10	0.00	0.00	0.1	0.10	0.00	0.00	0.00
		LPG consumption per capita per cooking session	ml/p/cs	20.42	18.50	7.27	52.78	10.5	50.70	2.44	7.44	1.505
	Macaroni and vermicelli	Daily per capita macaroni and vermicelli consumpt.	g/p/d	6.14	7.00	1.11	1.22	4	9.00	-0.04	-1.07	0.229
		Water consumption per capita per cooking session	l/p/cs	1.26	1.30	0.15	0.02	0.7	1.50	-1.39	3.87	0.032
		No. of cooking sessions per day	cs/d	0.10	0.10	0.00	0.00	0.1	0.10	0.00	0.00	0.00
		LPG consumption per capita per cooking session	ml/p/cs	11.20	10.10	3.20	10.26	6.3	25.40	2.84	10.09	0.663
	Buns, cake and biscuits	Daily per capita buns, cake and biscuits consumpt.	g/p/d	41.23	42.00	4.71	22.16	36	51.00	0.30	-0.97	0.975
		Water consumption per capita per cooking session	l/p/cs	0.82	0.80	0.15	0.02	0.3	1.00	-1.57	4.00	0.032
		No. of cooking sessions per day	cs/d	0.61	0.60	0.02	0.00	0.6	0.70	3.58	11.06	0.005
		LPG consumption per capita per cooking session	ml/p/cs	25.09	22.30	9.32	86.92	12.6	63.40	2.35	6.88	1.931
Meat	Sheep and goat	Daily per capita sheep and goat meat consumption	g/p/d	23.04	24.00	5.26	27.67	12	32.00	-0.34	-0.50	1.089
		Water consumption per capita per cooking session	l/p/cs	3.00	3.00	0.34	0.11	2	3.50	-1.08	1.94	0.070
		No. of cooking sessions per day	cs/d	0.61	0.60	0.02	0.00	0.6	0.70	3.58	11.06	0.005
		LPG consumption per capita per cooking session	ml/p/cs	122.72	111.30	43.56	1897.15	63.2	304.40	2.44	7.46	9.020
	Bovine	Daily per capita bovine meat consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
		No. of cooking sessions per day	cs/d	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
		LPG consumption per capita per cooking session	ml/p/cs	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.2 Summary of food commodity parameters for low income households (92 households) in winter

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Meat	Chicken and turkey	Daily per capita chicken and turkey consumption	g/p/d	32.51	36.00	8.12	65.90	18	52.00	0.02	-0.69	1.681
		Water consumption per capita per cooking session	l/p/cs	3.00	3.00	0.34	0.11	2	3.50	-1.08	1.94	0.070
		No. of cooking sessions per day	cs/d	0.52	0.60	0.10	0.01	0.4	0.60	-0.41	-1.88	0.020
		LPG consumption per capita per cooking session	ml/p/cs	67.28	60.70	19.08	364.19	37.9	152.20	2.86	10.24	3.952
	Fish and seafood	Daily per capita fish and seafood consumption	g/p/d	9.77	12.00	4.56	20.77	0	16.00	-1.19	0.41	0.944
		Water consumption per capita per cooking session	l/p/cs	3.20	3.40	0.99	0.98	0	4.00	-2.57	5.99	0.205
		No. of cooking sessions per day	cs/d	0.09	0.10	0.03	0.00	0	0.10	-3.25	8.76	0.006
		LPG consumption per capita per cooking session	ml/p/cs	19.53	20.20	6.56	43.03	0	28.70	-1.73	3.88	1.358
Dairy	Yogurt	Daily per capita yogurt consumption	g/p/d	28.54	29.00	7.52	56.58	12	46.00	-0.11	0.04	1.558
		No. of cooking sessions per day	cs/d	0.01	0.00	0.02	0.00	0	0.10	3.58	11.06	0.005
		LPG consumption per capita per cooking session	ml/p/cs	2.04	0.00	7.80	60.86	0	32.50	3.62	11.47	1.616
	Cheese	Daily per capita cheese consumption	g/p/d	5.82	6.00	1.86	3.45	0	10.00	-0.55	1.74	0.385
	Egg	Daily per capita egg consumption	egg/p/d	0.33	0.33	0.06	0.00	0.21	0.51	0.41	-0.03	0.013
		Water consumption per capita per cooking session	l/p/cs	0.82	0.80	0.15	0.02	0.3	1.00	-1.57	4.00	0.032
		No. of cooking sessions per day	cs/d	0.61	0.60	0.02	0.00	0.6	0.70	3.58	11.06	0.005
		LPG consumption per capita per cooking session	ml/p/cs	11.20	10.10	3.20	10.26	6.3	25.40	2.84	10.09	0.663
	Milk	Daily per capita milk consumption	g/p/d	18.53	17.90	5.42	29.40	0	30.60	-0.61	0.25	1.123
		No. of cooking sessions per day	cs/d	0.10	0.10	0.01	0.00	0	0.10	-9.59	92.00	0.002
		LPG consumption per capita per cooking session	ml/p/cs	15.41	14.80	4.91	24.12	0	37.60	1.92	8.39	1.017
	Butter	Daily per capita butter consumption	g/p/d	2.34	2.00	1.06	1.13	0	4.00	-0.43	0.41	0.220
Roots and tubers	Potato	Daily per capita potato consumption	g/p/d	66.74	71.00	11.58	134.15	36	92.00	-0.69	-0.03	2.399
		Water consumption per capita per cooking session	l/p/cs	1.26	1.30	0.15	0.02	0.7	1.50	-1.39	3.87	0.032
		No. of cooking sessions per day	cs/d	0.52	0.60	0.10	0.01	0.4	0.60	-0.41	-1.88	0.020
		LPG consumption per capita per cooking session	ml/p/cs	33.66	30.40	9.55	91.20	19	76.10	2.85	10.22	1.978
	Onion	Daily per capita onion consumption	g/p/d	41.09	43.00	8.71	75.93	24	61.00	-0.72	-0.17	1.805
	Carrots	Daily per capita carrot consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
		No. of cooking sessions per day	cs/d	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
		LPG consumption per capita per cooking session	ml/p/cs	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.2 Summary of food commodity parameters for low income households (92 households) in winter

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Roots & tubers	Garlic	Daily per capita garlic consumption	g/p/d	0.02	0.00	0.21	0.04	0	2.00	9.59	92.00	0.043
	Radish	Daily per capita radish consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
Vegetables and fruits	Tomato	Daily per capita tomato consumption	g/p/d	155.73	155.00	24.29	589.94	107	235.00	1.15	3.12	5.030
		Water consumption per capita per cooking session	l/p/cs	0.83	0.80	0.11	0.01	0.6	1.00	0.16	-0.03	0.022
		No. of cooking sessions per day	cs/d	0.96	1.00	0.05	0.00	0.9	1.00	-0.41	-1.88	0.010
	Cucumber	Daily per capita cucumber consumption	g/p/d	55.46	57.00	9.21	84.89	36	82.00	0.20	1.98	1.908
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
	Aubergine	Daily per capita aubergine consumption	g/p/d	38.11	36.00	8.50	72.27	24	61.00	-0.01	0.03	1.761
		Water consumption per capita per cooking session	l/p/cs	0.71	0.70	0.08	0.01	0.5	0.80	-0.55	-0.10	0.016
		No. of cooking sessions per day	cs/d	0.36	0.40	0.05	0.00	0.3	0.40	-0.41	-1.88	0.010
		LPG consumption per capita per cooking session	ml/p/cs	41.57	33.40	18.86	355.78	19	114.10	1.98	4.78	3.906
	Courgette	Daily per capita courgette consumption	g/p/d	20.04	21.00	4.66	21.76	12	31.00	-0.17	-0.15	0.966
		Water consumption per capita per cooking session	l/p/cs	0.71	0.70	0.08	0.01	0.5	0.80	-0.55	-0.10	0.016
		No. of cooking sessions per day	cs/d	0.11	0.10	0.05	0.00	0.1	0.30	3.58	11.06	0.010
		LPG consumption per capita per cooking session	ml/p/cs	47.48	44.50	15.59	243.16	25.3	114.10	2.59	8.42	3.229
	Okra	Daily per capita okra consumption	g/p/d	8.13	9.00	4.64	21.57	0	16.00	-0.66	-0.57	0.962
		Water consumption per capita per cooking session	l/p/cs	0.58	0.70	0.29	0.09	0	0.80	-1.36	0.15	0.061
		No. of cooking sessions per day	cs/d	0.08	0.10	0.04	0.00	0	0.10	-1.56	0.44	0.008
		LPG consumption per capita per cooking session	ml/p/cs	33.23	37.70	17.11	292.67	0	60.70	-1.29	0.09	3.543
	Lettuce	Daily per capita lettuce consumption	g/p/d	3.59	6.00	3.31	10.95	0	10.00	-0.06	-1.75	0.685
		Water consumption per capita per cooking session	l/p/cs	0.42	0.40	0.39	0.15	0	0.80	-0.09	-1.96	0.080
		No. of cooking sessions per day	cs/d	0.06	0.10	0.05	0.00	0	0.10	-0.22	-1.99	0.010
	Sweet pepper	Daily per capita sweet pepper consumption	g/p/d	3.55	6.00	3.17	10.07	0	8.00	-0.19	-1.91	0.657
		Water consumption per capita per cooking session	l/p/cs	0.18	0.20	0.17	0.03	0	0.40	0.08	-1.81	0.035
		No. of cooking sessions per day	cs/d	0.06	0.10	0.05	0.00	0	0.10	-0.27	-1.97	0.010
	Celery	Daily per capita celery consumption	g/p/d	3.51	6.00	3.31	10.96	0	10.00	-0.02	-1.75	0.685
		Water consumption per capita per cooking session	l/p/cs	0.18	0.30	0.17	0.03	0	0.40	-0.04	-1.85	0.035
		No. of cooking sessions per day	cs/d	0.05	0.10	0.05	0.00	0	0.10	-0.18	-2.01	0.010

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

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Table E3.2 Summary of food commodity parameters for low income households (92 households) in winter

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Vegetables and fruits	Water melon	Daily per capita water melon consumption	g/p/d	58.84	57.00	10.31	106.23	36	95.00	0.62	1.10	2.134
	Orange	Daily per capita orange consumption	g/p/d	18.74	18.00	5.49	30.17	12	32.00	0.48	-0.72	1.138
	Apple	Daily per capita apple consumption	g/p/d	18.61	18.00	5.51	30.35	12	32.00	0.52	-0.68	1.141
		Water consumption per capita per cooking session	l/p/cs	0.34	0.30	0.07	0.00	0.3	0.50	1.31	0.45	0.014
		No. of cooking sessions per day	cs/d	0.22	0.30	0.10	0.01	0.1	0.30	-0.41	-1.88	0.020
	Melon	Daily per capita melon consumption	g/p/d	11.72	12.00	3.24	10.49	0	24.00	-0.65	6.53	0.671
	Grape	Daily per capita grape consumption	g/p/d	6.13	9.00	5.54	30.64	0	16.00	-0.12	-1.83	1.146
		Water consumption per capita per cooking session	l/p/cs	0.18	0.30	0.17	0.03	0	0.50	0.05	-1.43	0.035
		No. of cooking sessions per day	cs/d	0.06	0.10	0.05	0.00	0	0.10	-0.27	-1.97	0.010
	Pumpkin	Daily per capita pumpkin consumption	g/p/d	6.39	9.00	5.52	30.50	0	16.00	-0.21	-1.80	1.144
		Water consumption per capita per cooking session	l/p/cs	0.19	0.30	0.17	0.03	0	0.50	-0.03	-1.40	0.035
		No. of cooking sessions per day	cs/d	0.06	0.10	0.05	0.00	0	0.10	-0.36	-1.91	0.010
		LPG consumption per capita per cooking session	ml/p/cs	23.76	37.70	20.61	424.82	0	62.60	-0.17	-1.71	4.268
	Banana	Daily per capita banana consumption	g/p/d	6.64	7.00	3.89	15.13	0	12.00	-0.60	-0.60	0.806
Oilseeds and pulses	Bean	Daily per capita bean consumption	g/p/d	13.14	13.00	4.09	16.74	0	20.00	-0.76	1.69	0.847
		Water consumption per capita per cooking session	l/p/cs	1.69	1.70	0.37	0.13	0	2.00	-3.30	13.03	0.076
		No. of cooking sessions per day	cs/d	0.11	0.10	0.05	0.00	0	0.30	2.72	8.71	0.011
		LPG consumption per capita per cooking session	ml/p/cs	62.36	60.70	16.07	258.18	0	87.30	-1.48	5.87	3.328
	Chickpea	Daily per capita chickpea consumption	g/p/d	12.76	12.00	3.82	14.60	0	20.00	-0.85	2.41	0.791
		Water consumption per capita per cooking session	l/p/cs	1.69	1.70	0.37	0.13	0	2.00	-3.30	13.03	0.076
		No. of cooking sessions per day	cs/d	0.11	0.10	0.05	0.00	0	0.30	2.72	8.71	0.011
		LPG consumption per capita per cooking session	ml/p/cs	62.36	60.70	16.07	258.18	0	87.30	-1.48	5.87	3.328
	Lentils	Daily per capita lentils consumption	g/p/d	13.15	14.00	4.03	16.22	0	20.00	-0.87	1.86	0.834
		Water consumption per capita per cooking session	l/p/cs	2.08	2.20	0.43	0.18	0	2.50	-3.76	16.28	0.089
		No. of cooking sessions per day	cs/d	0.11	0.10	0.05	0.00	0	0.30	2.72	8.71	0.011
		LPG consumption per capita per cooking session	ml/p/cs	62.36	60.70	16.07	258.18	0	87.30	-1.48	5.87	3.328
Oils & fats	Vegetable oil	Daily per capita vegetable oil consumption	g/p/d	28.36	29.00	3.73	13.90	18	36.00	-0.12	1.23	0.772
	Animal fats	Daily per capita animal fats consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.000
	Sugar	Daily per capita sugar consumption	g/p/d	66.10	71.00	7.88	62.13	36	77.00	-1.91	5.37	1.632

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Table E3.3 Summary of food commodity parameters for medium income households (176 households) in winter

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cereal grains	Wheat	Daily per capita wheat flour consumption	g/p/d	261.67	263.00	13.61	185.13	232	292.00	0.08	-0.53	2.024
		Water consumption per capita per cooking session	l/p/cs	1.63	1.30	0.53	0.28	1.1	2.50	0.65	-1.39	0.078
		No. of cooking sessions per day	cs/d	0.14	0.14	0.00	0.00	0.14	0.14	0.00	0.00	0.00
		LPG consumption per capita per cooking session	ml/p/cs	23.01	21.20	4.29	18.41	16.5	29.60	0.34	-1.23	0.638
	Rice	Daily per capita rice consumption	g/p/d	86.20	87.00	5.61	31.47	71	98.00	-0.19	-0.43	0.835
		Water consumption per capita per cooking session	l/p/cs	2.52	2.10	0.59	0.35	2	3.50	0.67	-1.37	0.088
		No. of cooking sessions per day	cs/d	1.10	1.10	0.10	0.01	1	1.30	1.05	0.33	0.014
		LPG consumption per capita per cooking session	ml/p/cs	14.14	13.30	3.19	10.16	9.7	18.90	0.47	-1.33	0.474
	Burgul and jareesh	Daily per capita burgul and jareesh consumption	g/p/d	5.47	5.00	0.55	0.31	5	7.00	0.64	-0.66	0.082
		Water consumption per capita per cooking session	l/p/cs	1.47	1.30	0.31	0.10	1.1	2.00	0.61	-1.21	0.046
		No. of cooking sessions per day	cs/d	0.10	0.10	0.00	0.00	0.1	0.10	0.00	0.00	0.00
		LPG consumption per capita per cooking session	ml/p/cs	14.14	13.30	3.19	10.16	9.7	18.90	0.47	-1.33	0.474
	Macaroni and vermicelli	Daily per capita macaroni and vermicelli consumpt.	g/p/d	7.60	8.00	0.79	0.62	5	9.00	-1.28	2.81	0.117
		Water consumption per capita per cooking session	l/p/cs	1.03	0.90	0.30	0.09	0.7	1.50	0.56	-1.45	0.044
		No. of cooking sessions per day	cs/d	0.13	0.10	0.07	0.01	0.1	0.30	1.94	1.78	0.011
		LPG consumption per capita per cooking session	ml/p/cs	8.34	8.00	1.49	2.22	6.2	11.10	0.60	-0.64	0.221
	Buns, cake and biscuits	Daily per capita buns, cake and biscuits consumpt.	g/p/d	48.57	49.00	3.65	13.34	43	55.00	-0.05	-1.12	0.543
		Water consumption per capita per cooking session	l/p/cs	0.56	0.40	0.25	0.06	0.3	1.00	0.73	-1.14	0.037
		No. of cooking sessions per day	cs/d	0.99	1.00	0.07	0.00	0.9	1.10	0.15	-0.67	0.010
		LPG consumption per capita per cooking session	ml/p/cs	17.31	15.90	3.85	14.81	12.4	23.60	0.58	-1.21	0.572
Meat	Sheep and goat	Daily per capita sheep and goat meat consumption	g/p/d	31.52	31.00	6.90	47.58	18	50.00	0.55	0.54	1.026
		Water consumption per capita per cooking session	l/p/cs	2.52	2.10	0.59	0.35	2	3.50	0.67	-1.37	0.088
		No. of cooking sessions per day	cs/d	0.97	1.00	0.05	0.00	0.9	1.00	-0.93	-1.14	0.007
		LPG consumption per capita per cooking session	ml/p/cs	84.80	79.60	19.10	364.81	58.3	113.10	0.47	-1.33	2.841
	Bovine	Daily per capita bovine meat consumption	g/p/d	2.14	0.00	3.15	9.94	0	14.00	1.56	2.13	0.469
		Water consumption per capita per cooking session	l/p/cs	1.29	0.00	1.51	2.28	0	3.50	0.43	-1.65	0.225
		No. of cooking sessions per day	cs/d	0.04	0.00	0.05	0.00	0	0.10	0.23	-1.97	0.007
		LPG consumption per capita per cooking session	ml/p/cs	42.58	0.00	50.12	2511.56	0	113.10	0.46	-1.62	7.456

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.3 Summary of food commodity parameters for medium income households (176 households) in winter

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Meat	Chicken and turkey	Daily per capita chicken and turkey consumption	g/p/d	47.63	46.00	9.98	99.51	29	75.00	0.85	0.53	1.484
		Water consumption per capita per cooking session	l/p/cs	2.52	2.10	0.59	0.35	2	3.50	0.67	-1.37	0.088
		No. of cooking sessions per day	cs/d	0.86	0.90	0.11	0.01	0.7	1.00	-0.54	-1.10	0.016
		LPG consumption per capita per cooking session	ml/p/cs	49.96	47.80	9.03	81.48	37.2	66.70	0.61	-0.66	1.343
	Fish and seafood	Daily per capita fish and seafood consumption	g/p/d	14.29	15.00	4.62	21.35	7	25.00	0.09	-0.43	0.687
		Water consumption per capita per cooking session	l/p/cs	2.97	2.60	0.61	0.37	2.4	4.00	0.66	-1.30	0.091
		No. of cooking sessions per day	cs/d	0.10	0.10	0.00	0.00	0.1	0.10	0.00	0.00	0.00
		LPG consumption per capita per cooking session	ml/p/cs	16.64	15.90	3.01	9.07	12.4	22.20	0.60	-0.70	0.448
Dairy	Yogurt	Daily per capita yogurt consumption	g/p/d	40.13	41.00	8.22	67.58	27	62.00	0.23	-0.20	1.223
		No. of cooking sessions per day	cs/d	0.04	0.00	0.05	0.00	0	0.10	0.23	-1.97	0.007
		LPG consumption per capita per cooking session	ml/p/cs	17.97	0.00	22.39	501.33	0	56.60	0.70	-1.20	3.331
	Cheese	Daily per capita cheese consumption	g/p/d	8.64	9.00	1.69	2.85	4	12.00	-0.31	-0.64	0.251
	Egg	Daily per capita egg consumption	egg/p/d	0.45	0.45	0.08	0.01	0.31	0.66	0.34	0.02	0.012
		Water consumption per capita per cooking session	l/p/cs	0.56	0.40	0.25	0.06	0.3	1.00	0.73	-1.14	0.037
		No. of cooking sessions per day	cs/d	0.86	0.90	0.11	0.01	0.7	1.00	-0.54	-1.10	0.016
		LPG consumption per capita per cooking session	ml/p/cs	8.05	8.00	1.79	3.22	4.9	11.10	0.21	-0.84	0.267
	Milk	Daily per capita milk consumption	g/p/d	26.82	26.80	6.09	37.08	14.3	42.20	0.30	-0.42	0.906
		No. of cooking sessions per day	cs/d	0.24	0.30	0.09	0.01	0.1	0.30	-0.93	-1.14	0.014
		LPG consumption per capita per cooking session	ml/p/cs	11.22	10.60	2.29	5.26	8.1	14.80	0.46	-1.30	0.341
	Butter	Daily per capita butter consumption	g/p/d	3.76	4.00	0.66	0.44	2	5.00	-1.13	1.53	0.098
Roots and tubers	Potato	Daily per capita potato consumption	g/p/d	82.90	82.00	10.94	119.61	71	117.00	1.03	0.81	1.627
		Water consumption per capita per cooking session	l/p/cs	1.03	0.90	0.30	0.09	0.7	1.50	0.56	-1.45	0.044
		No. of cooking sessions per day	cs/d	0.70	0.70	0.10	0.01	0.6	0.90	1.05	0.33	0.014
		LPG consumption per capita per cooking session	ml/p/cs	24.97	23.90	4.50	20.29	18.6	33.30	0.60	-0.68	0.670
	Onion	Daily per capita onion consumption	g/p/d	52.30	54.00	8.24	67.82	36	71.00	0.06	0.09	1.225
	Carrots	Daily per capita carrot consumption	g/p/d	0.39	0.00	1.11	1.23	0	4.00	2.57	4.86	0.165
		Water consumption per capita per cooking session	l/p/cs	0.03	0.00	0.10	0.01	0	0.30	2.46	4.08	0.014
		No. of cooking sessions per day	cs/d	0.01	0.00	0.03	0.00	0	0.10	2.46	4.08	0.005
		LPG consumption per capita per cooking session	ml/p/cs	0.83	0.00	2.32	5.38	0	7.80	2.48	4.28	0.345

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.3 Summary of food commodity parameters for medium income households (176 households) in winter

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Roots & tubers	Garlic	Daily per capita garlic consumption	g/p/d	0.93	0.00	1.21	1.47	0	4.00	0.72	-1.08	0.180
	Radish	Daily per capita radish consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
Vegetables and fruits	Tomato	Daily per capita tomato consumption	g/p/d	202.97	200.00	37.59	1412.86	143	293.00	0.57	-0.41	5.592
		Water consumption per capita per cooking session	l/p/cs	0.70	0.60	0.15	0.02	0.5	1.00	0.96	-0.37	0.022
		No. of cooking sessions per day	cs/d	1.07	1.10	0.05	0.00	1	1.10	-0.93	-1.14	0.007
	Cucumber	Daily per capita cucumber consumption	g/p/d	74.32	71.00	15.97	255.10	54	110.00	0.41	-0.78	2.376
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
	Aubergine	Daily per capita aubergine consumption	g/p/d	51.90	51.00	11.58	134.13	36	79.00	0.55	-0.41	1.723
		Water consumption per capita per cooking session	l/p/cs	0.64	0.60	0.12	0.01	0.5	0.80	0.32	-1.41	0.018
		No. of cooking sessions per day	cs/d	0.40	0.40	0.10	0.01	0.3	0.60	1.05	0.33	0.014
		LPG consumption per capita per cooking session	ml/p/cs	26.97	23.90	7.62	58.07	18.6	42.40	1.02	-0.26	1.134
	Courgette	Daily per capita courgette consumption	g/p/d	27.55	27.00	6.46	41.75	18	43.00	0.31	-0.39	0.961
		Water consumption per capita per cooking session	l/p/cs	0.64	0.60	0.12	0.01	0.5	0.80	0.32	-1.41	0.018
		No. of cooking sessions per day	cs/d	0.13	0.10	0.07	0.01	0.1	0.30	1.94	1.78	0.011
		LPG consumption per capita per cooking session	ml/p/cs	26.97	23.90	7.62	58.07	18.6	42.40	1.02	-0.26	1.134
	Okra	Daily per capita okra consumption	g/p/d	12.76	13.00	3.88	15.06	7	21.00	0.05	-1.06	0.577
		Water consumption per capita per cooking session	l/p/cs	0.64	0.60	0.12	0.01	0.5	0.80	0.32	-1.41	0.018
		No. of cooking sessions per day	cs/d	0.13	0.10	0.07	0.01	0.1	0.30	1.94	1.78	0.011
		LPG consumption per capita per cooking session	ml/p/cs	26.97	23.90	7.62	58.07	18.6	42.40	1.02	-0.26	1.134
	Lettuce	Daily per capita lettuce consumption	g/p/d	6.43	7.00	3.64	13.26	0	13.00	-0.42	-0.63	0.542
		Water consumption per capita per cooking session	l/p/cs	0.44	0.40	0.24	0.06	0	1.00	-0.36	-0.19	0.036
		No. of cooking sessions per day	cs/d	0.11	0.10	0.09	0.01	0	0.30	1.13	0.72	0.013
	Sweet pepper	Daily per capita sweet pepper consumption	g/p/d	6.55	7.00	3.48	12.13	0	13.00	-0.51	-0.40	0.518
		Water consumption per capita per cooking session	l/p/cs	0.16	0.10	0.12	0.02	0	0.40	0.85	-0.29	0.018
		No. of cooking sessions per day	cs/d	0.12	0.10	0.09	0.01	0	0.30	1.16	0.80	0.013
	Celery	Daily per capita celery consumption	g/p/d	6.21	6.50	3.64	13.23	0	13.00	-0.35	-0.68	0.541
		Water consumption per capita per cooking session	l/p/cs	0.26	0.30	0.12	0.02	0	0.40	-1.41	0.60	0.019
		No. of cooking sessions per day	cs/d	0.11	0.10	0.09	0.01	0	0.30	1.11	0.67	0.013

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.3 Summary of food commodity parameters for medium income households (176 households) in winter

Type	commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Vegetables and fruits	Water melon	Daily per capita water melon consumption	g/p/d	78.41	80.00	17.18	295.28	54	121.00	0.42	-0.26	2.556
	Orange	Daily per capita orange consumption	g/p/d	25.26	24.00	8.21	67.40	14	43.00	0.36	-0.82	1.221
	Apple	Daily per capita apple consumption	g/p/d	25.16	25.50	7.85	61.69	14	43.00	0.27	-0.80	1.168
		Water consumption per capita per cooking	l/p/cs	0.34	0.30	0.07	0.01	0.3	0.50	1.31	0.15	0.011
		No. of cooking sessions per day	cs/d	0.37	0.40	0.05	0.00	0.3	0.40	-0.93	-1.14	0.007
	Melon	Daily per capita melon consumption	g/p/d	17.82	18.00	5.82	33.85	0	30.00	-0.54	1.65	0.866
	Grape	Daily per capita grape consumption	g/p/d	8.63	10.00	6.42	41.24	0	21.00	0.00	-0.90	0.955
		Water consumption per capita per cooking	l/p/cs	0.21	0.30	0.14	0.02	0	0.40	-0.91	-1.13	0.020
		No. of cooking sessions per day	cs/d	0.21	0.30	0.14	0.02	0	0.30	-0.93	-1.14	0.020
	Pumpkin	Daily per capita pumpkin consumption	g/p/d	8.87	10.00	6.56	43.10	0	21.00	-0.06	-1.03	0.977
		Water consumption per capita per cooking	l/p/cs	0.21	0.30	0.14	0.02	0	0.40	-0.91	-1.13	0.020
		No. of cooking sessions per day	cs/d	0.07	0.10	0.05	0.00	0	0.10	-0.93	-1.14	0.007
		LPG consumption per capita per cooking session	ml/p/cs	20.27	24.80	13.58	184.47	0	37.20	-0.66	-1.24	2.021
	Banana	Daily per capita banana consumption	g/p/d	11.18	10.00	3.26	10.65	7	19.00	0.79	-0.21	0.486
Oilseeds and pulses	Bean	Daily per capita bean consumption	g/p/d	16.93	18.00	3.38	11.41	9	25.00	-0.53	0.32	0.502
		Water consumption per capita per cooking	l/p/cs	1.47	1.30	0.31	0.10	1.1	2.00	0.61	-1.21	0.046
		No. of cooking sessions per day	cs/d	0.24	0.30	0.09	0.01	0.1	0.30	-0.93	-1.14	0.014
		LPG consumption per capita per cooking session	ml/p/cs	48.28	47.80	10.82	117.13	29.2	66.70	0.23	-0.85	1.610
	Chickpea	Daily per capita chickpea consumption	g/p/d	17.20	18.00	3.10	9.62	9	25.00	-0.35	0.92	0.461
		Water consumption per capita per cooking	l/p/cs	1.47	1.30	0.31	0.10	1.1	2.00	0.61	-1.21	0.046
		No. of cooking sessions per day	cs/d	0.24	0.30	0.09	0.01	0.1	0.30	-0.93	-1.14	0.014
		LPG consumption per capita per cooking session	ml/p/cs	48.28	47.80	10.82	117.13	29.2	66.70	0.23	-0.85	1.610
	Lentils	Daily per capita lentils consumption	g/p/d	17.16	18.00	3.06	9.39	9	25.00	-0.23	0.72	0.456
		Water consumption per capita per cooking	l/p/cs	1.91	1.70	0.33	0.11	1.5	2.50	0.68	-1.10	0.050
		No. of cooking sessions per day	cs/d	0.24	0.30	0.09	0.01	0.1	0.30	-0.93	-1.14	0.014
		LPG consumption per capita per cooking session	ml/p/cs	48.28	47.80	10.82	117.13	29.2	66.70	0.23	-0.85	1.610
Oils & fats	Vegetable oil	Daily per capita vegetable oil consumption	g/p/d	34.86	36.00	4.09	16.76	27	43.00	-0.63	-0.15	0.609
	Animal fats	Daily per capita animal fats consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.000
	Sugar	Daily per capita sugar consumption	g/p/d	73.73	76.00	6.12	37.47	63	88.00	-0.25	-0.24	0.911

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Table E3.4 Summary of food commodity parameters for <u>high income households</u> (139 households) in <u>winter</u>

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cereal grains	Wheat	Daily per capita wheat flour consumption	g/p/d	268.00	268.00	6.79	46.09	256	282.00	0.15	-1.02	1.139
		Water consumption per capita per cooking session	l/p/cs	1.45	1.30	0.36	0.13	1.2	2.40	2.03	2.40	0.060
		No. of cooking sessions per day	cs/d	0.14	0.14	0.00	0.00	0.14	0.14	0.00	0.00	0.00
		LPG consumption per capita per cooking session	ml/p/cs	23.03	22.30	3.60	12.97	17.1	37.00	1.58	3.20	0.604
	Rice	Daily per capita rice consumption	g/p/d	92.04	92.00	3.05	9.33	83	98.00	-0.24	-0.26	0.512
		Water consumption per capita per cooking session	l/p/cs	2.36	2.30	0.37	0.14	2	3.40	1.87	2.23	0.062
		No. of cooking sessions per day	cs/d	1.33	1.30	0.08	0.01	1.1	1.40	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	12.35	11.50	2.44	5.93	8.6	24.70	1.91	5.40	0.408
	Burgul and jareesh	Daily per capita burgul and jareesh consumption	g/p/d	6.06	6.00	0.31	0.10	5	7.00	1.35	6.71	0.053
		Water consumption per capita per cooking session	l/p/cs	1.39	1.30	0.20	0.04	1.2	2.00	1.92	2.66	0.034
		No. of cooking sessions per day	cs/d	0.19	0.10	0.10	0.01	0.1	0.30	0.28	-1.95	0.017
		LPG consumption per capita per cooking session	ml/p/cs	12.35	11.50	2.44	5.93	8.6	24.70	1.91	5.40	0.408
	Macaroni and vermicelli	Daily per capita macaroni and vermicelli consumpt.	g/p/d	8.40	8.00	0.79	0.62	7	10.00	-0.04	-0.44	0.132
		Water consumption per capita per cooking session	l/p/cs	0.94	0.90	0.16	0.03	0.8	1.40	1.85	2.20	0.028
		No. of cooking sessions per day	cs/d	0.29	0.30	0.05	0.00	0.1	0.30	-3.58	10.95	0.008
		LPG consumption per capita per cooking session	ml/p/cs	7.66	7.40	1.19	1.43	5.7	12.30	1.61	3.32	0.200
	Buns, cake and biscuits	Daily per capita buns, cake and biscuits consumpt.	g/p/d	54.65	54.00	3.14	9.84	45	61.00	-0.41	0.23	0.526
		Water consumption per capita per cooking session	l/p/cs	0.46	0.40	0.17	0.03	0.3	1.00	2.23	3.67	0.028
		No. of cooking sessions per day	cs/d	1.33	1.30	0.08	0.01	1.1	1.40	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	15.46	14.80	2.75	7.54	11.4	30.80	2.27	7.72	0.460
Meat	Sheep and goat	Daily per capita sheep and goat meat consumption	g/p/d	47.41	48.00	7.55	57.07	24	61.00	-0.58	0.26	1.267
		Water consumption per capita per cooking session	l/p/cs	2.36	2.30	0.37	0.14	2	3.40	1.87	2.23	0.062
		No. of cooking sessions per day	cs/d	1.33	1.30	0.08	0.01	1.1	1.40	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	74.09	69.10	14.58	212.65	51.4	147.90	1.92	5.45	2.446
	Bovine	Daily per capita bovine meat consumption	g/p/d	10.46	11.00	4.47	19.96	0	20.00	-0.21	-0.32	0.749
		Water consumption per capita per cooking session	l/p/cs	2.36	2.30	0.37	0.14	2	3.40	1.87	2.23	0.062
		No. of cooking sessions per day	cs/d	0.19	0.10	0.10	0.01	0.1	0.30	0.28	-1.95	0.017
		LPG consumption per capita per cooking session	ml/p/cs	74.09	69.10	14.58	212.65	51.4	147.90	1.92	5.45	2.446

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.4 Summary of food commodity parameters for high income households (139 households) in winter

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Meat	Chicken and turkey	Daily per capita chicken and turkey consumption	g/p/d	71.32	71.00	11.02	121.45	43	91.00	-0.32	-0.51	1.848
		Water consumption per capita per cooking session	l/p/cs	2.36	2.30	0.37	0.14	2	3.40	1.87	2.23	0.062
		No. of cooking sessions per day	cs/d	1.18	1.10	0.11	0.01	1	1.30	0.09	-1.68	0.018
		LPG consumption per capita per cooking session	ml/p/cs	46.09	44.50	7.18	51.60	34.2	74.00	1.60	3.27	1.205
	Fish and seafood	Daily per capita fish and seafood consumption	g/p/d	22.37	22.00	4.75	22.60	9	30.00	-0.17	-0.69	0.797
		Water consumption per capita per cooking session	l/p/cs	2.85	2.70	0.40	0.16	2.4	4.00	1.80	2.20	0.068
		No. of cooking sessions per day	cs/d	0.19	0.10	0.10	0.01	0.1	0.30	0.28	-1.95	0.017
		LPG consumption per capita per cooking session	ml/p/cs	15.35	14.80	2.39	5.72	11.4	24.70	1.60	3.28	0.401
Dairy	Yogurt	Daily per capita yogurt consumption	g/p/d	58.86	58.00	9.58	91.81	36	75.00	-0.22	-0.64	1.607
		No. of cooking sessions per day	cs/d	0.01	0.00	0.02	0.00	0	0.10	3.58	10.95	0.004
		LPG consumption per capita per cooking session	ml/p/cs	3.29	0.00	12.76	162.79	0	74.00	3.82	13.68	2.140
	Cheese	Daily per capita cheese consumption	g/p/d	12.07	11.00	2.65	7.04	5	17.00	0.10	-0.97	0.445
	Egg	Daily per capita egg consumption	egg/p/d	0.65	0.64	0.10	0.01	0.43	0.83	0.01	-1.07	0.018
		Water consumption per capita per cooking session	l/p/cs	0.46	0.40	0.17	0.03	0.3	1.00	2.23	3.67	0.028
		No. of cooking sessions per day	cs/d	1.18	1.10	0.11	0.01	1	1.30	0.09	-1.68	0.018
		LPG consumption per capita per cooking session	ml/p/cs	6.89	6.90	1.65	2.71	4.3	12.30	0.98	1.12	0.276
	Milk	Daily per capita milk consumption	g/p/d	39.32	40.20	7.24	52.38	21.4	51.90	-0.22	-0.59	1.214
		No. of cooking sessions per day	cs/d	0.34	0.30	0.05	0.00	0.3	0.40	0.28	-1.95	0.008
		LPG consumption per capita per cooking session	ml/p/cs	10.00	9.30	1.80	3.24	7.1	18.50	1.81	4.59	0.302
	Butter	Daily per capita butter consumption	g/p/d	4.86	4.00	1.08	1.16	2	7.00	0.14	-1.38	0.181
Roots and tubers	Potato	Daily per capita potato consumption	g/p/d	111.02	107.00	17.45	304.57	71	143.00	-0.17	-0.83	2.927
		Water consumption per capita per cooking session	l/p/cs	0.94	0.90	0.16	0.03	0.8	1.40	1.85	2.20	0.028
		No. of cooking sessions per day	cs/d	0.89	0.90	0.05	0.00	0.7	0.90	-3.58	10.95	0.008
		LPG consumption per capita per cooking session	ml/p/cs	23.03	22.30	3.60	12.97	17.1	37.00	1.58	3.20	0.604
	Onion	Daily per capita onion consumption	g/p/d	71.84	71.00	11.05	122.03	43	93.00	-0.09	-0.86	1.853
	Carrots	Daily per capita carrot consumption	g/p/d	1.57	0.00	1.83	3.36	0	4.00	0.36	-1.80	0.308
		Water consumption per capita per cooking session	l/p/cs	0.13	0.00	0.15	0.02	0	0.40	0.31	-1.87	0.026
		No. of cooking sessions per day	cs/d	0.04	0.00	0.05	0.00	0	0.10	0.28	-1.95	0.008
		LPG consumption per capita per cooking session	ml/p/cs	3.14	0.00	3.65	13.33	0	8.20	0.34	-1.84	0.612

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.4 Summary of food commodity parameters for high income households (139 households) in winter

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Roots & tubers	Garlic	Daily per capita garlic consumption	g/p/d	2.52	2.00	0.98	0.96	0	4.00	-0.59	0.82	0.164
	Radish	Daily per capita radish consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
Vegetables and fruits	Tomato	Daily per capita tomato consumption	g/p/d	288.57	286.00	41.00	1681.25	171	357.00	-0.22	-0.45	6.877
		Water consumption per capita per cooking session	l/p/cs	0.66	0.60	0.10	0.01	0.5	1.00	1.92	3.79	0.017
		No. of cooking sessions per day	cs/d	1.18	1.10	0.11	0.01	1	1.30	0.09	-1.68	0.018
	Cucumber	Daily per capita cucumber consumption	g/p/d	109.55	107.00	16.71	279.07	71	137.00	-0.40	-0.30	2.802
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
	Aubergine	Daily per capita aubergine consumption	g/p/d	75.48	71.00	12.25	150.03	43	95.00	-0.21	-0.72	2.054
		Water consumption per capita per cooking session	l/p/cs	0.60	0.60	0.09	0.01	0.5	0.80	1.09	0.70	0.015
		No. of cooking sessions per day	cs/d	0.48	0.40	0.11	0.01	0.3	0.60	0.09	-1.68	0.018
		LPG consumption per capita per cooking session	ml/p/cs	23.36	22.30	4.87	23.76	17.1	55.50	3.23	15.43	0.818
	Courgette	Daily per capita courgette consumption	g/p/d	38.99	39.00	6.88	47.28	14	52.00	-0.56	1.01	1.153
		Water consumption per capita per cooking session	l/p/cs	0.60	0.60	0.09	0.01	0.5	0.80	1.09	0.70	0.015
		No. of cooking sessions per day	cs/d	0.33	0.30	0.08	0.01	0.1	0.40	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	23.36	22.30	4.87	23.76	17.1	55.50	3.23	15.43	0.818
	Okra	Daily per capita okra consumption	g/p/d	20.44	20.00	3.65	13.35	9	27.00	-0.36	-0.53	0.613
		Water consumption per capita per cooking session	l/p/cs	0.60	0.60	0.09	0.01	0.5	0.80	1.09	0.70	0.015
		No. of cooking sessions per day	cs/d	0.19	0.10	0.10	0.01	0.1	0.30	0.28	-1.95	0.017
		LPG consumption per capita per cooking session	ml/p/cs	23.36	22.30	4.87	23.76	17.1	55.50	3.23	15.43	0.818
	Lettuce	Daily per capita lettuce consumption	g/p/d	10.94	11.00	2.32	5.39	0	16.00	-0.91	2.47	0.389
		Water consumption per capita per cooking session	l/p/cs	0.54	0.50	0.15	0.02	0	1.00	1.27	3.44	0.025
		No. of cooking sessions per day	cs/d	0.19	0.10	0.10	0.01	0	0.30	0.25	-1.90	0.017
	Sweet pepper	Daily per capita sweet pepper consumption	g/p/d	11.06	12.00	2.51	6.28	0	15.00	-1.27	3.89	0.420
		Water consumption per capita per cooking session	l/p/cs	0.17	0.20	0.08	0.01	0	0.40	0.99	0.96	0.014
		No. of cooking sessions per day	cs/d	0.18	0.10	0.10	0.01	0	0.30	0.22	-1.86	0.017
	Celery	Daily per capita celery consumption	g/p/d	10.78	11.00	2.36	5.58	0	15.00	-0.72	2.04	0.396
		Water consumption per capita per cooking session	l/p/cs	0.31	0.30	0.04	0.00	0	0.40	-1.62	20.36	0.007
		No. of cooking sessions per day	cs/d	0.19	0.10	0.10	0.01	0	0.30	0.25	-1.90	0.017

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.4 Summary of food commodity parameters for high income households (139 households) in winter

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Vegetables and fruits	Water melon	Daily per capita water melon consumption	g/p/d	115.01	112.00	18.39	338.11	71	143.00	-0.16	-0.50	3.084
	Orange	Daily per capita orange consumption	g/p/d	40.12	40.00	7.63	58.23	14	54.00	-0.47	0.37	1.280
	Apple	Daily per capita apple consumption	g/p/d	39.35	40.00	7.11	50.55	14	52.00	-0.53	0.77	1.192
		Water consumption per capita per cooking	l/p/cs	0.31	0.30	0.03	0.00	0.3	0.40	2.23	3.02	0.006
		No. of cooking sessions per day	cs/d	0.63	0.60	0.08	0.01	0.4	0.70	-1.43	2.49	0.013
	Melon	Daily per capita melon consumption	g/p/d	27.14	27.00	6.25	39.10	0	36.00	-0.97	1.54	1.049
	Grape	Daily per capita grape consumption	g/p/d	19.18	20.00	5.27	27.80	0	29.00	-1.37	3.42	0.884
		Water consumption per capita per cooking	l/p/cs	0.30	0.30	0.06	0.00	0	0.40	-3.00	15.25	0.010
		No. of cooking sessions per day	cs/d	0.47	0.40	0.13	0.02	0	0.60	-1.10	2.50	0.022
	Pumpkin	Daily per capita pumpkin consumption	g/p/d	18.94	20.00	5.17	26.77	0	29.00	-1.50	3.48	0.868
		Water consumption per capita per cooking	l/p/cs	0.30	0.30	0.06	0.00	0	0.40	-3.00	15.25	0.010
		No. of cooking sessions per day	cs/d	0.10	0.10	0.02	0.00	0	0.10	-5.70	30.92	0.003
		LPG consumption per capita per cooking session	ml/p/cs	26.36	27.70	7.57	57.34	0	45.20	-0.58	3.32	1.270
	Banana	Daily per capita banana consumption	g/p/d	18.21	18.00	3.76	14.17	7	24.00	-0.84	0.95	0.631
Oilseeds and pulses	Bean	Daily per capita bean consumption	g/p/d	23.14	24.00	4.49	20.15	12	32.00	-0.24	-0.84	0.753
		Water consumption per capita per cooking	l/p/cs	1.39	1.30	0.20	0.04	1.2	2.00	1.92	2.66	0.034
		No. of cooking sessions per day	cs/d	0.33	0.30	0.08	0.01	0.1	0.40	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	41.37	41.50	9.94	98.78	25.7	74.00	0.98	1.09	1.667
	Chickpea	Daily per capita chickpea consumption	g/p/d	23.12	22.00	4.59	21.10	12	32.00	-0.11	-0.94	0.770
		Water consumption per capita per cooking	l/p/cs	1.39	1.30	0.20	0.04	1.2	2.00	1.92	2.66	0.034
		No. of cooking sessions per day	cs/d	0.33	0.30	0.08	0.01	0.1	0.40	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	41.37	41.50	9.94	98.78	25.7	74.00	0.98	1.09	1.667
	Lentils	Daily per capita lentils consumption	g/p/d	22.63	22.00	4.52	20.44	12	30.00	-0.17	-1.03	0.758
		Water consumption per capita per cooking	l/p/cs	1.85	1.80	0.21	0.04	1.6	2.40	1.58	1.46	0.035
		No. of cooking sessions per day	cs/d	0.33	0.30	0.08	0.01	0.1	0.40	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	41.37	41.50	9.94	98.78	25.7	74.00	0.98	1.09	1.667
Oils & fat	Vegetable oil	Daily per capita vegetable oil consumption	g/p/d	41.53	41.00	3.81	14.53	36	49.00	-0.08	-1.00	0.639
	Animal fats	Daily per capita animal fats consumption	g/p/d	0.56	0.00	0.71	0.51	0	2.00	0.88	-0.54	0.120
	Sugar	Daily per capita sugar consumption	g/p/d	83.55	85.00	8.39	70.45	60	97.00	-0.29	-0.66	1.408

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Table E3.5 Summary of food commodity parameters for all surveyed households (407 households) in summer

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cereal grains	Wheat	Daily per capita wheat flour consumption	g/p/d	251.95	253.00	9.66	93.29	226	272.00	-0.31	-0.47	0.941
		Water consumption per capita per cooking session	l/p/cs	1.68	1.40	0.50	0.25	1.1	2.50	0.45	-1.57	0.048
		No. of cooking sessions per day	cs/d	0.14	0.14	0.00	0.00	0.14	0.14			
		LPG consumption per capita per cooking session	ml/p/cs	25.14	25.10	6.15	37.79	16.5	69.70	3.16	18.74	0.599
	Rice	Daily per capita rice consumption	g/p/d	86.21	87.00	7.50	56.30	63	98.00	-0.62	-0.51	0.731
		Water consumption per capita per cooking session	l/p/cs	2.58	2.30	0.53	0.28	2	3.50	0.50	-1.37	0.051
		No. of cooking sessions per day	cs/d	1.16	1.10	0.15	0.02	1	1.40	0.35	-1.48	0.015
		LPG consumption per capita per cooking session	ml/p/cs	15.02	13.80	4.65	21.65	8.7	46.50	2.72	14.08	0.453
	Burgul and jareesh	Daily per capita burgul and jareesh consumption	g/p/d	5.66	6.00	0.60	0.36	4	7.00	-0.46	0.16	0.058
		Water consumption per capita per cooking session	l/p/cs	1.51	1.40	0.29	0.08	1.1	2.00	0.47	-1.25	0.028
		No. of cooking sessions per day	cs/d	0.13	0.10	0.07	0.01	0.1	0.30	2.00	2.00	0.007
		LPG consumption per capita per cooking session	ml/p/cs	15.02	13.80	4.65	21.65	8.7	46.50	2.72	14.08	0.453
	Macaroni and vermicelli	Daily per capita macaroni and vermicelli consumpt.	g/p/d	7.58	8.00	1.21	1.47	4	10.00	-0.65	0.55	0.118
		Water consumption per capita per cooking session	l/p/cs	1.05	0.90	0.26	0.07	0.7	1.50	0.43	-1.37	0.025
		No. of cooking sessions per day	cs/d	0.18	0.10	0.10	0.01	0.1	0.30	0.47	-1.79	0.009
		LPG consumption per capita per cooking session	ml/p/cs	8.82	8.40	2.09	4.35	5.8	23.20	2.72	14.85	0.203
	Buns, cake and biscuits	Daily per capita buns, cake and biscuits consumpt.	g/p/d	49.00	49.00	5.96	35.48	36	60.00	-0.50	-0.31	0.580
		Water consumption per capita per cooking session	l/p/cs	0.58	0.40	0.25	0.06	0.3	1.00	0.52	-1.38	0.024
		No. of cooking sessions per day	cs/d	1.02	1.00	0.28	0.08	0.6	1.40	-0.19	-1.12	0.027
		LPG consumption per capita per cooking session	ml/p/cs	18.53	16.80	5.69	32.34	11.6	58.10	3.04	16.11	0.554
Meat	Sheep and goat	Daily per capita sheep and goat meat consumption	g/p/d	34.86	31.00	11.53	133.02	12	61.00	0.33	-0.81	1.124
		Water consumption per capita per cooking session	l/p/cs	2.58	2.30	0.53	0.28	2	3.50	0.50	-1.37	0.051
		No. of cooking sessions per day	cs/d	1.01	1.00	0.28	0.08	0.6	1.40	-0.12	-1.11	0.027
		LPG consumption per capita per cooking session	ml/p/cs	90.15	83.10	27.95	781.12	52.2	278.90	2.70	13.95	2.723
	Bovine	Daily per capita bovine meat consumption	g/p/d	4.31	0.00	5.50	30.25	0	21.00	1.04	-0.14	0.536
		Water consumption per capita per cooking session	l/p/cs	0.86	0.00	1.11	1.23	0	3.40	0.57	-1.54	0.108
		No. of cooking sessions per day	cs/d	0.07	0.00	0.11	0.01	0	0.30	1.44	0.66	0.010
		LPG consumption per capita per cooking session	ml/p/cs	27.63	0.00	35.89	1288.36	0	110.50	0.61	-1.46	3.498

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

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Table E3.5 Summary of food commodity parameters for all surveyed households (407 households) in summer

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Meat	Chicken and turkey	Daily per capita chicken and turkey consumption	g/p/d	51.00	48.00	14.25	203.00	18	81.00	0.19	-0.88	1.388
		Water consumption per capita per cooking session	l/p/cs	2.84	2.80	0.34	0.11	2.4	3.50	0.52	-0.86	0.033
		No. of cooking sessions per day	cs/d	0.86	0.90	0.23	0.05	0.4	1.10	-0.62	-0.82	0.022
		LPG consumption per capita per cooking session	ml/p/cs	52.93	50.30	12.51	156.57	34.8	139.50	2.73	14.99	1.219
	Fish and seafood	Daily per capita fish and seafood consumption	g/p/d	19.46	20.00	7.59	57.57	0	36.00	0.08	-0.21	0.739
		Water consumption per capita per cooking session	l/p/cs	3.39	3.20	0.77	0.59	0	4.50	-1.52	6.25	0.075
		No. of cooking sessions per day	cs/d	0.10	0.10	0.03	0.00	0	0.30	4.05	27.27	0.003
		LPG consumption per capita per cooking session	ml/p/cs	16.92	16.60	4.06	16.52	0	26.10	-1.09	5.04	0.396
Dairy	Yogurt	Daily per capita yogurt consumption	g/p/d	52.11	52.00	11.79	139.00	24	74.00	-0.18	-0.80	1.149
		No. of cooking sessions per day	cs/d	0.02	0.00	0.04	0.00	0	0.10	1.30	-0.32	0.004
		LPG consumption per capita per cooking session	ml/p/cs	9.29	0.00	18.34	336.34	0	74.30	1.70	1.29	1.787
	Cheese	Daily per capita cheese consumption	g/p/d	9.26	9.00	3.13	9.79	0	16.00	0.21	-0.14	0.305
	Egg	Daily per capita egg consumption	egg/p/d	0.49	0.47	0.15	0.02	0.21	0.83	0.37	-0.58	0.015
		Water consumption per capita per cooking session	l/p/cs	0.58	0.40	0.25	0.06	0.3	1.00	0.52	-1.38	0.024
		No. of cooking sessions per day	cs/d	0.91	0.90	0.24	0.06	0.6	1.30	0.17	-1.12	0.023
		LPG consumption per capita per cooking session	ml/p/cs	8.43	8.30	2.46	6.04	4.4	23.20	1.66	7.94	0.239
	Milk	Daily per capita milk consumption	g/p/d	29.24	27.80	10.59	112.22	0	51.60	0.16	-0.53	1.032
		No. of cooking sessions per day	cs/d	0.24	0.30	0.11	0.01	0	0.40	-0.32	-1.38	0.011
		LPG consumption per capita per cooking session	ml/p/cs	11.76	11.10	3.04	9.26	0	34.50	1.41	8.24	0.297
	Butter	Daily per capita butter consumption	g/p/d	3.83	4.00	1.27	1.62	0	7.00	-0.14	0.53	0.124
Roots and tubers	Potato	Daily per capita potato consumption	g/p/d	72.10	71.00	10.13	102.58	48	98.00	0.27	-0.36	0.987
		Water consumption per capita per cooking session	l/p/cs	1.05	0.90	0.26	0.07	0.7	1.50	0.43	-1.37	0.025
		No. of cooking sessions per day	cs/d	0.68	0.70	0.13	0.02	0.4	0.90	-0.15	0.27	0.013
		LPG consumption per capita per cooking session	ml/p/cs	26.46	25.10	6.26	39.19	17.4	69.70	2.72	14.88	0.610
	Onion	Daily per capita onion consumption	g/p/d	56.61	54.00	15.34	235.24	24	93.00	0.33	-0.27	1.495
	Carrots	Daily per capita carrot consumption	g/p/d	1.37	0.00	1.84	3.39	0	6.00	0.64	-1.51	0.179
		Water consumption per capita per cooking session	l/p/cs	0.14	0.00	0.19	0.04	0	0.50	0.62	-1.57	0.019
		No. of cooking sessions per day	cs/d	0.08	0.00	0.12	0.01	0	0.30	1.14	-0.48	0.012
		LPG consumption per capita per cooking session	ml/p/cs	2.98	0.00	4.01	16.10	0	9.80	0.67	-1.43	0.391

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.5 Summary of food commodity parameters for <u>all surveyed households</u> (407 households) in <u>summer</u>

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Roots & tubers	Garlic	Daily per capita garlic consumption	g/p/d	1.26	0.00	1.36	1.86	0	4.00	0.43	-1.30	0.133
	Radish	Daily per capita radish consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00			
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00			
Vegetables and fruits	Tomato	Daily per capita tomato consumption	g/p/d	224.46	214.00	56.53	3195.97	143	336.00	0.34	-1.36	5.509
		Water consumption per capita per cooking session	l/p/cs	0.72	0.70	0.14	0.02	0.5	1.00	0.79	-0.50	0.014
		No. of cooking sessions per day	cs/d	1.19	1.30	0.12	0.01	1	1.30	-0.27	-1.61	0.012
	Cucumber	Daily per capita cucumber consumption	g/p/d	83.75	84.00	20.69	428.06	36	125.00	-0.11	-0.84	2.016
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00			
	Aubergine	Daily per capita aubergine consumption	g/p/d	57.80	61.00	13.32	177.37	24	87.00	-0.10	-0.76	1.298
		Water consumption per capita per cooking session	l/p/cs	0.64	0.60	0.11	0.01	0.5	0.80	0.30	-1.20	0.011
		No. of cooking sessions per day	cs/d	0.59	0.60	0.09	0.01	0.4	0.70	-1.09	0.63	0.009
		LPG consumption per capita per cooking session	ml/p/cs	29.08	25.10	11.25	126.49	17.4	104.60	3.02	14.29	1.096
	Courgette	Daily per capita courgette consumption	g/p/d	29.80	31.00	9.61	92.41	12	52.00	0.22	-0.76	0.937
		Water consumption per capita per cooking session	l/p/cs	0.64	0.60	0.11	0.01	0.5	0.80	0.30	-1.20	0.011
		No. of cooking sessions per day	cs/d	0.19	0.10	0.12	0.01	0.1	0.40	0.61	-1.36	0.012
		LPG consumption per capita per cooking session	ml/p/cs	30.41	25.10	11.86	140.62	17.4	104.60	2.38	9.99	1.156
	Okra	Daily per capita okra consumption	g/p/d	16.69	16.00	5.59	31.27	0	29.00	0.22	-0.20	0.545
		Water consumption per capita per cooking session	l/p/cs	0.64	0.60	0.12	0.01	0	0.80	-0.80	4.01	0.012
		No. of cooking sessions per day	cs/d	0.32	0.30	0.05	0.00	0	0.40	-1.11	11.63	0.005
		LPG consumption per capita per cooking session	ml/p/cs	29.64	25.10	10.33	106.63	0	59.50	0.92	0.86	1.006
	Lettuce	Daily per capita lettuce consumption	g/p/d	7.29	7.00	4.25	18.05	0	15.00	-0.41	-0.74	0.414
		Water consumption per capita per cooking session	l/p/cs	0.47	0.50	0.26	0.07	0	1.00	-0.42	-0.42	0.026
		No. of cooking sessions per day	cs/d	0.13	0.10	0.10	0.01	0	0.30	0.83	-0.40	0.010
	Sweet pepper	Daily per capita sweet pepper consumption	g/p/d	7.31	7.00	4.14	17.15	0	15.00	-0.47	-0.68	0.404
		Water consumption per capita per cooking session	l/p/cs	0.16	0.10	0.12	0.02	0	0.40	0.55	-0.68	0.012
		No. of cooking sessions per day	cs/d	0.13	0.10	0.10	0.01	0	0.30	0.84	-0.38	0.010
	Celery	Daily per capita celery consumption	g/p/d	8.52	9.00	3.66	13.40	0	16.00	-0.74	0.47	0.357
		Water consumption per capita per cooking session	l/p/cs	0.46	0.50	0.16	0.03	0	0.70	-1.85	3.16	0.016
		No. of cooking sessions per day	cs/d	0.29	0.30	0.10	0.01	0	0.40	-1.98	3.74	0.010

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.5 Summary of food commodity parameters for all surveyed households (407 households) in summer

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Vegetables and fruits	Water melon	Daily per capita water melon consumption	g/p/d	88.29	86.00	26.31	691.99	36	143.00	0.33	-0.80	2.563
	Orange	Daily per capita orange consumption	g/p/d	26.20	27.00	8.17	66.74	12	43.00	-0.11	-1.02	0.796
	Apple	Daily per capita apple consumption	g/p/d	36.13	36.00	8.22	67.62	18	54.00	-0.25	-0.60	0.801
		Water consumption per capita per cooking	l/p/cs	0.50	0.50	0.08	0.01	0.3	0.70	0.37	0.14	0.007
		No. of cooking sessions per day	cs/d	0.58	0.60	0.18	0.03	0.3	0.90	0.23	-0.83	0.018
	Melon	Daily per capita melon consumption	g/p/d	29.37	29.00	7.71	59.47	14	45.00	-0.21	-0.73	0.751
	Grape	Daily per capita grape consumption	g/p/d	21.41	20.00	6.09	37.11	12	33.00	0.05	-1.17	0.594
		Water consumption per capita per cooking	l/p/cs	0.66	0.70	0.07	0.01	0.5	0.80	0.21	-0.46	0.007
		No. of cooking sessions per day	cs/d	0.46	0.40	0.14	0.02	0.3	0.70	0.64	-1.02	0.014
	Pumpkin	Daily per capita pumpkin consumption	g/p/d	11.80	12.00	7.87	61.89	0	26.00	-0.18	-1.05	0.767
		Water consumption per capita per cooking	l/p/cs	0.24	0.30	0.13	0.02	0	0.50	-1.06	-0.29	0.013
		No. of cooking sessions per day	cs/d	0.08	0.10	0.04	0.00	0	0.10	-1.31	-0.27	0.004
		LPG consumption per capita per cooking session	ml/p/cs	23.67	28.70	14.22	202.19	0	57.90	-0.66	-0.76	1.386
	Banana	Daily per capita banana consumption	g/p/d	10.18	10.00	3.86	14.87	0	18.00	-0.43	0.42	0.376
Oilseeds and pulses	Bean	Daily per capita bean consumption	g/p/d	17.39	18.00	4.59	21.03	0	26.00	-0.46	0.46	0.447
		Water consumption per capita per cooking	l/p/cs	1.49	1.40	0.31	0.10	0	2.00	-0.34	2.13	0.031
		No. of cooking sessions per day	cs/d	0.24	0.30	0.11	0.01	0	0.40	-0.30	-1.39	0.011
		LPG consumption per capita per cooking session	ml/p/cs	49.55	49.80	13.31	177.13	0	79.40	-0.09	0.48	1.297
	Chickpea	Daily per capita chickpea consumption	g/p/d	17.03	18.00	4.31	18.59	0	26.00	-0.56	0.69	0.420
		Water consumption per capita per cooking	l/p/cs	1.49	1.40	0.31	0.10	0	2.00	-0.34	2.13	0.031
		No. of cooking sessions per day	cs/d	0.24	0.30	0.11	0.01	0	0.40	-0.30	-1.39	0.011
		LPG consumption per capita per cooking session	ml/p/cs	49.55	49.80	13.31	177.13	0	79.40	-0.09	0.48	1.297
	Lentils	Daily per capita lentils consumption	g/p/d	15.64	15.00	4.56	20.78	0	25.00	-0.55	1.24	0.444
		Water consumption per capita per cooking	l/p/cs	1.73	1.80	0.61	0.37	0	2.50	-1.87	3.31	0.059
		No. of cooking sessions per day	cs/d	0.23	0.30	0.13	0.02	0	0.40	-0.43	-1.20	0.012
		LPG consumption per capita per cooking session	ml/p/cs	43.93	48.50	17.76	315.25	0	74.30	-1.06	0.98	1.730
Oils & fats	Vegetable oil	Daily per capita vegetable oil consumption	g/p/d	35.56	36.00	6.40	41.02	18	49.00	-0.09	-0.59	0.624
	Animal fats	Daily per capita animal fats consumption	g/p/d	0.19	0.00	0.49	0.24	0	2.00	2.59	5.83	0.048
	Sugar	Daily per capita sugar consumption	g/p/d	75.41	76.00	10.26	105.29	36	97.00	-0.38	0.97	0.999

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Table E3.6 Summary of food commodity parameters for low income households (92 households) in summer

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cereal grains	Wheat	Daily per capita wheat flour consumption	g/p/d	241.30	241.00	7.12	50.68	226	255.00	-0.10	-0.95	1.474
		Water consumption per capita per cooking session	l/p/cs	2.13	2.20	0.29	0.08	1.1	2.50	-1.94	4.64	0.060
		No. of cooking sessions per day	cs/d	0.14	0.14	0.00	0.00	0.14	0.14			
		LPG consumption per capita per cooking session	ml/p/cs	30.45	28.60	8.95	80.04	16.5	69.70	2.80	9.95	1.853
	Rice	Daily per capita rice consumption	g/p/d	76.61	77.00	5.83	34.00	63	92.00	0.64	0.34	1.208
		Water consumption per capita per cooking session	l/p/cs	3.00	3.00	0.34	0.11	2	3.50	-1.08	1.94	0.070
		No. of cooking sessions per day	cs/d	1.02	1.00	0.07	0.01	1	1.30	3.58	11.06	0.015
		LPG consumption per capita per cooking session	ml/p/cs	19.63	18.50	6.27	39.25	10.3	46.50	2.65	8.91	1.298
	Burgul and jareesh	Daily per capita burgul and jareesh consumption	g/p/d	5.42	6.00	0.70	0.49	4	6.00	-0.81	-0.56	0.145
		Water consumption per capita per cooking session	l/p/cs	1.75	1.70	0.20	0.04	1.1	2.00	-1.03	2.00	0.041
		No. of cooking sessions per day	cs/d	0.10	0.10	0.00	0.00	0.1	0.10			
		LPG consumption per capita per cooking session	ml/p/cs	19.63	18.50	6.27	39.25	10.3	46.50	2.65	8.91	1.298
	Macaroni and vermicelli	Daily per capita macaroni and vermicelli consumpt.	g/p/d	6.17	7.00	1.11	1.22	4	8.00	-0.20	-1.38	0.229
		Water consumption per capita per cooking session	l/p/cs	1.26	1.30	0.15	0.02	0.7	1.50	-1.39	3.87	0.032
		No. of cooking sessions per day	cs/d	0.10	0.10	0.00	0.00	0.1	0.10			
		LPG consumption per capita per cooking session	ml/p/cs	10.80	9.50	2.75	7.55	6.2	23.20	2.99	11.48	0.569
	Buns, cake and biscuits	Daily per capita buns, cake and biscuits consumpt.	g/p/d	41.96	43.00	4.99	24.94	36	52.00	0.11	-1.20	1.034
		Water consumption per capita per cooking session	l/p/cs	0.82	0.80	0.15	0.02	0.3	1.00	-1.57	4.00	0.032
		No. of cooking sessions per day	cs/d	0.61	0.60	0.02	0.00	0.6	0.70	3.58	11.06	0.005
		LPG consumption per capita per cooking session	ml/p/cs	24.08	22.20	8.07	65.05	12.4	58.10	2.54	8.21	1.670
Meat	Sheep and goat	Daily per capita sheep and goat meat consumption	g/p/d	23.15	24.00	5.37	28.81	12	36.00	-0.29	-0.40	1.112
		Water consumption per capita per cooking session	l/p/cs	3.00	3.00	0.34	0.11	2	3.50	-1.08	1.94	0.070
		No. of cooking sessions per day	cs/d	0.61	0.60	0.02	0.00	0.6	0.70	3.58	11.06	0.005
		LPG consumption per capita per cooking session	ml/p/cs	117.85	110.90	37.57	1411.64	62	278.90	2.64	8.88	7.781
	Bovine	Daily per capita bovine meat consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00			
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00			
		No. of cooking sessions per day	cs/d	0.00	0.00	0.00	0.00	0	0.00			
		LPG consumption per capita per cooking session	ml/p/cs	0.00	0.00	0.00	0.00	0	0.00			

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.6 Summary of food commodity parameters for low income households (92 households) in summer

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Meat	Chicken and turkey	Daily per capita chicken and turkey consumption	g/p/d	34.41	36.00	6.13	37.54	18	48.00	-0.54	-0.34	1.269
		Water consumption per capita per cooking session	l/p/cs	3.03	3.00	0.27	0.07	2.4	3.50	0.00	-0.42	0.055
		No. of cooking sessions per day	cs/d	0.52	0.60	0.10	0.01	0.4	0.60	-0.41	-1.88	0.020
		LPG consumption per capita per cooking session	ml/p/cs	64.82	57.10	16.47	271.11	37.2	139.50	3.02	11.66	3.410
	Fish and seafood	Daily per capita fish and seafood consumption	g/p/d	11.68	12.00	4.86	23.62	0	20.00	-0.93	1.23	1.007
		Water consumption per capita per cooking session	l/p/cs	3.52	3.80	1.22	1.48	0	4.50	-2.35	4.34	0.252
		No. of cooking sessions per day	cs/d	0.09	0.10	0.03	0.00	0	0.10	-2.75	5.70	0.006
		LPG consumption per capita per cooking session	ml/p/cs	18.39	19.00	6.64	44.14	0	26.10	-1.93	3.35	1.376
Dairy	Yogurt	Daily per capita yogurt consumption	g/p/d	38.42	36.00	6.99	48.91	24	56.00	-0.10	0.23	1.448
		No. of cooking sessions per day	cs/d	0.01	0.00	0.02	0.00	0	0.10	3.58	11.06	0.005
		LPG consumption per capita per cooking session	ml/p/cs	2.03	0.00	7.74	59.94	0	32.30	3.63	11.51	1.603
	Cheese	Daily per capita cheese consumption	g/p/d	5.79	6.00	1.78	3.18	0	9.00	-0.84	1.90	0.369
	Egg	Daily per capita egg consumption	egg/p/d	0.32	0.33	0.07	0.00	0.21	0.49	0.23	-0.22	0.014
		Water consumption per capita per cooking session	l/p/cs	0.82	0.80	0.15	0.02	0.3	1.00	-1.57	4.00	0.032
		No. of cooking sessions per day	cs/d	0.61	0.60	0.02	0.00	0.6	0.70	3.58	11.06	0.005
		LPG consumption per capita per cooking session	ml/p/cs	10.80	9.50	2.75	7.55	6.2	23.20	2.99	11.48	0.569
	Milk	Daily per capita milk consumption	g/p/d	17.82	17.90	6.13	37.60	0	30.60	-0.38	0.36	1.270
		No. of cooking sessions per day	cs/d	0.10	0.10	0.01	0.00	0	0.10	-6.67	43.41	0.003
		LPG consumption per capita per cooking session	ml/p/cs	14.48	14.30	4.00	15.98	0	34.50	0.61	8.97	0.828
	Butter	Daily per capita butter consumption	g/p/d	2.52	2.00	1.07	1.15	0	4.00	-0.47	0.28	0.222
Roots and tubers	Potato	Daily per capita potato consumption	g/p/d	66.91	71.00	7.21	51.99	48	71.00	-1.49	0.85	1.493
		Water consumption per capita per cooking session	l/p/cs	1.26	1.30	0.15	0.02	0.7	1.50	-1.39	3.87	0.032
		No. of cooking sessions per day	cs/d	0.52	0.60	0.10	0.01	0.4	0.60	-0.41	-1.88	0.020
		LPG consumption per capita per cooking session	ml/p/cs	32.43	28.60	8.23	67.65	18.6	69.70	3.01	11.61	1.703
	Onion	Daily per capita onion consumption	g/p/d	40.98	43.00	8.52	72.64	24	56.00	-0.85	-0.28	1.765
	Carrots	Daily per capita carrot consumption	g/p/d	0.04	0.00	0.42	0.17	0	4.00	9.59	92.00	0.086
		Water consumption per capita per cooking session	l/p/cs	0.004	0.00	0.03	0.00	0	0.30	9.59	92.00	0.006
		No. of cooking sessions per day	cs/d	0.003	0.00	0.03	0.00	0	0.30	9.59	92.00	0.006
		LPG consumption per capita per cooking session	ml/p/cs	0.09	0.00	0.87	0.75	0	8.30	9.59	92.00	0.179

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.6 Summary of food commodity parameters for <u>low income households</u> (92 households) in <u>summer</u>

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Roots & tubers	Garlic	Daily per capita garlic consumption	g/p/d	0.02	0.00	0.21	0.04	0	2.00	9.59	92.00	0.043
	Radish	Daily per capita radish consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00			
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00			
Vegetables and fruits	Tomato	Daily per capita tomato consumption	g/p/d	170.57	167.00	14.55	211.63	143	230.00	0.94	3.18	3.013
		Water consumption per capita per cooking session	l/p/cs	0.83	0.80	0.11	0.01	0.6	1.00	0.16	-0.03	0.022
		No. of cooking sessions per day	cs/d	1.20	1.30	0.11	0.01	1	1.30	-0.30	-1.64	0.023
	Cucumber	Daily per capita cucumber consumption	g/p/d	62.30	71.00	11.05	122.06	36	82.00	-0.54	-0.92	2.288
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00			
	Aubergine	Daily per capita aubergine consumption	g/p/d	45.43	48.00	7.63	58.25	24	61.00	-0.24	0.21	1.581
		Water consumption per capita per cooking session	l/p/cs	0.71	0.70	0.08	0.01	0.5	0.80	-0.55	-0.10	0.016
		No. of cooking sessions per day	cs/d	0.60	0.60	0.00	0.00	0.6	0.60			
		LPG consumption per capita per cooking session	ml/p/cs	39.78	33.30	16.49	271.98	18.6	104.60	2.10	5.61	3.415
	Courgette	Daily per capita courgette consumption	g/p/d	19.95	21.00	4.81	23.17	12	32.00	0.11	0.14	0.997
		Water consumption per capita per cooking session	l/p/cs	0.71	0.70	0.08	0.01	0.5	0.80	-0.55	-0.10	0.016
		No. of cooking sessions per day	cs/d	0.11	0.10	0.05	0.00	0.1	0.30	3.58	11.06	0.010
		LPG consumption per capita per cooking session	ml/p/cs	45.68	42.90	13.42	180.09	24.8	104.60	2.80	9.99	2.779
	Okra	Daily per capita okra consumption	g/p/d	11.36	12.00	3.08	9.46	0	20.00	-1.47	4.74	0.637
		Water consumption per capita per cooking session	l/p/cs	0.69	0.70	0.14	0.02	0	0.80	-3.56	15.23	0.030
		No. of cooking sessions per day	cs/d	0.29	0.30	0.05	0.00	0	0.30	-5.35	27.22	0.011
		LPG consumption per capita per cooking session	ml/p/cs	42.28	42.90	11.15	124.29	0	59.50	-1.34	5.25	2.309
	Lettuce	Daily per capita lettuce consumption	g/p/d	3.68	6.00	3.24	10.48	0	10.00	-0.19	-1.79	0.670
		Water consumption per capita per cooking session	l/p/cs	0.43	0.80	0.39	0.15	0	0.80	-0.18	-1.94	0.080
		No. of cooking sessions per day	cs/d	0.06	0.10	0.05	0.00	0	0.10	-0.31	-1.94	0.010
	Sweet pepper	Daily per capita sweet pepper consumption	g/p/d	3.79	6.00	3.36	11.31	0	10.00	-0.12	-1.68	0.696
		Water consumption per capita per cooking session	l/p/cs	0.18	0.30	0.17	0.03	0	0.40	0.04	-1.81	0.035
		No. of cooking sessions per day	cs/d	0.06	0.10	0.05	0.00	0	0.10	-0.31	-1.94	0.010
	Celery	Daily per capita celery consumption	g/p/d	4.10	6.00	3.42	11.67	0	10.00	-0.22	-1.58	0.708
		Water consumption per capita per cooking session	l/p/cs	0.32	0.50	0.26	0.07	0	0.60	-0.34	-1.79	0.055
		No. of cooking sessions per day	cs/d	0.18	0.30	0.15	0.02	0	0.30	-0.45	-1.84	0.030

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.6 Summary of food commodity parameters for low income households (92 households) in summer

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Vegetables and fruits	Water melon	Daily per capita water melon consumption	g/p/d	59.29	57.00	10.86	117.86	36	92.00	0.72	1.24	2.248
	Orange	Daily per capita orange consumption	g/p/d	18.62	18.00	5.34	28.52	12	32.00	0.46	-0.72	1.106
	Apple	Daily per capita apple consumption	g/p/d	28.46	27.00	5.43	29.50	18	41.00	0.79	0.06	1.125
		Water consumption per capita per cooking	l/p/cs	0.54	0.50	0.09	0.01	0.3	0.70	0.14	0.12	0.019
		No. of cooking sessions per day	cs/d	0.36	0.40	0.05	0.00	0.3	0.40	-0.41	-1.88	0.010
	Melon	Daily per capita melon consumption	g/p/d	24.53	24.00	4.39	19.26	14	32.00	-1.10	1.12	0.909
	Grape	Daily per capita grape consumption	g/p/d	14.91	14.00	3.48	12.08	12	24.00	1.08	0.30	0.720
		Water consumption per capita per cooking	l/p/cs	0.65	0.70	0.08	0.01	0.5	0.80	-0.37	-0.64	0.017
		No. of cooking sessions per day	cs/d	0.35	0.40	0.05	0.00	0.3	0.40	-0.13	-2.03	0.010
	Pumpkin	Daily per capita pumpkin consumption	g/p/d	6.17	9.00	5.44	29.57	0	12.00	-0.19	-1.86	1.126
		Water consumption per capita per cooking	l/p/cs	0.19	0.30	0.17	0.03	0	0.50	0.01	-1.42	0.035
		No. of cooking sessions per day	cs/d	0.06	0.10	0.05	0.00	0	0.10	-0.31	-1.94	0.010
		LPG consumption per capita per cooking session	ml/p/cs	22.52	37.70	19.74	389.48	0	57.90	-0.21	-1.85	4.087
	Banana	Daily per capita banana consumption	g/p/d	6.03	6.50	3.55	12.63	0	15.00	-0.41	0.05	0.736
Oilseeds and pulses	Bean	Daily per capita bean consumption	g/p/d	12.92	12.00	3.77	14.18	0	18.00	-1.05	2.72	0.780
		Water consumption per capita per cooking	l/p/cs	1.69	1.70	0.37	0.13	0	2.00	-3.30	13.03	0.076
		No. of cooking sessions per day	cs/d	0.11	0.10	0.05	0.00	0	0.30	2.72	8.71	0.011
		LPG consumption per capita per cooking session	ml/p/cs	60.29	57.10	14.41	207.64	0	79.40	-2.16	8.30	2.984
	Chickpea	Daily per capita chickpea consumption	g/p/d	11.91	12.00	3.03	9.20	0	18.00	-1.77	6.17	0.628
		Water consumption per capita per cooking	l/p/cs	1.69	1.70	0.37	0.13	0	2.00	-3.30	13.03	0.076
		No. of cooking sessions per day	cs/d	0.11	0.10	0.05	0.00	0	0.30	2.72	8.71	0.011
		LPG consumption per capita per cooking session	ml/p/cs	60.29	57.10	14.41	207.64	0	79.40	-2.16	8.30	2.984
	Lentils	Daily per capita lentils consumption	g/p/d	11.03	12.00	3.88	15.09	0	16.00	-1.89	3.21	0.804
		Water consumption per capita per cooking	l/p/cs	1.22	2.00	1.02	1.04	0	2.20	-0.36	-1.86	0.211
		No. of cooking sessions per day	cs/d	0.06	0.10	0.05	0.00	0	0.10	-0.41	-1.88	0.010
		LPG consumption per capita per cooking session	ml/p/cs	35.45	56.60	29.67	880.48	0	66.50	-0.32	-1.83	6.145
Oils & fats	Vegetable oil	Daily per capita vegetable oil consumption	g/p/d	28.42	29.00	3.81	14.51	18	36.00	-0.08	1.06	0.789
	Animal fats	Daily per capita animal fats consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00			
	Sugar	Daily per capita sugar consumption	g/p/d	65.46	71.00	8.61	74.21	36	77.00	-1.76	3.46	1.784

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Table E3.7 Summary of food commodity parameters for medium income group (176 households) in summer

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cereal grains	Wheat	Daily per capita wheat flour consumption	g/p/d	255.73	256.00	8.99	80.87	232	272.00	-0.48	-0.36	1.338
		Water consumption per capita per cooking session	l/p/cs	1.63	1.30	0.53	0.28	1.1	2.50	0.65	-1.39	0.078
		No. of cooking sessions per day	cs/d	0.14	0.14	0.00	0.00	0.14	0.14			
		LPG consumption per capita per cooking session	ml/p/cs	23.37	22.10	4.14	17.10	17	30.30	0.37	-1.03	0.615
	Rice	Daily per capita rice consumption	g/p/d	86.39	87.00	5.23	27.38	71	98.00	-0.12	-0.61	0.778
		Water consumption per capita per cooking session	l/p/cs	2.52	2.10	0.59	0.35	2	3.50	0.67	-1.37	0.088
		No. of cooking sessions per day	cs/d	1.10	1.10	0.10	0.01	1	1.30	1.05	0.33	0.014
		LPG consumption per capita per cooking session	ml/p/cs	14.34	13.80	3.10	9.59	9.6	18.90	0.32	-1.35	0.461
	Burgul and jareesh	Daily per capita burgul and jareesh consumption	g/p/d	5.47	5.00	0.55	0.31	5	7.00	0.64	-0.66	0.082
		Water consumption per capita per cooking session	l/p/cs	1.47	1.30	0.31	0.10	1.1	2.00	0.61	-1.21	0.046
		No. of cooking sessions per day	cs/d	0.10	0.10	0.00	0.00	0.1	0.10			
		LPG consumption per capita per cooking session	ml/p/cs	14.34	13.80	3.10	9.59	9.6	18.90	0.32	-1.35	0.461
	Macaroni and vermicelli	Daily per capita macaroni and vermicelli consumpt.	g/p/d	7.62	8.00	0.75	0.56	5	9.00	-1.25	2.77	0.111
		Water consumption per capita per cooking session	l/p/cs	1.03	0.90	0.30	0.09	0.7	1.50	0.56	-1.45	0.044
		No. of cooking sessions per day	cs/d	0.13	0.10	0.07	0.01	0.1	0.30	1.94	1.78	0.011
		LPG consumption per capita per cooking session	ml/p/cs	8.48	8.30	1.53	2.33	6.4	11.40	0.68	-0.45	0.227
	Buns, cake and biscuits	Daily per capita buns, cake and biscuits consumpt.	g/p/d	48.49	49.00	3.59	12.87	43	57.00	-0.02	-1.01	0.534
		Water consumption per capita per cooking session	l/p/cs	0.56	0.40	0.25	0.06	0.3	1.00	0.73	-1.14	0.037
		No. of cooking sessions per day	cs/d	0.99	1.00	0.07	0.00	0.9	1.10	0.15	-0.67	0.010
		LPG consumption per capita per cooking session	ml/p/cs	17.58	16.60	3.68	13.53	12.7	22.90	0.43	-1.35	0.547
Meat	Sheep and goat	Daily per capita sheep and goat meat consumption	g/p/d	31.60	31.00	7.04	49.59	18	50.00	0.59	0.30	1.048
		Water consumption per capita per cooking session	l/p/cs	2.52	2.10	0.59	0.35	2	3.50	0.67	-1.37	0.088
		No. of cooking sessions per day	cs/d	0.97	1.00	0.05	0.00	0.9	1.00	-0.93	-1.14	0.007
		LPG consumption per capita per cooking session	ml/p/cs	86.17	83.10	18.67	348.60	57.4	113.60	0.31	-1.36	2.778
	Bovine	Daily per capita bovine meat consumption	g/p/d	2.30	0.00	3.48	12.13	0	14.00	1.64	2.13	0.518
		Water consumption per capita per cooking session	l/p/cs	0.32	0.00	0.76	0.58	0	2.30	1.95	1.85	0.113
		No. of cooking sessions per day	cs/d	0.02	0.00	0.04	0.00	0	0.10	1.94	1.78	0.005
		LPG consumption per capita per cooking session	ml/p/cs	9.91	0.00	23.42	548.46	0	68.80	1.96	1.91	3.484

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.7 Summary of food commodity parameters for medium income group (176 households) in summer

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Meat	Chicken and turkey	Daily per capita chicken and turkey consumption	g/p/d	46.78	46.00	6.40	40.95	36	65.00	0.41	0.44	0.952
		Water consumption per capita per cooking session	l/p/cs	2.81	2.60	0.40	0.16	2.4	3.50	0.63	-1.15	0.059
		No. of cooking sessions per day	cs/d	0.86	0.90	0.11	0.01	0.7	1.00	-0.54	-1.10	0.016
		LPG consumption per capita per cooking session	ml/p/cs	50.79	49.80	9.12	83.12	38.2	68.20	0.66	-0.45	1.356
	Fish and seafood	Daily per capita fish and seafood consumption	g/p/d	17.81	18.00	4.71	22.16	9	29.00	0.11	0.13	0.700
		Water consumption per capita per cooking session	l/p/cs	3.43	3.00	0.66	0.43	2.8	4.50	0.64	-1.42	0.098
		No. of cooking sessions per day	cs/d	0.10	0.10	0.00	0.00	0.1	0.10			
		LPG consumption per capita per cooking session	ml/p/cs	16.93	16.60	3.02	9.13	12.7	22.70	0.66	-0.45	0.450
Dairy	Yogurt	Daily per capita yogurt consumption	g/p/d	50.26	51.00	8.19	67.13	36	71.00	0.28	0.21	1.219
		No. of cooking sessions per day	cs/d	0.04	0.00	0.05	0.00	0	0.10	0.23	-1.97	0.007
		LPG consumption per capita per cooking session	ml/p/cs	17.84	0.00	22.17	491.59	0	55.00	0.68	-1.27	3.298
	Cheese	Daily per capita cheese consumption	g/p/d	8.69	9.00	1.66	2.75	4	12.00	-0.09	-0.74	0.247
	Egg	Daily per capita egg consumption	egg/p/d	0.46	0.45	0.08	0.01	0.31	0.68	0.59	0.27	0.012
		Water consumption per capita per cooking session	l/p/cs	0.56	0.40	0.25	0.06	0.3	1.00	0.73	-1.14	0.037
		No. of cooking sessions per day	cs/d	0.86	0.90	0.11	0.01	0.7	1.00	-0.54	-1.10	0.016
		LPG consumption per capita per cooking session	ml/p/cs	8.20	8.30	1.86	3.47	4.8	11.40	0.15	-0.66	0.277
	Milk	Daily per capita milk consumption	g/p/d	26.78	26.80	5.84	34.16	14.3	42.20	0.15	-0.37	0.869
		No. of cooking sessions per day	cs/d	0.24	0.30	0.09	0.01	0.1	0.30	-0.93	-1.14	0.014
		LPG consumption per capita per cooking session	ml/p/cs	11.43	11.10	2.27	5.17	8	15.20	0.37	-1.15	0.338
	Butter	Daily per capita butter consumption	g/p/d	3.69	4.00	0.71	0.51	2	5.00	-1.09	0.88	0.106
Roots and tubers	Potato	Daily per capita potato consumption	g/p/d	67.96	71.00	8.48	71.83	54	95.00	1.08	0.95	1.261
		Water consumption per capita per cooking session	l/p/cs	1.03	0.90	0.30	0.09	0.7	1.50	0.56	-1.45	0.044
		No. of cooking sessions per day	cs/d	0.67	0.70	0.05	0.00	0.6	0.70	-0.93	-1.14	0.007
		LPG consumption per capita per cooking session	ml/p/cs	25.39	24.90	4.56	20.82	19.1	34.10	0.66	-0.46	0.679
	Onion	Daily per capita onion consumption	g/p/d	52.51	54.00	8.34	69.51	36	71.00	0.19	0.28	1.240
	Carrots	Daily per capita carrot consumption	g/p/d	1.49	0.00	1.88	3.52	0	4.00	0.50	-1.72	0.279
		Water consumption per capita per cooking session	l/p/cs	0.15	0.00	0.19	0.04	0	0.50	0.50	-1.70	0.028
		No. of cooking sessions per day	cs/d	0.12	0.00	0.15	0.02	0	0.30	0.45	-1.82	0.022
		LPG consumption per capita per cooking session	ml/p/cs	3.31	0.00	4.19	17.60	0	9.60	0.53	-1.64	0.624

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.7 Summary of food commodity parameters for medium income group (176 households) in summer

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Roots & tubers	Garlic	Daily per capita garlic consumption	g/p/d	0.95	0.00	1.24	1.55	0	4.00	0.77	-0.93	0.185
	Radish	Daily per capita radish consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00			
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00			
Vegetables and fruits	Tomato	Daily per capita tomato consumption	g/p/d	202.68	196.00	37.33	1393.62	143	299.00	0.63	-0.24	5.554
		Water consumption per capita per cooking session	l/p/cs	0.70	0.60	0.15	0.02	0.5	1.00	0.96	-0.37	0.022
		No. of cooking sessions per day	cs/d	1.18	1.30	0.14	0.02	1	1.30	-0.38	-1.73	0.020
	Cucumber	Daily per capita cucumber consumption	g/p/d	78.25	82.00	14.73	217.07	54	104.00	-0.55	-1.00	2.192
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00			
	Aubergine	Daily per capita aubergine consumption	g/p/d	54.27	59.00	10.62	112.83	36	71.00	-0.48	-1.00	1.580
		Water consumption per capita per cooking session	l/p/cs	0.64	0.60	0.12	0.01	0.5	0.80	0.32	-1.41	0.018
		No. of cooking sessions per day	cs/d	0.56	0.60	0.11	0.01	0.4	0.70	-0.54	-1.10	0.016
		LPG consumption per capita per cooking session	ml/p/cs	27.34	24.90	7.22	52.07	19.1	41.20	0.84	-0.62	1.073
	Courgette	Daily per capita courgette consumption	g/p/d	27.72	27.50	6.49	42.16	18	43.00	0.20	-0.55	0.966
		Water consumption per capita per cooking session	l/p/cs	0.64	0.60	0.12	0.01	0.5	0.80	0.32	-1.41	0.018
		No. of cooking sessions per day	cs/d	0.13	0.10	0.07	0.01	0.1	0.30	1.94	1.78	0.011
		LPG consumption per capita per cooking session	ml/p/cs	27.34	24.90	7.22	52.07	19.1	41.20	0.84	-0.62	1.073
	Okra	Daily per capita okra consumption	g/p/d	15.01	15.00	3.42	11.73	7	21.00	-0.48	-0.31	0.509
		Water consumption per capita per cooking session	l/p/cs	0.64	0.60	0.12	0.01	0.5	0.80	0.32	-1.41	0.018
		No. of cooking sessions per day	cs/d	0.32	0.30	0.04	0.00	0.3	0.40	1.94	1.78	0.005
		LPG consumption per capita per cooking session	ml/p/cs	27.34	24.90	7.22	52.07	19.1	41.20	0.84	-0.62	1.073
	Lettuce	Daily per capita lettuce consumption	g/p/d	6.29	7.00	3.63	13.21	0	13.00	-0.45	-0.73	0.541
		Water consumption per capita per cooking session	l/p/cs	0.44	0.40	0.25	0.06	0	1.00	-0.34	-0.24	0.037
		No. of cooking sessions per day	cs/d	0.11	0.10	0.09	0.01	0	0.30	1.11	0.67	0.013
	Sweet pepper	Daily per capita sweet pepper consumption	g/p/d	6.41	7.00	3.55	12.61	0	13.00	-0.45	-0.54	0.528
		Water consumption per capita per cooking session	l/p/cs	0.15	0.10	0.12	0.01	0	0.40	0.89	-0.16	0.018
		No. of cooking sessions per day	cs/d	0.11	0.10	0.09	0.01	0	0.30	1.13	0.75	0.013
	Celery	Daily per capita celery consumption	g/p/d	8.52	9.00	1.94	3.78	5	13.00	-0.22	-0.45	0.289
		Water consumption per capita per cooking session	l/p/cs	0.49	0.50	0.07	0.01	0.4	0.70	0.39	-0.57	0.011
		No. of cooking sessions per day	cs/d	0.32	0.30	0.04	0.00	0.3	0.40	1.94	1.78	0.005

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.7 Summary of food commodity parameters for medium income group (176 households) in summer

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Vegetables and fruits	Water melon	Daily per capita water melon consumption	g/p/d	81.69	80.00	15.14	229.12	54	121.00	0.34	-0.37	2.252
	Orange	Daily per capita orange consumption	g/p/d	24.50	27.00	6.69	44.81	14	39.00	-0.15	-1.11	0.996
	Apple	Daily per capita apple consumption	g/p/d	35.65	36.00	7.67	58.83	18	52.00	-0.55	0.25	1.141
		Water consumption per capita per cooking	l/p/cs	0.48	0.50	0.07	0.01	0.4	0.60	0.24	-0.98	0.011
		No. of cooking sessions per day	cs/d	0.54	0.60	0.09	0.01	0.4	0.60	-0.93	-1.14	0.014
	Melon	Daily per capita melon consumption	g/p/d	26.20	27.00	6.94	48.14	14	42.00	-0.15	-0.88	1.032
	Grape	Daily per capita grape consumption	g/p/d	21.02	20.00	4.70	22.06	14	30.00	0.27	-0.90	0.699
		Water consumption per capita per cooking	l/p/cs	0.65	0.60	0.07	0.01	0.6	0.80	0.98	-0.50	0.011
		No. of cooking sessions per day	cs/d	0.37	0.40	0.05	0.00	0.3	0.40	-0.93	-1.14	0.007
	Pumpkin	Daily per capita pumpkin consumption	g/p/d	8.96	10.00	6.69	44.80	0	21.00	-0.01	-0.99	0.996
		Water consumption per capita per cooking	l/p/cs	0.21	0.30	0.14	0.02	0	0.40	-0.91	-1.13	0.020
		No. of cooking sessions per day	cs/d	0.07	0.10	0.05	0.00	0	0.10	-0.93	-1.14	0.007
		LPG consumption per capita per cooking session	ml/p/cs	20.83	25.50	14.08	198.38	0	38.80	-0.61	-1.26	2.095
	Banana	Daily per capita banana consumption	g/p/d	9.82	9.00	2.43	5.91	5	18.00	0.83	0.91	0.362
Oilseeds and pulses	Bean	Daily per capita bean consumption	g/p/d	16.55	18.00	3.23	10.42	9	24.00	-0.69	0.45	0.480
		Water consumption per capita per cooking	l/p/cs	1.47	1.30	0.31	0.10	1.1	2.00	0.61	-1.21	0.046
		No. of cooking sessions per day	cs/d	0.24	0.30	0.09	0.01	0.1	0.30	-0.93	-1.14	0.014
		LPG consumption per capita per cooking session	ml/p/cs	49.14	49.80	11.10	123.26	28.7	68.20	0.15	-0.66	1.652
	Chickpea	Daily per capita chickpea consumption	g/p/d	16.98	18.00	3.01	9.05	9	23.00	-0.81	0.71	0.447
		Water consumption per capita per cooking	l/p/cs	1.47	1.30	0.31	0.10	1.1	2.00	0.61	-1.21	0.046
		No. of cooking sessions per day	cs/d	0.24	0.30	0.09	0.01	0.1	0.30	-0.93	-1.14	0.014
		LPG consumption per capita per cooking session	ml/p/cs	49.14	49.80	11.10	123.26	28.7	68.20	0.15	-0.66	1.652
	Lentils	Daily per capita lentils consumption	g/p/d	15.07	15.00	3.16	9.98	9	23.00	-0.25	-0.04	0.470
		Water consumption per capita per cooking	l/p/cs	1.91	1.70	0.33	0.11	1.5	2.50	0.68	-1.10	0.050
		No. of cooking sessions per day	cs/d	0.24	0.30	0.09	0.01	0.1	0.30	-0.93	-1.14	0.014
		LPG consumption per capita per cooking session	ml/p/cs	49.14	49.80	11.10	123.26	28.7	68.20	0.15	-0.66	1.652
Oils & fats	Vegetable oil	Daily per capita vegetable oil consumption	g/p/d	34.52	36.00	4.30	18.48	27	43.00	-0.49	-0.52	0.640
	Animal fats	Daily per capita animal fats consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00			
	Sugar	Daily per capita sugar consumption	g/p/d	73.49	76.00	6.29	39.62	63	89.00	-0.17	-0.34	0.936

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Table E3.8 Summary of food commodity parameters for high income households (139 households) in summer

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Cereal grains	Wheat	Daily per capita wheat flour consumption	g/p/d	254.21	254.00	6.29	39.56	241	266.00	-0.03	-0.74	1.055
		Water consumption per capita per cooking session	l/p/cs	1.45	1.30	0.36	0.13	1.2	2.40	2.03	2.40	0.060
		No. of cooking sessions per day	cs/d	0.14	0.14	0.00	0.00	0.14	0.14			
		LPG consumption per capita per cooking session	ml/p/cs	23.87	22.60	3.51	12.30	17.4	37.10	1.25	2.29	0.588
	Rice	Daily per capita rice consumption	g/p/d	92.33	93.00	3.04	9.25	83	98.00	-0.36	0.05	0.510
		Water consumption per capita per cooking session	l/p/cs	2.36	2.30	0.37	0.14	2	3.40	1.87	2.23	0.062
		No. of cooking sessions per day	cs/d	1.33	1.30	0.08	0.01	1.1	1.40	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	12.82	12.30	2.45	6.01	8.7	24.80	1.49	4.02	0.411
	Burgul and jareesh	Daily per capita burgul and jareesh consumption	g/p/d	6.06	6.00	0.31	0.10	5	7.00	1.35	6.71	0.053
		Water consumption per capita per cooking session	l/p/cs	1.39	1.30	0.20	0.04	1.2	2.00	1.92	2.66	0.034
		No. of cooking sessions per day	cs/d	0.19	0.10	0.10	0.01	0.1	0.30	0.28	-1.95	0.017
		LPG consumption per capita per cooking session	ml/p/cs	12.82	12.30	2.45	6.01	8.7	24.80	1.49	4.02	0.411
	Macaroni and vermicelli	Daily per capita macaroni and vermicelli consumpt.	g/p/d	8.47	8.00	0.83	0.69	7	10.00	0.16	-0.50	0.139
		Water consumption per capita per cooking session	l/p/cs	0.94	0.90	0.16	0.03	0.8	1.40	1.85	2.20	0.028
		No. of cooking sessions per day	cs/d	0.29	0.30	0.05	0.00	0.1	0.30	-3.58	10.95	0.008
		LPG consumption per capita per cooking session	ml/p/cs	7.96	7.50	1.17	1.36	5.8	12.40	1.27	2.36	0.195
	Buns, cake and biscuits	Daily per capita buns, cake and biscuits consumpt.	g/p/d	54.32	54.00	3.11	9.66	45	60.00	-0.46	-0.02	0.521
		Water consumption per capita per cooking session	l/p/cs	0.46	0.40	0.17	0.03	0.3	1.00	2.23	3.67	0.028
		No. of cooking sessions per day	cs/d	1.33	1.30	0.08	0.01	1.1	1.40	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	16.05	15.10	2.68	7.18	11.6	30.90	1.98	6.90	0.450
Meat	Sheep and goat	Daily per capita sheep and goat meat consumption	g/p/d	46.72	46.00	7.93	62.87	24	61.00	-0.55	-0.06	1.330
		Water consumption per capita per cooking session	l/p/cs	2.36	2.30	0.37	0.14	2	3.40	1.87	2.23	0.062
		No. of cooking sessions per day	cs/d	1.33	1.30	0.08	0.01	1.1	1.40	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	76.85	73.80	14.67	215.10	52.2	148.50	1.51	4.05	2.460
	Bovine	Daily per capita bovine meat consumption	g/p/d	9.71	10.00	5.17	26.68	0	21.00	-0.11	-0.72	0.866
		Water consumption per capita per cooking session	l/p/cs	2.11	2.20	0.67	0.45	0	3.40	-2.21	5.54	0.112
		No. of cooking sessions per day	cs/d	0.18	0.10	0.11	0.01	0	0.30	0.07	-1.65	0.018
		LPG consumption per capita per cooking session	ml/p/cs	68.34	73.10	22.73	516.72	0	110.50	-1.93	4.15	3.812

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.8 Summary of food commodity parameters for high income households (139 households) in summer

Type	Commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Meat	Chicken and turkey	Daily per capita chicken and turkey consumption	g/p/d	67.31	67.00	6.82	46.49	48	81.00	-0.28	-0.05	1.144
		Water consumption per capita per cooking session	l/p/cs	2.77	2.70	0.24	0.06	2.4	3.40	1.07	0.71	0.039
		No. of cooking sessions per day	cs/d	1.09	1.10	0.02	0.00	1	1.10	-3.58	10.95	0.004
		LPG consumption per capita per cooking session	ml/p/cs	47.76	45.20	7.03	49.38	34.8	74.30	1.24	2.27	1.179
	Fish and seafood	Daily per capita fish and seafood consumption	g/p/d	26.69	27.00	5.41	29.24	12	36.00	-0.27	-0.31	0.907
		Water consumption per capita per cooking session	l/p/cs	3.26	3.10	0.42	0.18	2.8	4.40	1.79	1.98	0.070
		No. of cooking sessions per day	cs/d	0.11	0.10	0.05	0.00	0.1	0.30	3.58	10.95	0.008
		LPG consumption per capita per cooking session	ml/p/cs	15.94	15.10	2.34	5.49	11.6	24.80	1.23	2.24	0.393
Dairy	Yogurt	Daily per capita yogurt consumption	g/p/d	63.50	63.00	5.62	31.54	48	74.00	-0.54	0.11	0.942
		No. of cooking sessions per day	cs/d	0.01	0.00	0.02	0.00	0	0.10	3.58	10.95	0.004
		LPG consumption per capita per cooking session	ml/p/cs	3.27	0.00	12.72	161.80	0	74.30	3.84	13.85	2.133
	Cheese	Daily per capita cheese consumption	g/p/d	12.28	12.00	2.37	5.59	7	16.00	0.01	-1.10	0.397
	Egg	Daily per capita egg consumption	egg/p/d	0.64	0.64	0.10	0.01	0.43	0.83	0.09	-1.03	0.017
		Water consumption per capita per cooking session	l/p/cs	0.46	0.40	0.17	0.03	0.3	1.00	2.23	3.67	0.028
		No. of cooking sessions per day	cs/d	1.18	1.10	0.11	0.01	1	1.30	0.09	-1.68	0.018
		LPG consumption per capita per cooking session	ml/p/cs	7.16	7.30	1.72	2.95	4.4	12.40	0.61	0.11	0.288
	Milk	Daily per capita milk consumption	g/p/d	39.93	40.80	7.23	52.26	21.4	51.60	-0.37	-0.51	1.212
		No. of cooking sessions per day	cs/d	0.34	0.30	0.05	0.00	0.3	0.40	0.28	-1.95	0.008
		LPG consumption per capita per cooking session	ml/p/cs	10.38	9.80	1.78	3.16	7.3	18.60	1.45	3.49	0.298
	Butter	Daily per capita butter consumption	g/p/d	4.86	4.00	1.06	1.12	2	7.00	0.14	-1.44	0.178
Roots and tubers	Potato	Daily per capita potato consumption	g/p/d	80.77	80.00	7.80	60.90	63	98.00	-0.09	-0.80	1.309
		Water consumption per capita per cooking session	l/p/cs	0.94	0.90	0.16	0.03	0.8	1.40	1.85	2.20	0.028
		No. of cooking sessions per day	cs/d	0.80	0.90	0.10	0.01	0.7	0.90	-0.01	-2.03	0.017
		LPG consumption per capita per cooking session	ml/p/cs	23.87	22.60	3.51	12.30	17.4	37.10	1.25	2.29	0.588
	Onion	Daily per capita onion consumption	g/p/d	72.16	71.00	11.32	128.22	43	93.00	-0.06	-0.85	1.899
	Carrots	Daily per capita carrot consumption	g/p/d	2.11	3.00	1.91	3.65	0	6.00	-0.12	-1.83	0.320
		Water consumption per capita per cooking session	l/p/cs	0.22	0.40	0.20	0.04	0	0.50	-0.20	-1.92	0.034
		No. of cooking sessions per day	cs/d	0.08	0.10	0.10	0.01	0	0.30	1.25	0.72	0.016
		LPG consumption per capita per cooking session	ml/p/cs	4.47	6.30	4.07	16.60	0	9.80	-0.10	-1.82	0.683

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.8 Summary of food commodity parameters for <u>high income households</u> (139 households) in <u>summer</u>

Type	commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Roots & tubers	Garlic	Daily per capita garlic consumption	g/p/d	2.46	2.00	0.94	0.89	0	4.00	-0.62	1.08	0.158
	Radish	Daily per capita radish consumption	g/p/d	0.00	0.00	0.00	0.00	0	0.00			
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00			
Vegetables and fruits	Tomato	Daily per capita tomato consumption	g/p/d	287.71	293.00	30.42	925.57	179	336.00	-1.46	2.85	5.102
		Water consumption per capita per cooking session	l/p/cs	0.66	0.60	0.10	0.01	0.5	1.00	1.92	3.79	0.017
		No. of cooking sessions per day	cs/d	1.19	1.10	0.10	0.01	1.1	1.30	0.28	-1.95	0.017
	Cucumber	Daily per capita cucumber consumption	g/p/d	104.91	107.00	10.37	107.56	83	125.00	0.05	-0.89	1.739
		Water consumption per capita per cooking session	l/p/cs	0.00	0.00	0.00	0.00	0	0.00			
	Aubergine	Daily per capita aubergine consumption	g/p/d	70.45	71.00	7.82	61.22	48	87.00	-0.10	-0.22	1.312
		Water consumption per capita per cooking session	l/p/cs	0.60	0.60	0.09	0.01	0.5	0.80	1.09	0.70	0.015
		No. of cooking sessions per day	cs/d	0.63	0.60	0.08	0.01	0.4	0.70	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	24.20	22.60	4.76	22.63	17.4	55.70	3.09	15.26	0.798
	Courgette	Daily per capita courgette consumption	g/p/d	38.96	36.00	6.96	48.39	14	52.00	-0.52	0.84	1.167
		Water consumption per capita per cooking session	l/p/cs	0.60	0.60	0.09	0.01	0.5	0.80	1.09	0.70	0.015
		No. of cooking sessions per day	cs/d	0.33	0.30	0.08	0.01	0.1	0.40	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	24.20	22.60	4.76	22.63	17.4	55.70	3.09	15.26	0.798
	Okra	Daily per capita okra consumption	g/p/d	22.35	22.00	4.02	16.14	12	29.00	-0.18	-0.59	0.674
		Water consumption per capita per cooking session	l/p/cs	0.60	0.60	0.09	0.01	0.5	0.80	1.09	0.70	0.015
		No. of cooking sessions per day	cs/d	0.34	0.30	0.05	0.00	0.3	0.40	0.28	-1.95	0.008
		LPG consumption per capita per cooking session	ml/p/cs	24.20	22.60	4.76	22.63	17.4	55.70	3.09	15.26	0.798
	Lettuce	Daily per capita lettuce consumption	g/p/d	10.94	11.00	2.47	6.10	0	15.00	-1.23	3.95	0.414
		Water consumption per capita per cooking session	l/p/cs	0.54	0.50	0.15	0.02	0	1.00	0.90	3.82	0.026
		No. of cooking sessions per day	cs/d	0.18	0.10	0.10	0.01	0	0.30	0.22	-1.86	0.017
	Sweet pepper	Daily per capita sweet pepper consumption	g/p/d	10.77	11.00	2.38	5.69	0	15.00	-1.37	4.51	0.400
		Water consumption per capita per cooking session	l/p/cs	0.17	0.20	0.08	0.01	0	0.40	0.99	0.96	0.014
		No. of cooking sessions per day	cs/d	0.18	0.10	0.10	0.01	0	0.30	0.22	-1.86	0.017
	Celery	Daily per capita celery consumption	g/p/d	11.45	12.00	2.30	5.28	0	16.00	-0.91	3.31	0.385
		Water consumption per capita per cooking session	l/p/cs	0.51	0.50	0.09	0.01	0	0.70	-0.97	7.63	0.015
		No. of cooking sessions per day	cs/d	0.34	0.30	0.06	0.00	0	0.40	-1.27	6.95	0.010

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Continue

Table E3.8 Summary of food commodity parameters for high income households (139 households) in summer

Type	commodity	Parameters	Unit	Mean	Median	Std. Deviation	Variance	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95%)
Vegetables and fruits	Water melon	Daily per capita water melon consumption	g/p/d	115.83	116.00	16.96	287.67	71	143.00	-0.02	-0.93	2.845
	Orange	Daily per capita orange consumption	g/p/d	33.37	36.00	5.18	26.87	14	43.00	-0.69	1.14	0.869
	Apple	Daily per capita apple consumption	g/p/d	41.82	42.00	5.72	32.73	24	54.00	-0.33	-0.10	0.959
		Water consumption per capita per cooking	l/p/cs	0.50	0.50	0.06	0.00	0.4	0.70	0.16	0.17	0.010
		No. of cooking sessions per day	cs/d	0.78	0.70	0.11	0.01	0.6	0.90	0.09	-1.68	0.018
	Melon	Daily per capita melon consumption	g/p/d	36.58	36.00	4.53	20.55	18	45.00	-1.13	2.94	0.760
	Grape	Daily per capita grape consumption	g/p/d	26.19	27.00	4.67	21.85	14	33.00	-0.84	0.14	0.784
		Water consumption per capita per cooking	l/p/cs	0.68	0.70	0.07	0.00	0.5	0.80	0.01	-0.28	0.011
		No. of cooking sessions per day	cs/d	0.63	0.60	0.08	0.01	0.4	0.70	-1.43	2.49	0.013
	Pumpkin	Daily per capita pumpkin consumption	g/p/d	19.11	20.00	4.54	20.58	0	26.00	-1.35	3.33	0.761
		Water consumption per capita per cooking	l/p/cs	0.31	0.30	0.05	0.00	0	0.40	-2.60	19.81	0.008
		No. of cooking sessions per day	cs/d	0.10	0.10	0.01	0.00	0	0.10	-8.24	66.94	0.002
		LPG consumption per capita per cooking session	ml/p/cs	28.04	29.30	7.48	56.02	0	45.60	-0.24	1.89	1.255
	Banana	Daily per capita banana consumption	g/p/d	13.40	13.00	2.43	5.89	7	18.00	-0.43	-0.13	0.407
Oilseeds and pulses	Bean	Daily per capita bean consumption	g/p/d	21.41	22.00	2.97	8.81	12	26.00	-0.72	0.52	0.498
		Water consumption per capita per cooking	l/p/cs	1.39	1.30	0.20	0.04	1.2	2.00	1.92	2.66	0.034
		No. of cooking sessions per day	cs/d	0.33	0.30	0.08	0.01	0.1	0.40	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	42.96	43.90	10.34	107.01	26.1	74.30	0.61	0.07	1.735
	Chickpea	Daily per capita chickpea consumption	g/p/d	20.49	20.00	2.76	7.63	12	26.00	-0.37	0.51	0.463
		Water consumption per capita per cooking	l/p/cs	1.39	1.30	0.20	0.04	1.2	2.00	1.92	2.66	0.034
		No. of cooking sessions per day	cs/d	0.33	0.30	0.08	0.01	0.1	0.40	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	42.96	43.90	10.34	107.01	26.1	74.30	0.61	0.07	1.735
	Lentils	Daily per capita lentils consumption	g/p/d	19.41	20.00	3.11	9.66	9	25.00	-0.32	-0.05	0.521
		Water consumption per capita per cooking	l/p/cs	1.85	1.80	0.21	0.04	1.6	2.40	1.58	1.46	0.035
		No. of cooking sessions per day	cs/d	0.33	0.30	0.08	0.01	0.1	0.40	-1.43	2.49	0.013
		LPG consumption per capita per cooking session	ml/p/cs	42.96	43.90	10.34	107.01	26.1	74.30	0.61	0.07	1.735
Oils & fat	Vegetable oil	Daily per capita vegetable oil consumption	g/p/d	41.60	41.00	3.94	15.55	36	49.00	-0.03	-1.10	0.661
	Animal fats	Daily per capita animal fats consumption	g/p/d	0.56	0.00	0.71	0.51	0	2.00	0.88	-0.54	0.120
	Sugar	Daily per capita sugar consumption	g/p/d	84.42	87.00	7.62	58.00	60	97.00	-0.70	0.25	1.277

Note: g=grams, p=person, d=day, l=litres, cs=cooking session, d=day, ml=millilitres

Appendix E4 Duration of Food Cooking Session

Table E4.1 Average duration of cooking session of each food commodity in different income groups

Type	Commodity	Parameters	Unit	All surveyed households	Low income group	Medium income group	High income group
Cereal grains	Wheat	Duration of using hob ring in each cooking session	min/cs	44	36	42	51
	Rice	Duration of using hob ring in each cooking session	min/cs	25	23	25	27
	Burgul and jareesh	Duration of using hob ring in each cooking session	min/cs	25	23	25	27
	Macaroni and vermicelli	Duration of using hob ring in each cooking session	min/cs	15	13	15	17
	Buns, cake and biscuits	Duration of using hob ring in each cooking session	min/cs	31	28	31	34
Meat	Sheep and goat	Duration of using hob ring in each cooking session	min/cs	152	138	150	162
	Bovine	Duration of using hob ring in each cooking session	min/cs	84	0	150	162
	Chicken and turkey	Duration of using hob ring in each cooking session	min/cs	92	78	90	102
	Fish and seafood	Duration of using hob ring in each cooking session	min/cs	30	24	30	34
Dairy	Yogurt	Duration of using hob ring in each cooking session	min/cs	14	4	4	4
	Egg	Duration of using hob ring in each cooking session	min/cs	14	13	14	15
	Milk	Duration of using hob ring in each cooking session	min/cs	20	18	20	22
Roots and tubers	Potato	Duration of using hob ring in each cooking session	min/cs	46	39	45	51
	Carrots	Duration of using hob ring in each cooking session	min/cs	4	0	2	9
Vegetables and fruits	Aubergine	Duration of using hob ring in each cooking session	min/cs	48	45	47	51
	Courgette	Duration of using hob ring in each cooking session	min/cs	50	54	47	51
	Okra	Duration of using hob ring in each cooking session	min/cs	48	45	47	51
	Pumpkin	Duration of using hob ring in each cooking session	min/cs	46	32	43	58
Oilseeds and pulses	Bean	Duration of using hob ring in each cooking session	min/cs	85	76	86	89
	Chickpea	Duration of using hob ring in each cooking session	min/cs	85	76	86	89
	Lentils	Duration of using hob ring in each cooking session	min/cs	85	76	86	89

Note: min/cs=minutes per cooking session

Appendix E5 Comparison between Food Consumption in Winter and Summer Season

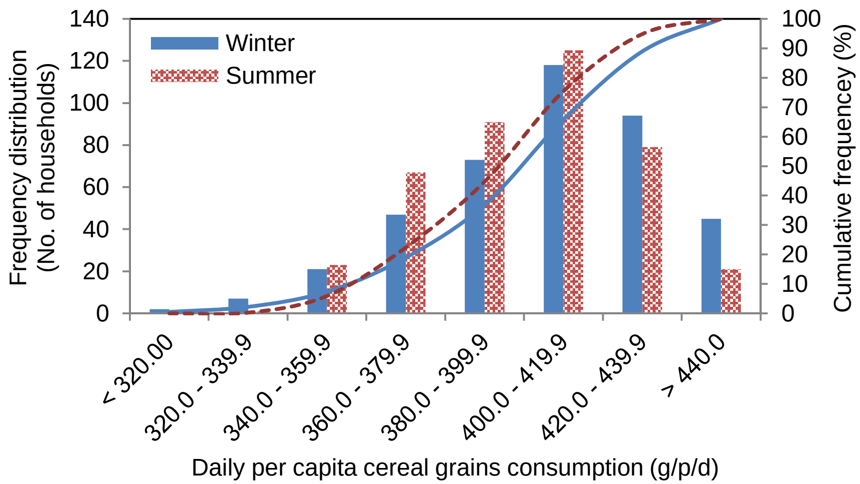

Figure E5.1 Comparison between per capita cereal grains consumption in winter and summer

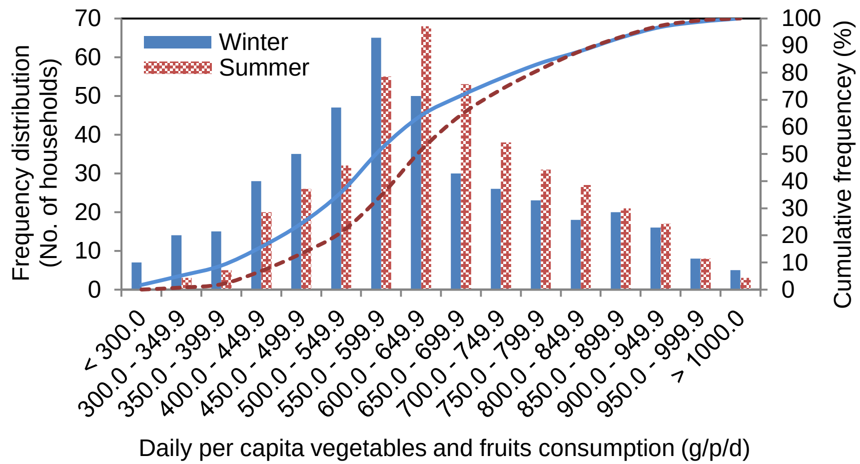

Figure E5.2 Comparison between per capita vegetables and fruits consumption in winter and summer

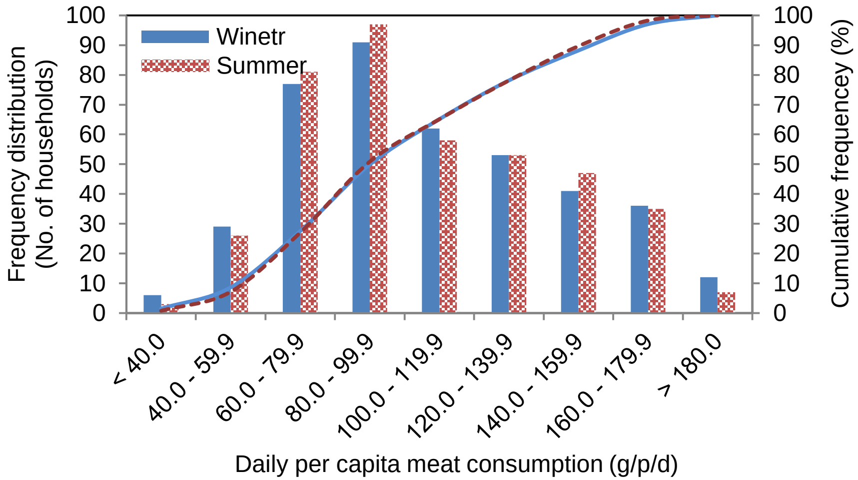

Figure E5.3 Comparison between per capita meat consumption in winter and summer

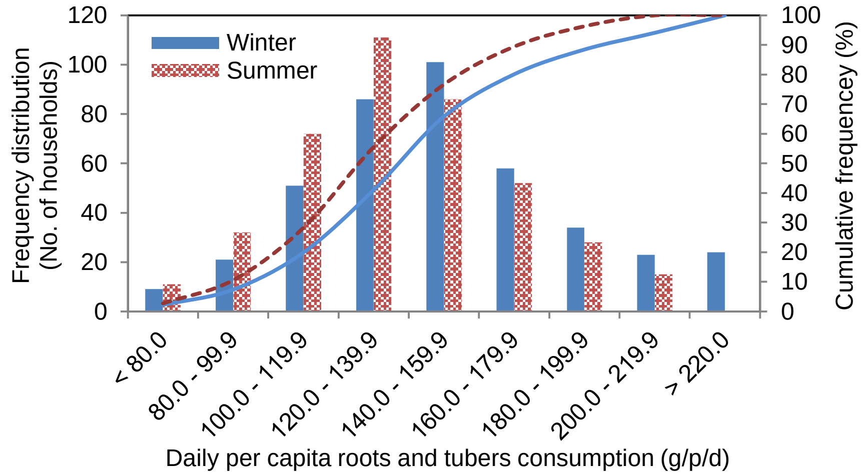

Figure E5.4 Comparison between per capita roots and tubers consumption in winter and summer

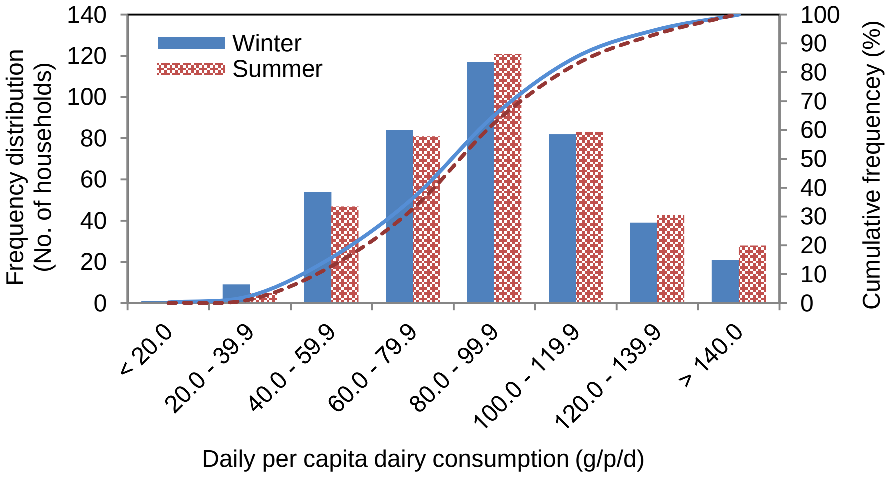

Figure E5.5 Comparison between per capita dairy consumption in winter and summer

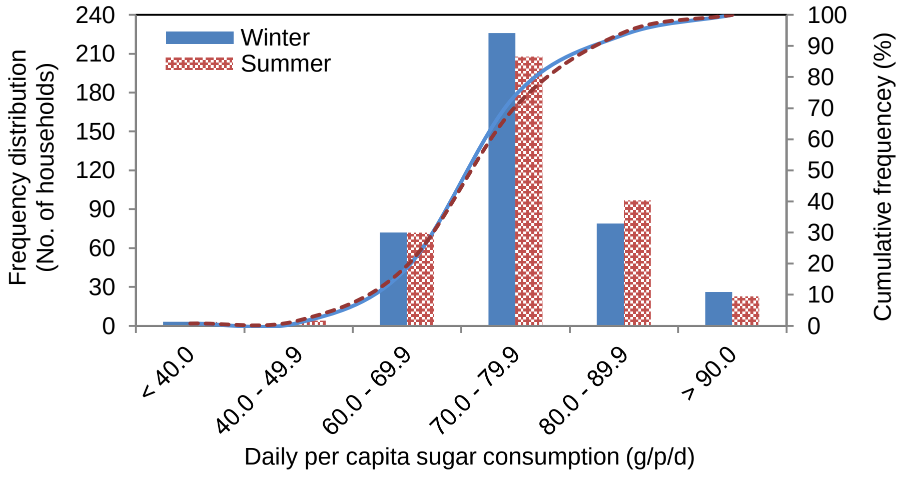

Figure E5.6 Comparison between per capita sugar consumption in winter and summer

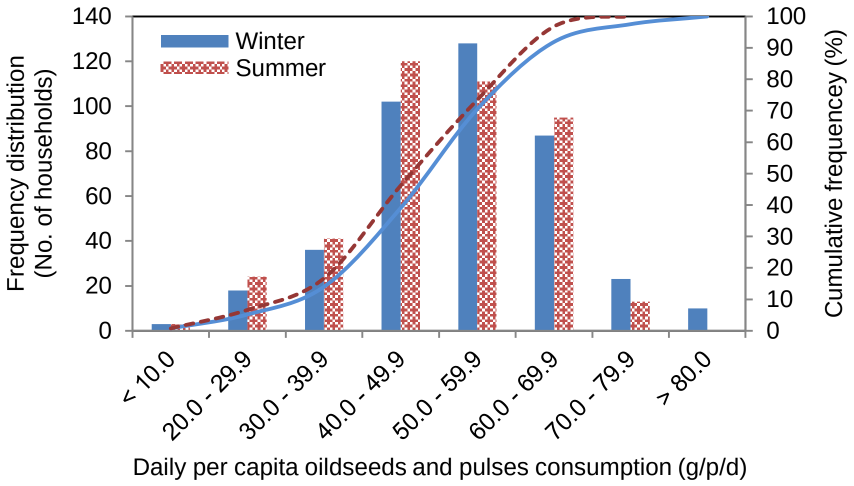

Figure E5.7 Comparison between per capita oilseeds and pulses consumption in winter and summer

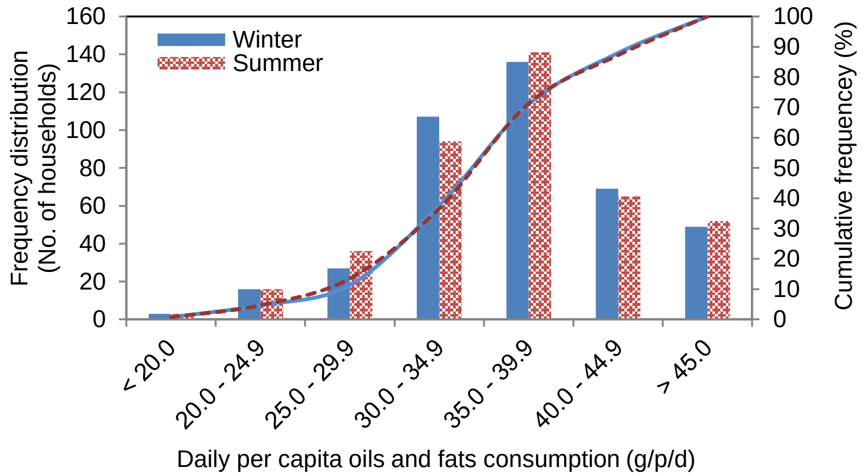

Figure E5.8 Comparison between per capita oils and fats consumption in winter and summer

APPENDIX F: PUBLISHED AND SUBMITTED PAPERS

Water Resour Manage
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Assessing and Modelling the Influence of Household Characteristics on Per Capita Water Consumption

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Abstract Sustainable urban water supply management requires, ideally, accurate evidence based estimations on per capita consumption and a good understanding of the factors influencing the consumption. The information can then be used to achieve improved water demand forecasts. Water consumption patterns in the developed countries have been extensively investigated. However, very little is known for the developing world. This paper investigates per capita water consumption resulting from water use activities in different types of households typically found in urban areas of the developing world. A data collection programme was executed for 407 households to extract information on household characteristics, water user behaviour and intensity and the nature of indoor and outdoor water use activities. The rigorous statistical analysis of the data shows that per capita water consumption increases with income: 241, 272 and 290 l/capita/day for low, medium and high income households, respectively. Additionally, the results suggest that per capita consumption increases with the number of adult female members in the household and almost one-third of consumption is via taps. The collected data has been used to develop statistical models using two different regression techniques: multiple linear (STEPWISE) and evolutionary polynomial regression (EPR). The inclusion of demographic parameters in the developed models considerably improved the prediction accuracy. Two of the best performing models are used to forecast the water demand for the city, using four future scenarios: market forces, fortress world, policy reform and great transition. The results suggest that the domestic water demand would be highest in the fortress world scenario due to the increase in population and size of built-up area.

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Keywords Water end-use · Household characteristics · Built-up area · Income · Evolutionary polynomial regression · STEPWISE regression

1 Introduction

Water scarcity is a major issue in many developed and developing countries. Rapid population growth, urbanization and climate change related uncertainties are some of the factors influencing land use patterns and need to be considered during water resources management planning. Since 2007, the fraction of urban population has exceeded the rural fraction and is largely attributed to the economic migration (United Nation 2015). In order to accommodate this rapid increase in urban population on limited urban land, there is a considerable upward shift towards developing apartments in multi-storey buildings with the associated change in physical household characteristics (e.g., built-up area, number of rooms and area of front garden). These characteristics can in turn influence domestic water consumption. Additionally, the interactions between climate change and land use and management can affect the availability of freshwater resources (Houghton-Carr et al. 2013), as a result of change in the amount of returned evapotranspiration to the atmosphere and also runoff and groundwater pathways (Holman and Hess 2014). Emphasis is growing on the implementation of demand management measures, water reuse and better understanding of our water consumption behaviours and factors influencing or contributing to domestic water consumption.

The modelling of domestic water demand has been effectively examined and analysed in the developed countries, while less effort has been made for the developing countries (Nauges and Whittington 2009). This can be due to the household's access to more than one type of water sources in the developing countries. Rizaiza (1991) developed water demand models for households supplied by water distribution network and tankers, separately, to estimate water demand in four cities in Saudi Arabia. Also, Cheesman et al. (2008) separated water demand for households with a private connection only and households combining private connection and well water. Different household characteristics are used for water demand modelling and estimation in the developing countries, such as, walking time to water source (Persson 2002), number of women in the household (Mu et al. 1990), family size (Larson et al. 2006), education level (Madanat and Humplick 1993), income (Nauges and Strand 2007) and reliability of water from other sources (Nauges and van den Berg 2009). However, physical household characteristics (e.g. built-up area, garden area, number of rooms and number of floors) should be taken into account to develop effective models for domestic water demand estimation.

The domestic water consumption in Iraq is investigated in some studies. For example, Al-Samawi and Hassan (1988) and Isehak (2001) investigated the residential water demand in Basrah and Baghdad city, respectively. Al-Anbari et al. (2009) analysed the residential water consumption for Hilla city, and found that the number of occupants and hand wash basin taps have a significant impact on the household water consumption.

This paper examines water consumption for over 400 households, of different types, and explores the influence of various household characteristics on per capita consumption patterns currently prevailing in urban areas of an Iraqi city, Duhok. The collected water consumption data has been used to develop statistical models demonstrating the influence of household characteristics on the total per capita daily water consumption. A selection of statistical models is used to investigate the impact of four future scenarios (i.e., market forces, fortress world, policy reform and great transition) on likely changes in per capita consumption.

2 Methodology for Data Collection

Study Area Domestic water consumption patterns have been investigated for Duhok city, which is located in north-western Iraqi Kurdistan (Fig. 1). The city has a population of around 295,000 inhabitants with 42000 households and spreads over 577 km^2, accounting for 0.13 % of total area of Iraq (Kurdistan Regional Statistics Office 2014). The city witnessed a rapid expansion in the area covered and the growth in the population during several decades. This is due to the high fertility (5 %) and the movement from rural areas to the city (Kurdistan Ministry of Planning 2014).

One of the water sources in the city is Duhok earth dam with storage capacity of 47.5 million m^3. The dam is mainly used for agricultural purposes (Kurdistan Ministry of Water Resources 2014). Domestic water (66.1×10^6 m^3/year) is supplied by the national water supply board through a pipe from Khrabdeem, the main water treatment plant in Duhok. In addition, around 8.3×10^6 m^3/year of water from up to 100 wells is pumped for domestic use (Duhok Directorate of Water and Sewerage 2014). Water is supplied to households 3 to 4 times every week with each supply session lasting not more than 6 h. People store water in overhead tanks and consume it for different activities including drinking.

Data Collection Programme A detailed questionnaire was prepared in the native language (Kurdish) and included over 40 questions. A multiple-choice format was used to answer some of the questions. Household characteristics, such as number of children, elders, adult males and females, household type, total built-up area, garden area, number of rooms, number of floors and monthly income were investigated. Furthermore, questions regarding the *frequency, duration of use and flow rate* of each water end-use (e.g. showering, hand wash basin, toilet flushing, dishwashing, laundry, house washing, cooking, garden watering and vehicle washing) were also included.

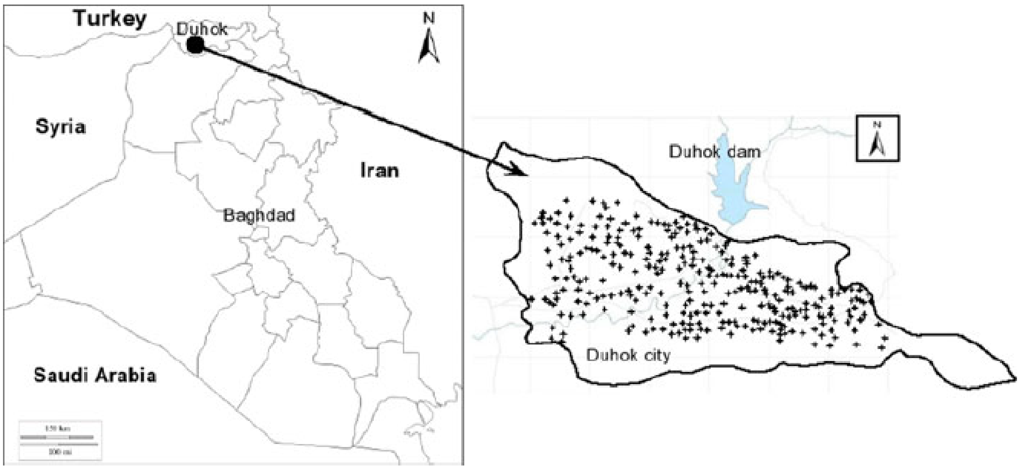


Fig. 1 Duhok city location in Kurdistan, Iraq and the distribution of surveyed households in the city (Kurdistan Ministry of Planning 2014)

The questionnaire was distributed to 419 randomly selected households in February 2015. The replies were received from 407 households. The analyses of the collected data was performed using IBM SPSS Statistics (v. 22) package and included estimation of statistical parameters (i.e., average, minimum, maximum and distribution shape identification through kurtosis and skewness) for the characteristics of the 407 households. Based on per capita income, the dwellings were divided into low, medium and high income groups and each group was analyzed separately to identify the influence of variation in income on household and water use characteristics. A summary of results is discussed in Section 3.

Development of Statistical Models The research resulted in a comprehensive data set on factors contributing to water consumption. Using the data set, 24 statistical models were developed using two techniques: multiple linear regression (STEPWISE) and evolutionary polynomial regression (EPR). The resulting models and their performance is discussed in Section 3.4.

3 Results and Discussion

3.1 Household Characteristics

The analyses of household characteristics of 407 residential units (92 % houses and 8 % apartments) are summarized in Table 1. It shows that the average household occupancy is 7.04 persons, which is approximately equivalent to the average standard family size (6.7 persons) in Duhok as reported by KRSO (2014). In terms of family composition, the average number of adult females, adult males and children are 2.33, 2.27 and 2.22, respectively. The average number of elders (≥65 years) was very low (0.22), accounting only for 3.2 % of the investigated sample.

The socio-economic characteristics of the households show that the average built-up area of all floors is between 100 and 500 m^2 with approximately 30 m^2 occupied by the garden. Of the 407 households, 58 % were single-story, 36 % were double-story and 6 % were triple-story. The average number of rooms was just over 4. The variation in the family income was high and ranged from 3×10^5 Iraqi Dinar (ID)/month (≈ £150) to 44.7×10^5 ID/month (≈ £2,200) with average per capita income equivalent to 25×10^4 ID/month (≈ £125).

3.1.1 The Influence of Household Characteristics on the Total Average Water Consumption (l/hh/day)

The correlation coefficient can be used to assess the strength of relationship between variables (Kerns 2010). The analyses of the data suggest a strong positive relationship between household occupancy (i.e., the number of people in the household) and total water consumption ($R = 0.87$) whilst there is a negative relationship between per person usage and household occupancy. Water consumption increases with the increase in the total household built-up area, number of rooms and garden area with a correlation coefficient of 0.94, 0.96 and 0.77, respectively (Fig. 2). This finding is consistent with those of Cavanagh et al. (2002) who found that the household built-up area and number of rooms increased water consumption in the developed countries (e.g. the U.S. and Canada).

Table 1 Summary of household characteristics (407 households)

Household characteristics	Unit	Mean	Median	Standard deviation	Minimum	Maximum	Skewness	Kurtosis	Confidence interval (95 %)
Household size (occupancy)	No./hh	7.04	7.00	2.35	2	13	0.24	−0.55	0.23
Number of children (<15 years)		2.22	2.00	1.74	0	7	0.53	−0.35	0.17
Number of adult males members (15–65 years)		2.27	2.00	1.07	0	5	−0.13	0.24	0.10
Number of adult females members (15–65 years)		2.33	2.00	1.01	1	5	0.45	−0.72	0.09
Number of elders (>65 years)		0.22	0.00	0.49	0	2	2.12	3.77	0.05
Household type	%	Houses (91.9 %)				Apartments (8.1 %)			
Total built-up area of all floors	m^2/hh	314.6	325.0	114.5	100.	500.	−0.10	−1.03	11.2
Garden area per household		29.56	30.00	24.38	0.00	100.	1.26	1.81	2.38
Number of rooms in the household	No.	4.19	4.00	1.18	2	6	−0.16	−0.82	0.11
Number of floors in the household	No.	1.48	1.00	0.61	1	3	0.89	−0.21	0.06
Monthly family income/household	1000 ID/month	1857	1570	1105	258	4470	0.5	−0.9	108

* *hh* household, *ID* Iraqi Dinar (1000 ID = £ 0.5)

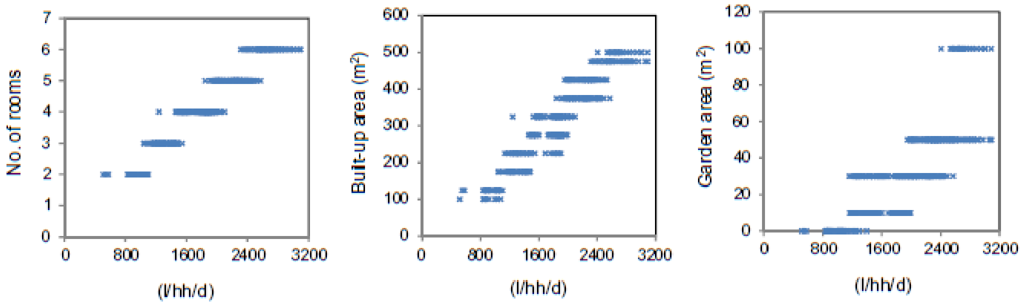


Fig. 2 Relationship between household water consumption (l/hh/d) and household characteristics

3.1.2 The Influence of Household Characteristics on the Average Per Capita Water Consumption (l/p/d)

The distribution of the average daily per capita water consumption for the whole sample is shown in Fig. 3, suggesting that the average is about 271 l/p/d. For houses it is approximately 274 l/p/d and that for apartments is about 247 l/p/d. The higher consumption for houses is mainly because of additional outdoor water use. In agreement with Edwards and Martin (1995), the daily per capita consumption increases with increase in the total built-up area of the household; however, it decreases with the increase in the number of household occupants. The decline in per person usage suggests household uses of water such as clothes washing, dish washing and water used for cooking and cleaning are more efficient on a per person basis for higher occupancy households. The influence of children is higher than elders. In other words, increased number of children in the household leads to a higher reduction in per capita consumption than elders. On the other hand, increased number of male adults in the household reduces per capita consumption and the increase in female members increases per capita consumption. This increase in per capita consumption with the increase in number of females in a household appears to be because of the fact that many female members most of times stay at home and have primary responsibility to look after family.

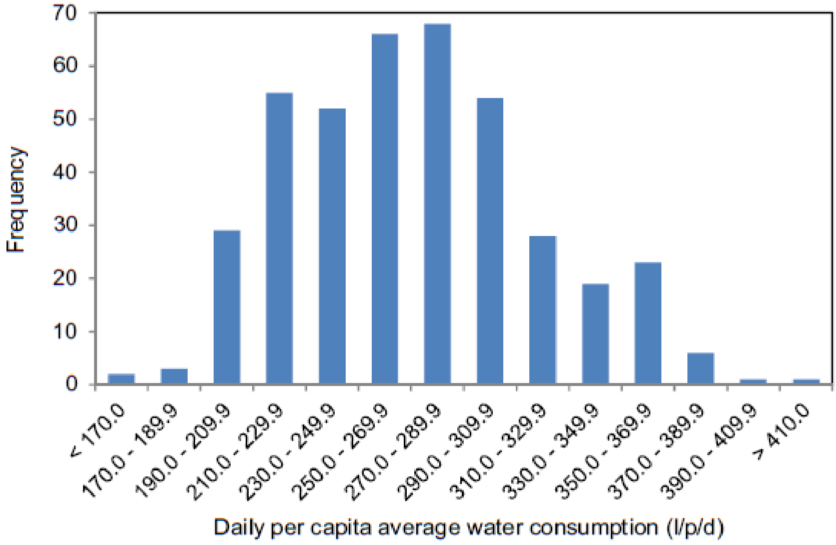


Fig. 3 Frequency distribution of average per capita water consumption (l/p/d)

3.1.3 Influence of Per Capita Income on the Average Per Capita Water Consumption (l/p/d)

In Iraq, a household socio-economic survey was conducted by the Central Statistical Organization (CSO) and KRSO in 2012. In the survey, the monthly family income was divided into three groups (Table 2). This classification was based on the average family size of 6.7 persons. The last column in Table 2 shows per capita income for respective household groups and has been obtained by dividing the household income by the average family size. Using per capita figures of column three, the investigated 407 households where divided into three income groups (Table 3).

The analysis of the data shows that the average per capita consumption increases with the household income (i.e., 241, 272 and 290 l/p/d in low, medium and high income group, respectively). Although the average per capita water consumption rises with the increase in the household income, the fraction of water used for different activities broadly remains the same in all the investigated households regardless of the income group (Fig. 4). The figure shows that the highest fraction of water consumption is via taps. This is in contrast to many countries in the developed world where about one-third of water is used to flush toilets (Post 2000).

3.2 Average Per Capita Water Use for Different End-Uses (Micro-Components)

A household's total water consumption is disaggregated into a number of end-uses: showering, bath, hand wash basin, toilet flushing, dishwashing, laundry, cooking, house washing, garden watering, car washing and swimming pool. The average daily use of each of these components in all income groups is illustrated in Fig. 5. A notable feature in this figure is the considerable variation in daily water end-use per person between income groups. It is apparent from this figure that the swimming pool use in all income groups is low (less than 0.2 l/p/d). Of the 407 households, only two houses were found to have a swimming pool and, therefore, they will not be included in any further analysis. Another finding is the per capita water consumption for outdoor purposes (garden watering, car washing and swimming pool) is less than 10 % of the total daily usage in all income groups. However, the consumption for outdoor purposes may become much higher in the summer season.

3.3 The Influence of Per Capita Income on Water End-Uses

The summary of average values of water end-use parameters per person (e.g., frequency, duration of use and flow rate) is illustrated in Table 4. It shows the comparison between these

Table 2 Income groups classification for Iraq (CSO and KRSO 2012)

Income group	Income range in Iraqi Dinar (ID)	
	Per household	Per capita
Low	$<1 \times 10^6$	$<15 \times 10^4$
Medium	$1 \times 10^6 - 2 \times 10^6$	$15 \times 10^4 - 30 \times 10^4$
High	$>2 \times 10^6$	$>30 \times 10^4$

Table 3 Number of investigated households in different income groups

Income group	Low	Medium	High
Number of households	92	176	139

parameters in low, medium and high income households. The key findings are explained in the following sections.

3.3.1 Shower and Bath

Shower and bath use are positively related to family income (Gato 2006). Throughout the study of 407 households, there were no baths recorded in low and medium income families. There were only 10 baths recorded in high income households with a very low frequency (once a week) of use.

The daily per capita water use for showering is the function of the frequency, the duration and the flow rate of shower. Although, the frequency of showering is high (0.61 showers/p/d) in the high income group, the flow rate of shower (8.39 l/min) is lower than that recorded in the low and medium income groups (Table 4). Most of the high income households were found to be constructed recently and therefore they are likely to have more water efficient appliances (e.g., shower heads). The duration of shower was found to be less sensitive to income groups. However, frequency of showering tends to increase with increase in per capita income.

3.3.2 Hand Wash Basin (taps)

In all income groups, hand wash basin uses are the highest water users accounting for approximately 32 % of the total water use (Fig. 4). Similarly to showering, hand wash basin water consumption is influenced by the number of times the basin is used.

As with showers, the flow rate from hand wash basin taps decreases with the increase in household income. This confirms that the high income group households are relatively new

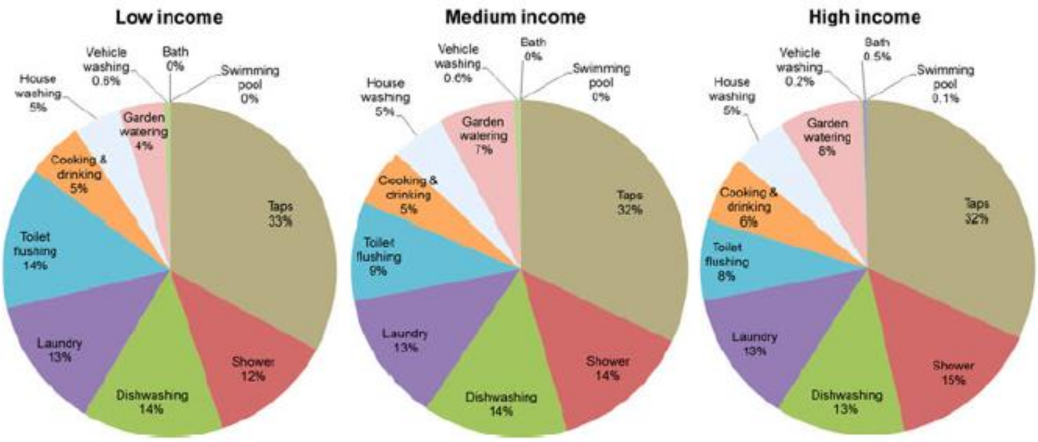
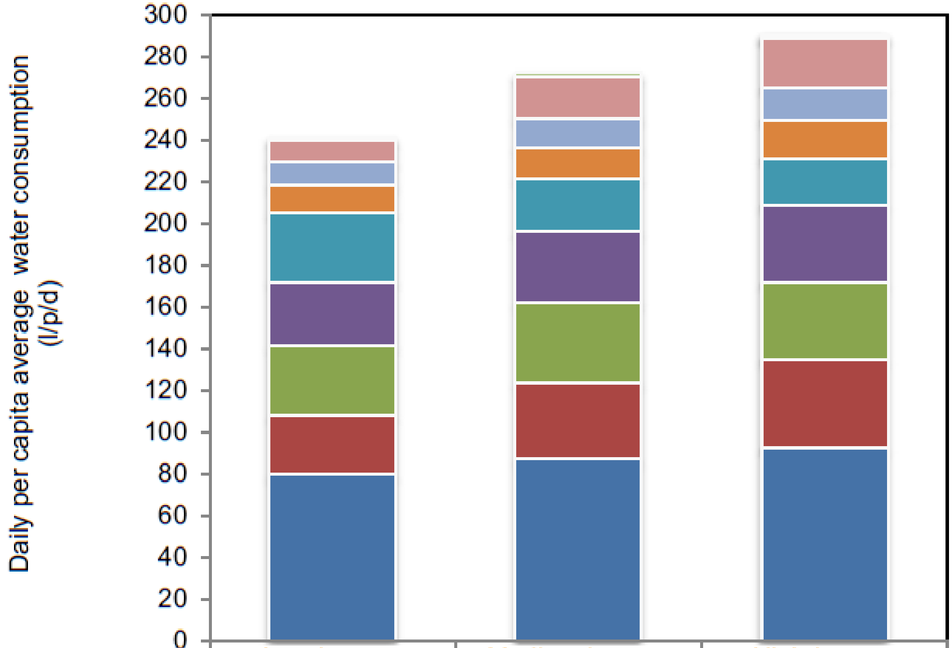


Fig. 4 Summary of percentages of water end-uses in all income groups



	Low income	Medium income	High income
Swimming pool	0	0	0.19
Bath	0	0	1.36
Vehicle washing	1.4	1.65	0.53
Garden watering	10.38	20.09	23.3
House washing	11.18	14.23	15.41
Cooking and drinking	13.2	14.85	18.33
Toilet flushing	32.99	25.45	22.51
Laundry	30.91	33.99	37.14
Dishwashing	32.98	37.98	36.69
Shower	28.74	36.67	42.31
Taps	79.43	87.27	92.59

Fig. 5 Impact of per capita monthly income on water end-uses in Duhok

and fitted with water efficient appliances which decrease the flow rate. The frequency of hand wash basin use rises with the increase in income. The duration of use is similar in low, medium and high income families. The duration of tap use for all income groups is about 60 s per event. When multiplied with the frequency of hand wash basin tap use, the total daily per capita tap duration becomes 9.68, 10.49 and 11.38 min/capita/day for low, medium and high income households, respectively. The duration of the daily hand wash basin tap use obtained in this study is much higher than the values found in the literature of developed countries. It ranges between 6.66 and 8.33 min/capita/day in Yarra valley, Australia (Roberts 2005) and much lower than this (i.e., 2.73 min/capita/day) in the Netherlands (Gato 2006). The high tap duration can be attributed to additional water using activities in the Islamic culture (e.g., ablution before each prayer time).

Table 4 Summary of mean values of water end-use parameters

End-use	Parameter/variable	Unit	Full sample	Low income	Medium income	High income	Comparison with past studies
Bath	Frequency of taking bath per capita per day	frequency/day	0.004	0.00	0.00	0.01	0.044 (Blokker et al. 2010)
	Volume of water use in each bath	liter/bath	132.00	0.00	0.00	132.00	100 in France (Estrela et al. 2001)
Shower	Frequency of showering per capita per day	frequency/day	0.49	0.34	0.47	0.61	0.73 (Athuraliya et al. 2012)
	Duration of each shower	min/shower	8.64	8.87	8.72	8.38	7.55 (Gato 2006)
	Flow rate	liter/min	9.02	9.48	9.27	8.39	16 in France (OFWAT 1997)
Hand wash basin	Frequency of using taps per capita per day	frequency/day	10.46	9.96	10.31	10.98	4.1 (Blokker et al. 2010)
	Duration of tap use	seconds/use	60.81	58.31	61.02	62.20	21.3 (Gato 2006)
	Flow rate	liter/min	8.14	8.13	8.24	8.02	2.6 (Athuraliya et al. 2012)
Toilet	Frequency of toilet use per capita per day	frequency/day	4.65	5.39	4.66	4.14	4.2 (Roberts 2005)
	Water use in each flush (L)	liter/flush	5.51	6.01	5.36	5.38	9.5 in the UK (OFWAT 1997)
Dish washing	Frequency of washing dishes per day	frequency/day	3.00	3.00	3.00	3.00	2.1 (Jacobs and Haarhoff 2004)
	Duration of running water in each wash	min/capita	1.47	1.16	1.50	1.64	
	Flow rate	liter/min	8.36	9.54	8.39	7.54	5.4 (Marinoski et al. 2014)
Laundry	Frequency of laundry per day	frequency/day	1.48	0.83	1.46	1.93	0.69 (Athuraliya et al. 2012)
	Volume of water/washing load	liter/load	167.32	190.02	161.01	160.28	80 in the UK (Estrela et al. 2001)
House washing	Frequency of house washing per day	frequency/day	0.69	0.51	0.69	0.80	
	Duration of each wash	min/capita	2.13	1.79	2.1	2.38	
	Flow rate	liter/min	9.80	12.20	9.88	8.12	
Vehicle washing	Frequency of vehicles washing per day	washes/day	0.07	0.06	0.10	0.04	

Table 4 (continued)

End-use	Parameter/variable	Unit	Full sample	Low income	Medium income	High income	Comparison with past studies
	Duration of each wash	min/capita	1.39	1.81	1.34	1.1	
	Flow rate	liter/min	12.82	12.79	12.75	13.08	10.2 (Marinoski et al. 2014)
Swimming pool	Frequency of filling swimming pool per day	frequency/day	0.001	0.00	0.00	0.002	
	Volume of water provided to fill the swimming pool	m^3	36.00	0.00	0.00	36.00	
Garden watering	Frequency of garden watering per day	frequency/day	0.13	0.07	0.14	0.14	0.4 (Roberts 2005)
	Duration of each watering	min/capita	13.01	13.11	11.88	14.49	20 (Athuraliya et al. 2012)
	Flow rate	liter/min	11.67	11.64	11.94	11.34	10.2 (Marinoski et al. 2014)
Cooking	Volume of water consumed in cooking	l/p/d	13.66	11.20	12.85	16.33	10–20 (Gleick and Iwra 1996)
	Total water consumption	l/p/d	271.39	241.22	272.18	290.36	180 in urban residential areas (Stephenson 2003)

* l/p/d = liter per person per day

3.3.3 Toilet Use

In line with the observation made above, again high income group households appear to have water efficient toilet (5.4 l/flush) in comparison to low income households (6.0 l/flush). This increases the average daily per capita toilet consumption in low income group to 33.0 l/p/d, it being higher than that in medium (25.5 l/p/d) and high (22.5 l/p/d) income families.

The frequency of toilet per capita daily use was higher in low income families (5.4 times/day) than that in medium (4.7 times/day) and high (4.1 times/day) income families. From the data presented in Table 4, it appears that in the medium and high income households water consumption for personal hygiene related activities is higher. This is reflected in higher frequencies of shower, clothes-wash and hand wash basin use indicating an increased emphasis on cleanliness. The less emphasis (inability) on cleanliness in low income group may be a cause of increased water borne diseases; consequently the frequency of toilet use might increase. Another reason for lower toilet use frequency for high income group is the high number of people in employment working away from home during the day.

3.3.4 Dishwashing

Dishwashing accounted for the second highest end-use being approximately 14 % of total water use in all income groups (Fig. 4). Although, 7 % of the 407 households own dishwasher, they still wash dishes manually. The daily water consumption for dishwashing is a function of flow rate, duration and number of washes. The frequency of washing dishes is same in all income groups, i.e., after each meal (breakfast, lunch and dinner). The flow rate of kitchen tap decreases with the increase in household income from 9.5 l/min in low income to 7.5 l/min in high income households (Table 4). However, the variability in total water use for dishwashing between income groups is due to the duration of each dishwashing session, which is dependent on the number of dishes and indirectly the size of the family. For example, the duration of each wash in six occupants family for each income group was found to be 6.3, 9.3 and 10.5 min for low, medium and high income group, respectively.

3.3.5 Laundry

The main parameters to identify water consumption for laundry washing are the volume of water used per washing cycle and the frequency. The volume of water used in each wash is fixed depending upon the brand, style, and size of the washing machine in each house. The analysis shows that there is a difference in the average volume of water used per wash between income groups, accounting approximately for 160 l/washing load in medium and high income houses and much higher in low income (190 l/washing load) (Table 4). It looks that in comparison with lower income group; medium and higher income households have water efficient washing machines.

The second parameter (the frequency of laundry per household per week) can be influenced by the number of occupants. The collected data suggests that it rises with the increase in household income, indicating more emphasis on hygiene with increased income. Therefore, the difference in total amount of laundry water consumption is significantly high between income groups. It is 146, 235 and 310 liters/hh/day in low, medium and high income families, respectively.

3.3.6 House Washing

About 5 % of the total water consumption is used for house washing (Fig. 4). The house washing activities include floor washing, washroom and kitchen cleaning. The analysis shows that the frequency and duration of household washing increase with the rise in the household income. The frequency is 3.6, 4.8 and 5.6 times/week with duration of each wash approximately 8.4, 14.2 and 19.5 min in low, medium and high income households, respectively. This suggests that the emphasis on cleanliness and hygiene increases with the increase in the household income or due to the size of household area.

3.3.7 Cooking

According to the studies of the NRC (1989) and Black (1990), food preparations in both developed and developing countries would require about 10 to 20 l/p/d of water; for example, in Sri Lanka, daily per capita average water consumption for cooking is 16 l/p/d (Sivakumaran and Aramaki 2010). The Duhok study shows that average value for water required for food preparation lies within the values found in the literature. However, water consumption for food preparation increases with the increase in the family income, accounting 11.2, 12.9 and 16.3 l/p/d in low, medium and high income households, respectively (Table 4).

3.3.8 Garden Watering

Outdoor water use (garden watering, car washing and swimming pool) is related to the size of the residential dwelling area (Gato 2006). In terms of the frequency of garden watering, it is much lower in low income group than that in the medium and high income groups (Table 4). Most of the houses recorded only one irrigation event per week. This may be because of the timing of the study, which was conducted during winter time. In order to quantify the seasonality impact, a similar study in the same area will be repeated to account for water consumption variations in the summer.

The duration of each watering session in the high income group is the longest (approximately 2 h). This appears to be mainly because of the larger garden area (average of 51.8 m^2) in comparison with low (9.3 m^2) and medium (22.6 m^2) income households. However, the flow rate from the outside tap for the garden watering is broadly similar (11.5 l/min) in all households regardless of their income group (Table 4). Therefore, the total volume of water used for garden irrigation in high income households is clearly the highest (192 liters/hh/day) with less consumption in medium (134 liters/hh/day) and low (59 liters/hh/day) income houses.

3.3.9 Vehicle Washing

In terms of water use for vehicle washing, the highest consumer is medium income families (75.6 l/hh/week), which is probably because of less ownership in low income families (47.2 l/hh/week). On the other hand, people in high income households prefer their cars washed at washing services rather than doing it themselves (28 l/hh/week). Because of this, water consumption for vehicle washing in high income group is low. It can be seen from the data in Fig. 5 that the average per capita water use for vehicle washing is relatively small in all income groups but this may increase in the summer season due to the frequent dust storms.

3.4 Modelled Daily Per Capita Usage with Household Characteristics

The water consumption data from the 407 households was divided into calibration and validation sets. 70 % of the data was used for calibration (i.e., training), while the remaining 30 % was spared for validation (i.e., testing) purposes. The calibration data set was used to develop statistical models to predict per capita consumption as a function of household characteristics. The household characteristics were divided into two groups, that is:

- Demographic characteristics: number of children, elders, adult males and adult females.
- Physical characteristics: total household built-up area, garden area, number of rooms, number of floors and per capita income.

Two different techniques were used to build regression models in order to identify the models which are computationally efficient and provide reliable predictions. The two techniques applied are: multiple linear regression (STEPWISE) and evolutionary polynomial regression (EPR). These techniques have been used for modelling the water related applications (Mountains 2013; Doglioni et al. 2010) and achieved good results.

3.4.1 Models Based on Multiple Linear Regression (STEPWISE)

Multiple linear regression technique has been used widely to explore the relationship between the dependent and several independent variables (Abdul-Wahab et al. 2005). The technique is looking for the combination of relevant independent variables to construct the best fit model based on strong statistical foundations. One of the multiple regression techniques is *STEPWISE*, which is a potential approach for selecting the best combination of independent variables (Cevik 2007).

The *STEPWISE* multiple regression approach is applied using IBM SPSS Statistics (v. 22) software to determine the best subset model for daily per capita water use estimation. Using the calibration set of data, the relationships between the independent variables (household characteristics) and the dependent variable (per capita water consumption) were investigated and the values of correlation coefficient (R) are shown in Table 5. From the table, it can be seen

Table 5 Correlation coefficients between household characteristics and per capita water consumption

		Correlation coefficient value (R)								
		Demographic characteristics				Physical characteristics				
		No. of children	No. of adult females	No. of adult males	No. of elders	No. of rooms	No. of floors	Total built-up area	Garden area	Income
Per capita water consumption (l/p/d)	All investigated households	−0.560	0.467	−0.474	−0.204	−0.028	−0.064	0.008	0.013	0.602
	Low income households	−0.745	−0.279	−0.263	−0.408	−0.773	0.000	−0.664	−0.361	0.777
	Medium income households	−0.808	0.467	−0.766	−0.270	−0.859	−0.638	−0.699	−0.330	0.844
	High income households	−0.501	0.196	−0.807	−0.254	−0.766	−0.532	−0.678	−0.443	0.803

* l/p/d = litres per capita per day

that the strongest relationship of per capita consumption is with the number of children in the household and per capita income. The selection or deletion of an independent variable for the regression model is based on the strength of relationship (i.e., the magnitude of the correlation coefficient) and also its contribution to the decrease of the residual sum of squares (Cevik 2007). The regression coefficients and model are then statistically tested at the every iteration to select or delete the independent variable. The statistical testes are:

- The ANOVA (F-test) to examine the significance of the regression model. The model is statically significant when $p<0.05$, which means the overall regression model is a good fit for the independent variables entered in the model (Yasar et al. 2012).
- The *t*-test to examine the significance of the regression coefficients. The regression coefficients are statistically significant (i.e. different to zero) if $p<0.05$ (Yasar et al. 2012).

Using *STEPWISE* approach with the calibration set of data of whole investigated households, three models were developed based on demographic, physical and whole characteristics (i.e., Model 1, 2 and 3 in Table 6, respectively). The similar procedure is repeated using the calibration set of low, medium and high income households data. These models are shown in Table 6 and they are statistically significant ($p<0.05$).

The predictions from these models were plotted against the actual per capita water consumption values obtained from the study as shown in Fig. 6. The figure shows that the trend-lines of validation and calibration set are relatively identical in all cases. Additionally, the R^2 value improves further when the water consumption data was disaggregated into low, medium and high income groups.

3.4.2 Models Based on Evolutionary Polynomial Regression (EPR)

The evolutionary polynomial regression (EPR) is a modelling technique which combines the effectiveness of genetic algorithm with numerical regression to develop mathematical model expressions (Giustolisi and Savic 2009). This technique has been used in a number of other applications, such as evapotranspiration process (El-Baroudy et al. 2010), rainfall-groundwater dynamics (Doglioni et al. 2010), water distribution and wastewater networks (Berardi et al. 2008), and have shown good performance.

The EPR MOGA-XL tool[1] (ver.1), which performs multi-objective genetic algorithm search for plausible models, is used to develop the models for daily per capita water use estimation. The two objective functions that were used for the evolutionary search by EPR are:

- The minimization of the number of terms, and
- Maximization of the accuracy of the model to calibration set (i.e. minimization of the summation of square errors) (Giustolisi and Savic 2009).

Various mathematical nonlinear expressions were chosen to model per capita water consumption as a function of household characteristics (i.e., independent variables). However, the results of simple mathematical structure (Equation 1) were the best in most cases. For each mathematical model, the candidate exponents for the independent variables (ES) and the maximum number of terms are selected through experimentation. The bias term is considered as zero. Finally, the number of generations within genetic algorithm is selected as 400.

[1] http://www.hydroinformatics.it/index.php?option=com_docman&Itemid=105

Table 6 Models and coefficients of determination (R^2) using multiple linear regression method (STEPWISE)

	Model	R^2 Calibration set	R^2 Validation set
All investigated households	Model based on demographic characteristics of the household $TW_w = 294.53 - 10.50 \times C_w + 15.23 \times AF_w - 13.50 \times AM_w - 14.85 \times E_w$ ……(1)	0.54	0.63
	Model based on physical characteristics of the household $TW_w = 294.69 - 27.86 \times R_w - 31.76 \times F_w + 0.58 \times G_w + 0.49 \times I_w$ ……(2)	0.74	0.74
	Model based on all (demographic and physical) characteristics of the household $TW_w = 287.50 - 15.24 \times C_w - 11.03 \times AF_w - 24.48 \times AM_w - 20.06 \times E_w + 12.76 \times R_w - 17.26 \times F_w + 0.43 \times G_w + 0.25 \times I_w$ ……(3)	0.87	0.88
Low income households	Model based on demographic characteristics of the household $TW_l = 324.43 - 22.26 \times C_l - 36.09 \times AF_l - 28.68 \times E_l$ ……(4)	0.88	0.82
	Model based on physical characteristics of the household $TW_l = 230.11 - 44.39 \times R_l + 0.58 \times G_l + 1.00 \times I_l$ ……(5)	0.82	0.77
	Model based on all (demographic and physical) characteristics of the household $TW_l = 267.12 - 17.27 \times C_l - 25.01 \times AF_l - 20.22 \times E_l - 14.01 \times R_l + 0.62 \times G_l + 0.54 \times I_l$ ……(6)	0.95	0.84
Medium income households	Model based on demographic characteristics of the household $TW_m = 416.05 - 18.69 \times C_m - 15.04 \times AF_m - 28.07 \times AM_m - 25.39 \times E_m$ ……(7)	0.92	0.93
	Model based on physical characteristics of the household $TW_m = 368.39 - 56.80 \times R_m + 0.69 \times G_m + 0.55 \times I_m$ ……(8)	0.86	0.87
	Model based on all (demographic and physical) characteristics of the household $TW_m = 418.81 - 17.52 \times C_m - 21.19 \times AF_m - 20.29 \times AM_m - 24.85 \times E_m - 26.98 \times R_m + 29.05 \times F_m + 0.50 \times G_m + 0.26 \times I_m$ ……(9)	0.96	0.94
High income households	Model based on demographic characteristics of the household $TW_h = 422.56 - 11.97 \times C_h - 10.92 \times AF_h - 23.15 \times AM_h - 16.57 \times E_h$ ……(10)	0.84	0.92
	Model based on physical characteristics of the household $TW_h = 268.18 - 24.73 \times R_h + 0.40 \times I_h$ ……(11)	0.76	0.73
	Model based on all (demographic and physical) characteristics of the household $TW_h = 317.01 - 10.46 \times C_h - 10.81 \times AF_h - 19.93 \times AM_h - 11.59 \times E_h + 0.20 \times G_h + 0.21 \times I_h$ ……(12)	0.90	0.92

* where:
TW = daily per capita water consumption (l/p/d),
C = number of children in the household,
AF = number of adult females in the household,
AM = number of adult males in the household,
E = number of elders in the household,
R = number of rooms in the household,
F = number of floors in the household,
HH = total household built-up area (m^2),
G = total garden area (m^2),
I = per capita monthly income (Thousand ID),
w = whole sample,
l = low income households,
m = medium income households, and
h = high income households.

* where:

TW, daily per capita water consumption (l/p/d), C number of children in the household, AF number of adult females in the household, AM number of adult males in the household, E number of elders in the household, R number of rooms in the household, F number of floors in the household, HH total household built-up area (m^2), G total garden area (m^2), I per capita monthly income (Thousand ID), w whole sample, l low income households, m medium income households, h high income households

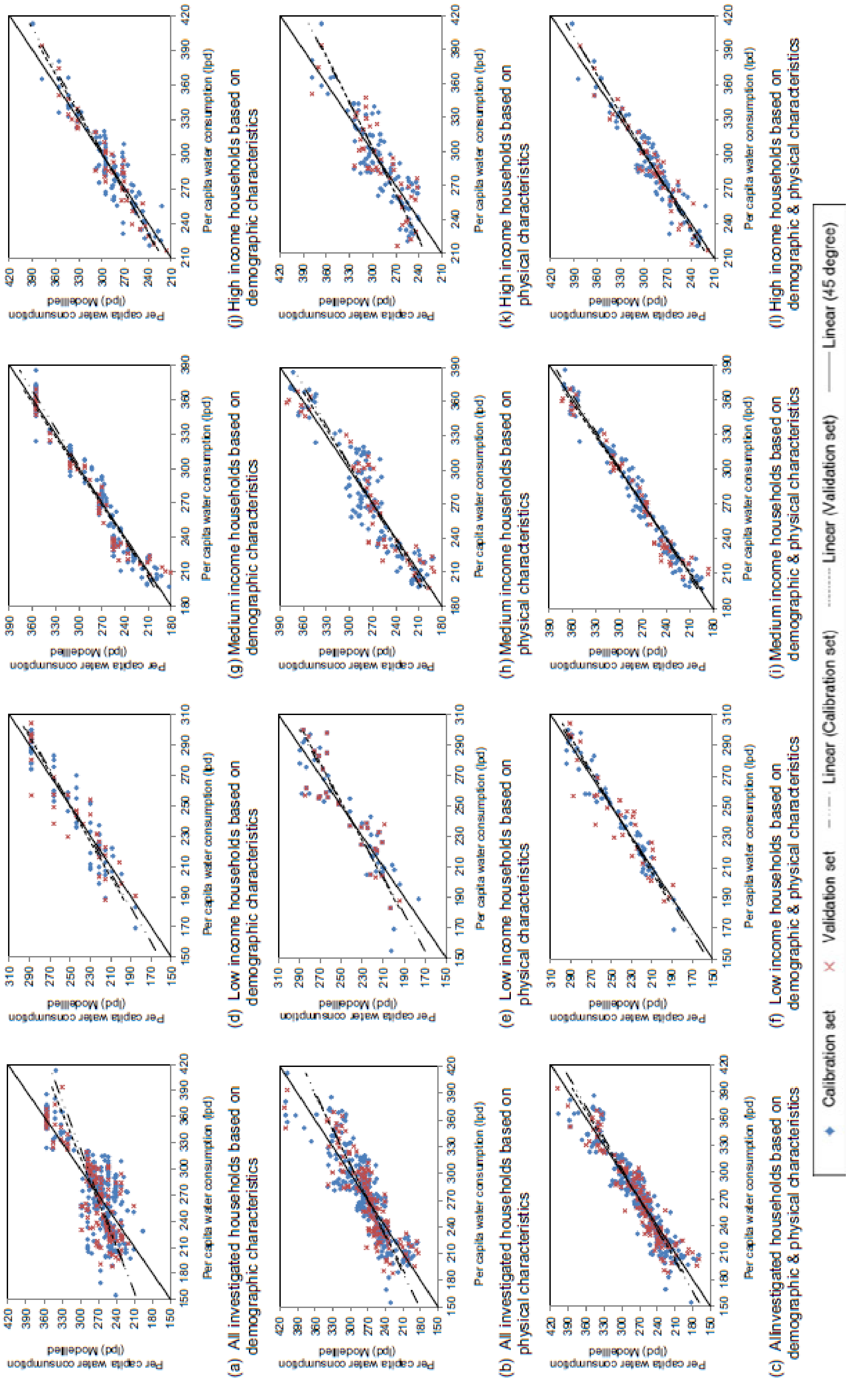


Fig. 6 Relationship between actual and predicted daily per capita water consumption using STEPWISE method

$$Y = a_0 + \sum_{j=1}^{m} a_j \times f\left\{(X_1)^{ES(j,1)} \ldots\ldots (X_k)^{ES(j,k)}\right\} \tag{1}$$

where,

Y	the EPR estimated water consumption
a_o	the bias term
m	the total number of polynomial terms
a_j	the coefficients of j_{th} polynomial term
$f(X)$	the polynomial function constructed by EPR
ES	the matrix of unknown exponents, and
X_k	the k_{th} independent variable (household characteristics)

Using the calibration set of data (70 % of the whole investigated households) with the EPR MOGA-XL tool, three nonlinear regression models are developed as a function of demographic, physical and all characteristics (Model 1, 2 and 3 in Table 7, respectively). Similarly, three mathematical models were developed for each income group (low, medium and high) using their calibration set of data as shown in Table 7. These models have been chosen due to achieving the highest coefficient of determination (R^2).

The predictions from EPR models were plotted against the actual per capita water consumption values as shown in Fig. 7. For all models in this figure, the trend-lines of calibration and validation set of data are relatively identical. From this figure, it can be concluded that the R^2 value increases when the models were developed for each household income group. Moreover, the R^2 value increases significantly when all (demographic and physical) household characteristics were included in the model rather than only demographic or physical characteristics.

3.4.3 Comparison of Models

The twelve models developed in EPR and STEPWISE were compared using R^2 values as shown in Table 8. From the table it can be seen that the R^2 values of both modelling techniques are relatively high (over 0.8) for most cases. However, the R^2 of EPR based model improved considerably when the number of polynomial terms and the exponents was increased. On the other hand, STEPWISE based model also offers good predictions.

Both modelling approaches suggest the strong influence of demographic characteristics on per capita water consumption when the data was disaggregated into household income groups and the role of household physical characteristics is minimal.

3.4.4 Sensitivity

Sensitivity measures to what extent the magnitude of a dependent variable (i.e. estimated total water demand) could change over the practical range of variation of the input independent variables (e.g., household characteristics) (Jacobs 2004). Sensitivity analysis provides insights into the applicability of the model under consideration. Additionally, it identifies the effect of each household characteristic on the estimated water demand.

Jacobs (2004) considered the range of variation of each input parameter (i.e. household characteristic) as the standard deviation below and above the average. The sensitivity for each input parameter is tested using three values (i.e., average, average + standard deviation and

Table 7 Models and coefficients of determination (R^2) using evolutionary polynomial regression method (EPR)

	Model	R^2 Calibration set	R^2 Validation set
All investigated households	Model based on demographic characteristics of the household $TW_w = 235.05 - 16.87 \times E_w^{0.5} + 32.6 \times AF_w - 0.63 \times AF_w^{2.5} \times AM_w - 4.65 \times C_w^{2} \times AF_w^{0.5} + 1.27 \times C_w^{2.5} \times AM_w^{0.5}$ .... (1)	0.63	0.69
	Model based on physical characteristics of the household $TW_w = -173.7 + 45.37 \times I_w^{0.5} + 0.22 \times G_w^{0.5} \times I_w^{0.5} - 0.29 \times R_w \times I_w + 6.2 \times 10^{-6} \times R_w^{3} \times I_w^{2}$ .... (2)	0.85	0.83
	Model based on all (demographic and physical) characteristics of the household $TW_w = 4.32 + 33.99 \times I_w^{0.5} - 0.75 \times I_w - 15.19 \times E_w - 11.57 \times AF_w^{0.5} \times AM_w - 12.26 \times C_w$ .... (3)	0.92	0.93
Low income households	Model based on demographic characteristics of the household $TW_l = 299.88 - 11.13 \times AF_l^{2} - 8.14 \times AF_l^{2.5} \times AM_l^{2.5} \times E_l^{0.5} - 8.26 \times C_l^{0.5} \times AM_l^{1.5} - 2.89 \times C_l^{2} \times AF_l^{0.5} + 0.53 \times C_l^{2} \times AF_l^{3} \times AM_l^{2} \times E_l^{3}$ .... (4)	0.90	0.89
	Model based on physical characteristics of the household $TW_l = 102 + 13.4 \times R_l^{0.5} \times I_l^{0.5} + 0.03 \times R_l \times HH_l \times G_l^{0.5} \times I_l^{0.5} - 13.2 \times R_l^{2} \times F_l^{2} \times G_l^{0.5} - 4.3 \times 10^{-4} \times R_l^{0.5} \times HH_l^{2} \times G_l^{1.5} \times I_l - 0.5 \times R_l^{2} \times I_l^{1.5}$ .... (5)	0.85	0.79
	Model based on all (demographic and physical) characteristics of the household $TW_l = 279.8 - 0.03 \times AM_l^{2.5} \times E_l \times R_l^{4.5} \times F_l^{2} + 10^{-11} \times AM_l^{5} \times R_l^{5} \times HH_l^{2} \times G_l^{0.5} \times I_l^{1.5} + 0.002 \times AF_l^{2.5} \times AM_l \times R_l \times F_l \times I_l^{1.5} - 0.02 \times AF_l^{5} \times F_l^{2.5} \times HH_l^{0.5} \times I_l^{0.5} - 0.41 \times C_l^{0.5} \times AM_l^{1.5} \times R_l \times HH_l^{0.5}$ .... (6)	0.97	0.83
Medium income households	Model based on demographic characteristics of the household $TW_m = 567.9 - 65.11 \times AM_m^{0.5} - 6.23 \times AM_m \times E_m^{2.5} - 104.86 \times AF_m^{0.5} - 14.3 \times C_m^{1.5} + 0.21 \times C_m^{3} \times AF_m^{0.5} \times AM_m^{0.5}$ .... (7)	0.96	0.95
	Model based on physical characteristics of the household $TW_m = 557 + 0.0002 \times F_m^{2} \times HH_m^{0.5} \times I_m^{2} + 6.6 \times R_m^{0.5} \times HH_m^{0.5} + 6 \times 10^{-11} \times R_m^{0.5} \times F_m^{3} \times G_m^{0.5} \times I_m^{4.5} - 146.8 \times R_m^{1.5} - 7.1 \times R_m^{1.5} \times F_m^{1.5} \times I_m^{0.5}$ .... (8)	0.89	0.89
	Model based on all (demographic and physical) characteristics of the household $TW_m = 336.6 + 0.001 \times G_m^{1.5} \times I_m^{1.5} - 0.002 \times AF_m^{0.5} \times AM_m \times E_m^{2} \times I_m^{1.5} - 3.26 \times AF_m^{0.5} \times AM_m^{2} - 16.8 \times C_m \times AF_m^{0.5} + 2.5 \times 10^{-12} \times C_m^{4} \times AF_m^{2} \times AM_m^{2} \times R_m \times F_m^{5} \times HH_m^{2} \times I_m^{0.5}$ .... (9)	0.98	0.94
High income households	Model based on demographic characteristics of the household $TW_h = 403.87 - 39.83 \times AM_h^{1.5} + 13.48 \times AM_h^{2} - 7.75 \times AF_h^{0.5} \times E_h - 0.35 \times AF_h^{3} - 1.85 \times C_h^{1.5} \times AF_h$ .... (10)	0.86	0.92
	Model based on physical characteristics of the household $TW_h = 25.3 + 10^{-5} \times HH_h^{2} - 5 \times 10^{-10} \times F_h^{0.5} \times HH_h^{2} \times I_h^{1.5} + 7 \times 10^{-10} \times F_h^{2.5} \times HH_h^{2} \times G_h^{0.5} \times I_h^{0.5} - 3 \times 10^{-7} \times R_h^{1.5} \times F_h \times HH_h^{2} + 4 \times 10^{-5} \times R_h^{2.5} \times I_h^{2}$ .... (11)	0.79	0.76
	Model based on all (demographic and physical) characteristics of the household $TW_h = 227 + 7.2 \times I_h^{0.5} - 27 \times AM_h + 0.0006 \times AM_h^{1.5} \times R_h^{0.5} \times G_h^{0.5} \times I_h - 3 \times 10^{-9} \times AF_h^{1.5} \times AM_h^{3.5} \times E_h^{0.5} \times F_h^{2.5} \times I_h^{2} - 0.009 \times C_h^{1.5} \times AF_h^{1.5} \times R_h \times I_h^{0.5}$ .. (12)	0.91	0.92

* where:

TW =	daily per capita water consumption (l/p/d),	R =	number of rooms in the household,	w =	whole sample
C =	number of children in the household,	F =	number of floors in the household,	l =	low income households,
AF =	number of adult females in the household,	HH =	total household built-up area (m^2),	m =	medium income households, and
AM =	number of adult males in the household,	G =	total garden area (m^2),	h =	high income households.
E =	number of elders in the household,	I =	per capita monthly income (Thousand ID).		

* where:

TW daily per capita water consumption (l/p/d), C number of children in the household, AF number of adult females in the household, AM number of adult males in the household, E number of elders in the household, R number of rooms in the household, F number of floors in the household, HH total household built-up area (m^2), G total garden area (m^2), I per capita monthly income (Thousand ID), w whole sample, l low income households, m medium income households, h high income households

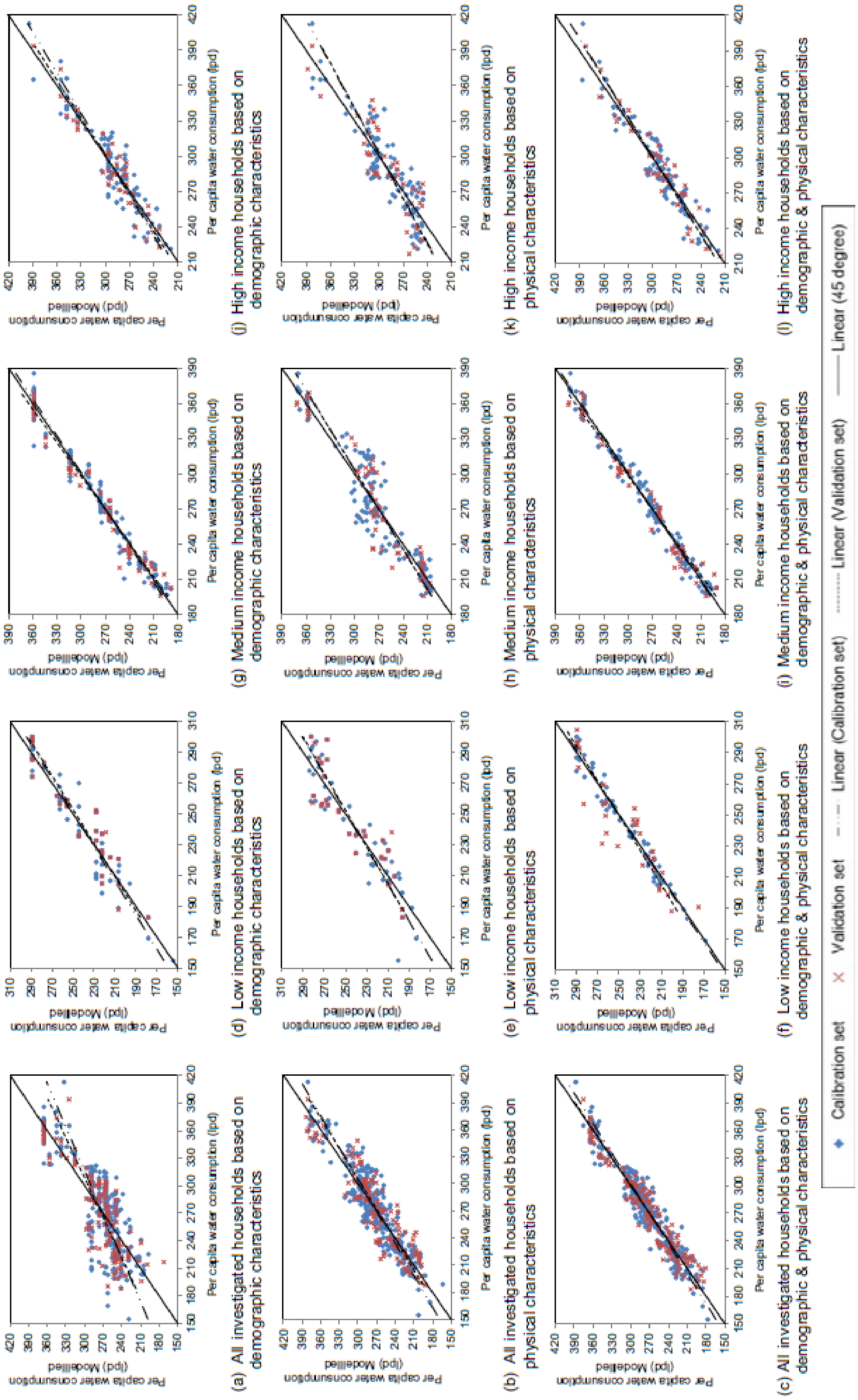


Fig. 7 Relationship between actual and predicted daily per capita water consumption using EPR method

Table 8 Coefficients of determination (R^2) of the final regression models

	Per capita water consumption modelled with household demographic characteristics		Per capita water consumption modelled with household physical characteristics		Per capita water consumption modelled with demographic and physical characteristics	
	STEPWISE	EPR	STEPWISE	EPR	STEPWISE	EPR
All investigated households	0.54	0.63	0.74	0.85	0.87	0.92
Low income households	0.88	0.90	0.82	0.85	0.95	0.97
Medium income households	0.92	0.96	0.86	0.89	0.96	0.98
High income households	0.84	0.86	0.76	0.79	0.90	0.91

average - standard deviation). The low and high value of each household characteristic are calculated using the average and standard deviation statistics in Table 1. The calculated upper and lower value of each household characteristic have been used with STEPWISE and EPR developed models to estimate the annual total water demand as shown in Fig. 8. The figure shows that the developed models are very sensitive to per capita income, number of children and number of adult males in the households.

4 Model Application

4.1 Scenarios Definition

In this paper, the implication of four alternative scenarios on the domestic water demand estimation is explored. These are market forces (MF), fortress world (FW), great transition

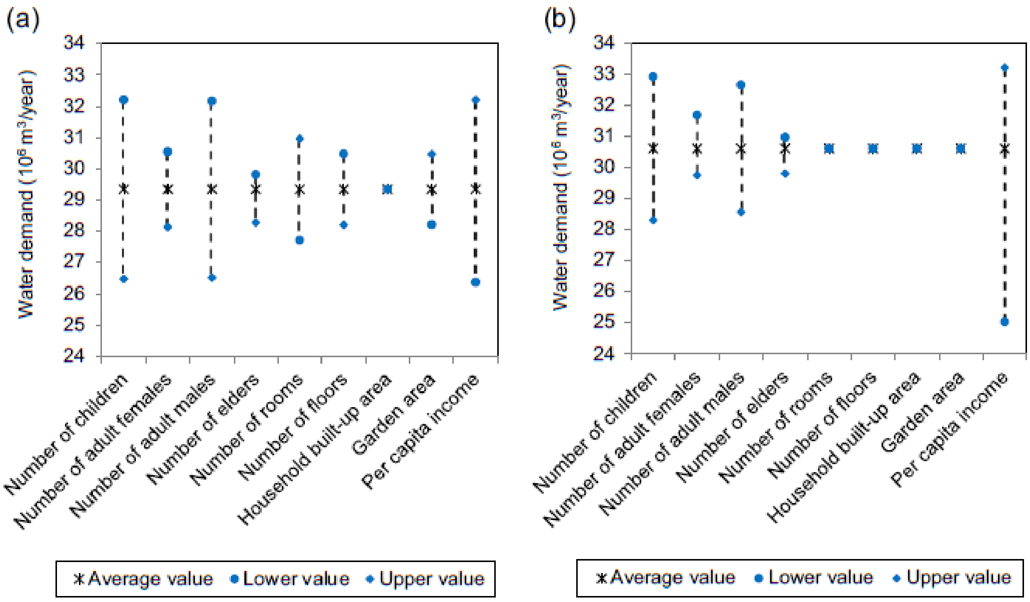


Fig. 8 Sensitivity analysis of input parameters for (a) STEPWISE and (b) EPR based domestic water demand prediction models for Duhok city

(GT) and policy reform (PR). The definitions of these scenarios are given by Global Scenario Group (GSG) (Kemp-Benedict et al. 2002). These alternative pathways for world development have been extensively used in numerous global, regional, and national studies (Hunt et al. 2012). Each one of these scenarios tells a different plausible story of the twenty-first century with varying patterns of resource use, environmental impacts, and social conditions (Raskin et al. 2010).

4.2 Implication of Future Scenarios on Water Demand

The expected annual growth rate values of all indicators (i.e., population, income and built-up area) from the long-term trends analysis for each scenario relevant to the Middle East region are collected from Global Scenario Group (GSG 2002) as summarized in Table 9. Using average annual growth rate values of these indicators with STEPWISE and EPR developed models, annual demand has been simulated for 35 years ahead and is shown in Fig. 9. The time horizon of 35 years is the most often considered timeline in scenarios (Hunt et al. 2012; Ercin and Hoekstra 2014) and also recommended for socioeconomic planning (Simonovic and Fahmy 1999).

The figure shows that of the four considered scenarios, the total domestic water demand would be highest in the fortress world scenario. This is mainly because of relatively higher increase in population and built-up area in this scenario (Table 9).

5 Conclusion

This paper studied the domestic water consumption at end-use level in a developing country. The influence of household characteristics (demographic and socio-economic) on the water consumption was investigated. Using multiple linear regression (STEPWISE) and evolutionary polynomial regression (EPR) method, 24 statistical models were developed to estimate the daily per capita water consumption as a function of household characteristics. The developed models have been trained and validated. The STEPWISE and EPR regression models were compared. Finally, the best fit models were used to predict the future water demand for the city under the

Table 9 Growth rate of each indicator in GSG scenarios

GSG scenarios	Period	Average annual growth rate of indicators (%)		
		Population	Income	Built-up area
Market forces (KF)	1995–2025	2.2	1.8	2.3
	2025–2050	1.1	1.6	1.5
Fortress world (FW)	1995–2025	2.4	1.7	2.5
	2025–2050	1.5	0.7	1.7
Great transition (GT)	1995–2025	2.0	2.3	1.8
	2025–2050	0.8	1.8	0.5
Policy reform (PR)	1995–2025	2.1	1.9	2.0
	2025–2050	1	1.7	0.9

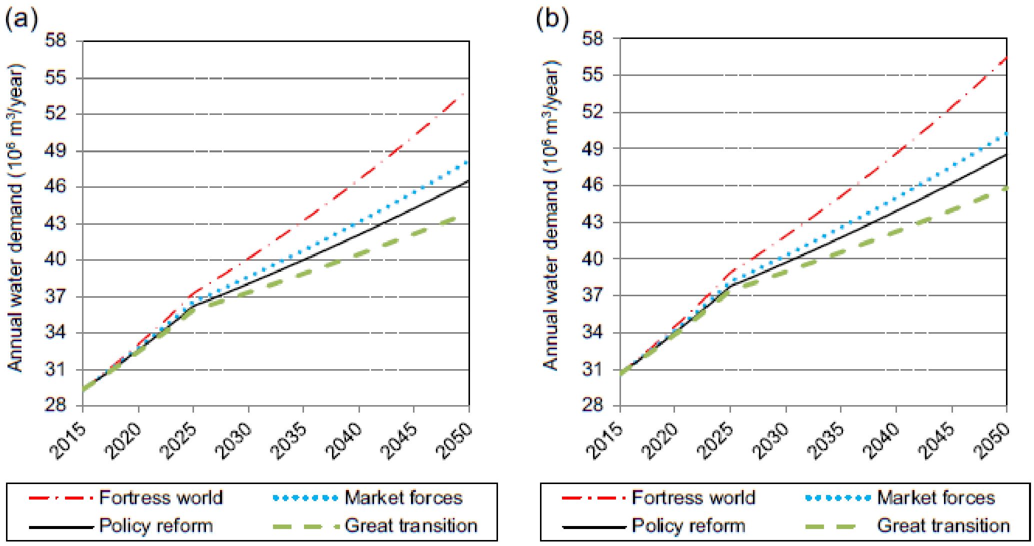


Fig. 9 Impact of four scenarios on total domestic water demand using (a) STEPWISE and (b) EPR

impact of four future scenarios. The key messages from the analysis of the presented work are:

- The per capita water consumption increases with the rise in household income and decreases with the increase in the household occupancy.
- Frequency of all water end-uses increases with the increase in per capita income except for toilet usage. Toilet use frequency in low income households is higher than that in medium and high income groups.
- The duration of hand wash basin tap in Duhok is much higher than typical values in the developed world. This indicates an additional water use activities (e.g. ablution) via the hand wash basin tap.
- Flow rate from different water end-uses decreases with increase in the per capita income, suggesting that households in high income group are relatively new and fitted with water efficient appliances.
- Per capita consumption decreases with the increase in male adults, elders and children but increases with the increase in number of adult females in a household. Additionally, the change in the number of elders and children has identical effect on per capita consumption.
- Using the collected data, it is possible to predict per capita water consumption. The quality of prediction improves when the full data was disaggregated into low, medium and high income group households.
- The models based on EPR offer a marginal improvement in the predictions quality.
- The demographic characteristics provide more accurate predictions of per capita water consumption than the predictions resulting from the use of physical characteristics of the investigated households.
- Of the investigated scenarios, domestic water demand is expected to be highest in the fortress world scenario. This is because of the expected growth rate of population and built-up area is high in this scenario.

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Position Paper

An integrated model to evaluate water-energy-food nexus at a household scale

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A B S T R A C T

To achieve a sustainable supply and effectively manage water, energy and food (WEF) demand, interactions between WEF need to be understood. This study developed an integrated model, capturing the interactions between WEF at end-use level at a household scale. The model is based on a survey of 419 households conducted to investigate WEF over winter and summer for the city of Duhok, Iraq. A bottom-up approach was used to develop this system dynamics-based model. The model estimates WEF demand and the generated organic waste and wastewater quantities. It also investigates the impact of change in user behaviour, diet, income, family size and climate.

The simulation results show a good agreement with the historical data. Using the model, the impact of Global Scenario Group (GSG) scenarios was investigated. The results suggest that the 'fortress world' scenario (an authoritarian response to the threat of breakdown) had the highest impact on WEF.

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1. Introduction

Water, energy and food resources are key for satisfying the basic human needs. Global demand for these rapidly increases while billions of people are still lacking access to these resources (Bazilian et al., 2011). The main drivers behind increased demand for water, energy and food are population growth, urbanisation, economic growth and climate change (Bonn Nexus Conference, 2011; World Economic Forum, 2011).

Households consume considerable quantities of resources (water, food and energy) to meet everyday demand of inhabitants. The household is a unit of demand and it can also be the most appropriate unit for influencing consumption practices. A high portion of water, energy and food consumption in the cities can be attributed to household uses. For instance, energy consumption at a household level in Burkina Faso and Duhok in Iraq accounts approximately 75% (Hermann et al., 2012) and 80% (General Directorate of Duhok Electricity, 2014) of the total city consumption, respectively. Most studies investigated the Nexus at the national and international scale, while limited attention has been paid to the interactions between water, energy and food at a household scale (Djanibekov et al., 2016; Endo et al., 2015; Loring et al., 2013). A single element of the nexus has been addressed in some studies. For example, Cominola et al. (2016) and Daioglou et al. (2012) modelled domestic water demand at end-use level. Sarker and Gato-Trinidad (2015) developed a model for household water demand estimation in Yarra Valley Water, Australia at end-use level. However, their model did not include garden watering end-use. Additionally, energy consumption and associated emissions from a household in Delhi is modelled by Kadian et al. (2007). They considered the impact of income and family size on energy consumption. Aydinalp et al. (2002) modelled domestic energy consumption at end-use level.

The interactions between water and energy at a household level have not been addressed very intensively (Kenway et al., 2013). For example, Cheng (2002) analysed water-related energy in residential buildings in Taiwan. They found that 88% of water-related energy use is attributed to water heating and household water pumping, while the rest is used for water treatment, water supply and wastewater treatment. Arpke and Hutzler (2006) modelled four household types and showed that 97% of water-related energy is attributed to water heating. Based on this model, Flower (2009) simulated water heating-related energy in Victoria, Australia using electricity and gas heater. Kenway et al. (2013) developed a

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model to investigate the energy use for household water heating in Brisbane, Australia, without considering the impact of household characteristics. They found that the household is the key driver for energy consumption and associated greenhouse gas emissions in the city.

Additionally, Abdallah and Rosenberg (2012) developed an approach to model household indoor water and energy use and their interactions. Their approach considers the impact of behavioural and technological water and energy use factors that affect the indoor use. Ren et al. (2013) developed a tool to predict the energy consumption at end-use level and related greenhouse gas emissions of Australian households, considering the impact of household occupancy patterns. However, their model does not address the seasonal variation of energy consumption. A residential end-use model was developed to estimate cold (indoor and outdoor) and hot water demand as well as wastewater generated for each month of the year (Jacobs and Haarhoff, 2004). This model highlights the impact of seasonal variability on water consumption.

Moreover, some studies addressed food consumption at a household scale. Demerchant (1997) investigated the user's influence on the energy consumption of the cooking system using electricity. The possibility to reduce the electricity use for food preparation is investigated by Wallgren and Höjer (2009). They suggested that using a microwave oven is more energy-efficient than a conventional oven for cooking some types of food. Additionally, an electric kettle consumes less energy for boiling water than a hotplate. Singh and Gundimeda (2014) found that in Indian households the highest energy efficient fuel for cooking purposes is liquefied petroleum gas (LPG). The impact of bioenergy use on rural households, environment and natural resource use has been partly addressed for the developing countries by Djanibekov et al. (2016). Wenhold et al. (2007) provided an overview of the interactions between agriculture using residential land, irrigation water and household food security for South African countries.

As an integrated global model addressing the interactions between water, energy and food at end-use level at a household scale is lacking, this study is aimed at developing one. This system dynamics-based model is developed using a bottom-up approach. The model captures the impact of user behaviour, family size, income, diet, appliances efficiency and seasonal variability on water, energy and food consumption. The disaggregation of water, energy and food into end-uses in the model and their behaviour may help to establish the best practice of management and also to identify areas for improvement (i.e., reduction of consumption).

In this paper, the structure of the developed WEF model is presented with the related mathematical relations. Then, the model assumptions, applications and the required input variables are presented. A brief description about the case study used in the WEF model is described. Then, the sensitivity of model estimations is analysed and its validity tested using Monte Carlo technique. The model results are then compared with the historical data. Finally, the developed model has been applied to investigate the impacts of Global Scenario Group (GSG) scenarios.

2. Model development

Fig. 1 shows the structure of the developed dynamic simulation model for water, energy and food at a household scale. A bottom-up approach was used to develop the model, comprising the interactions between water, energy and food at end-use level. This approach has become very common for modelling sustainable livelihood issues at a household, city and national scales (Biggs et al., 2015). This approach helps to understand the contribution of each end-use in the total consumption. Furthermore, it is the only option to investigate the impact of new interventions and technologies on consumption (Swan and Ugursal, 2009). An end-use based model can identify the end-use with highest resource consumption. Therefore, the proposed model can support the development of retrofitting programs and prioritisation schemes for resource efficient devices.

The key variables of this model are family size, appliances efficiency and the impact of seasonal variability (the duration of winter and summer season) on water, energy and food consumption. Another key variable is the impact of household income (i.e., low, medium and high) on water, energy and food consumption (Fig. 1). Many aspects of water, energy and food are addressed in this model, such as the generated wastewater and food waste from a household (Fig. 1). The model also calculates the consumption of individual end-use of water, energy and food.

The model components have over 300 variables in total and a simplified version of the model components is presented in Fig. 1. The values of all input variables and parameters into the model depend on the trend and pattern of water, energy and food end-uses for the particular region. The detailed explanation of these variables and the mathematical equations which describe the relationships between water, energy and food are explained in Sections 2.1–2.6.

System dynamics modelling has been used to model environmental and water systems at various scales (Simonovic, 2002; Stave, 2003; Kojiri et al., 2008; Khan et al., 2009; Qi and Chang, 2011; Mereu et al., 2016). This particular model has been coded using SIMILE modelling environment. SIMILE is a system dynamics modelling software that is used for modelling the interactions between various system components and capturing the changes in this system behaviour over time. SIMILE is selected for its ability to host sub-models and simplify the complex process of interactions between the variables (Vanclay, 2014). The causal-loops between various model components are shown in Fig. 2.

Within the developed model, stocks represent the accumulated change of a system component (e.g., family size and percentage of each income group: low, medium and high). Flows represent the amount of increase or decrease in the family size and each income group. The factors that affect the system are represented as convertors, such as duration of winter and summer season, variation in the size of each income group, and the parameters that impact water, energy and food end-uses (Sections 2.1–2.5).

2.1Modelling of household water consumption

Within the water, energy and food model, household water consumption is disaggregated into various end-uses: showering, bathing, hand wash basin tap use, toilet flushing, dishwashing, clothes washing, cooking, house floor washing, vehicle washing, garden watering, and swimming pool. The model captures the influence of human behaviour for water end-uses, through involving the parameters of water end-use into the model. For example, the frequency of use and the duration of water run during each event of water use are included (components no. 2 in Fig. 1). The model involves also the flow rate of water end-use (efficiency of water use fixtures) and the ownership level of water use fixtures and appliances (i.e., clothes washer, dishwasher and bathtub). Using these parameters in Equation (1), the quantity of water consumption of each water end-use (showering, tap use, manual dishwashing, cooking, house floor washing, vehicle washing and garden watering) can be calculated. Equation (2) has been used to quantify water consumption for clothes washing, toilet flushing and bath. The model also calculates black and grey water collected from a household as shown in Fig. 3, using Equation (3) and Equation (4).

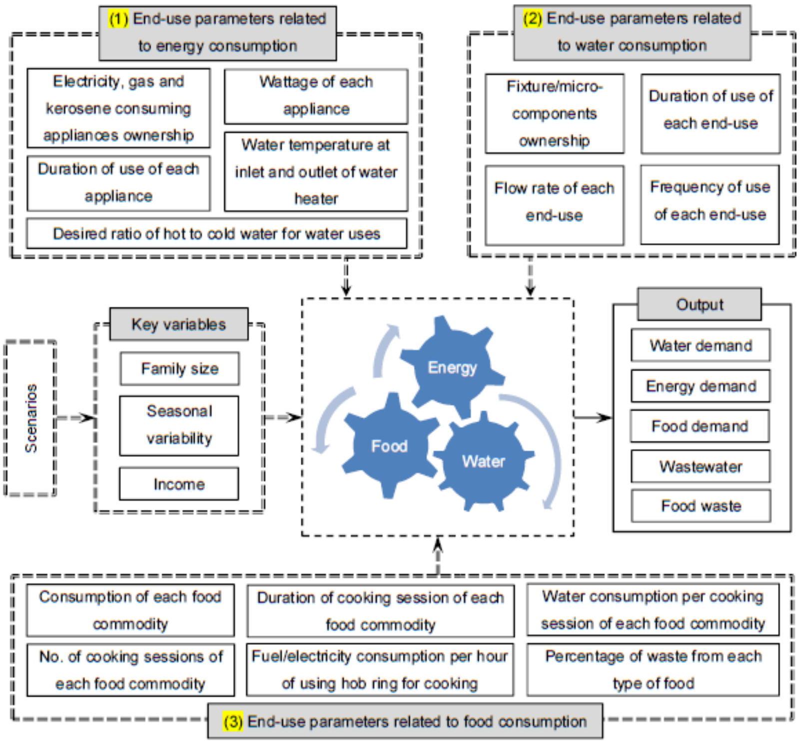

Fig. 1. The structure of the water-energy-food model at a household scale.

$$We_i = Fe_i \times De_i \times Re_i \tag{1}$$

$$We_i = Fe_i \times Ve_i \tag{2}$$

where:

We_i = daily per capita average consumption for water end-use i (l/p/d),
Fe_i = daily per capita average frequency of water end-use i (number of events/p/d),
De_i = duration of water run during each event of water end-use i (min/event),
Re_i = average flow rate of water end-use i (l/min), and
Ve_i = quantity of water consumption during each event of water end-use i (l/event).

$$GW = WW_b + WW_{sh} + WW_{hw} + WW_{cw} \tag{3}$$

$$BW = WW_{dw} + WW_c + WW_{tf} + WW_{fw} + WW_{vw} \tag{4}$$

where: GW = grey water, b = bathing, sh = showering, hw = hand wash basin tap use, cw = clothes washing, BW = black water, dw = dishwashing, c = cooking, tf = toilet flushing, fw, house floor washing, vw = vehicle washing.

Fig. 3 shows the interactions between water, energy and food end-uses at a household scale. The direction of an arrow shows water or energy consumption associated with each end-use. These interactions are addressed in the developed model. For instance, the energy consumption for water heating, water for space cooling (i.e., evaporative air-cooler), wet appliances (i.e., water pump, dishwasher, clothes washer), water and energy use for food preparation and energy for food preservation.

2.2. Modelling of household energy consumption

The household energy consumption (i.e., electricity, kerosene and LPG) is divided into several end-uses: space heating, water heating, lighting, and refrigeration, wet, electronic, cooking and miscellaneous appliances. Each energy end-use comprises different types of appliances, with the same purpose of use as listed in Table 1. The model involves the appliances presented in this table. The calculation of energy consumption in the developed model for water heating and other appliances is explained in Sections 2.2.1–2.2.3.

2.2.1. Energy consumption for water heating

Different types of energy (e.g., electricity, kerosene, and LPG) can be used for household water heating for various uses (i.e., bathing, showering, hand washing basin, laundry, dishwashing, and cooking). The amount of energy consumed for water heating depends on the household composition, inflow and outflow water temperature and fuel type (Aguilar et al., 2005). Another factor is the wattage and efficiency of a water heater (Isaacs et al., 2004). Additionally, energy consumption for water heating may vary with the seasons and climate (Goldner, 1994). Energy consumption for

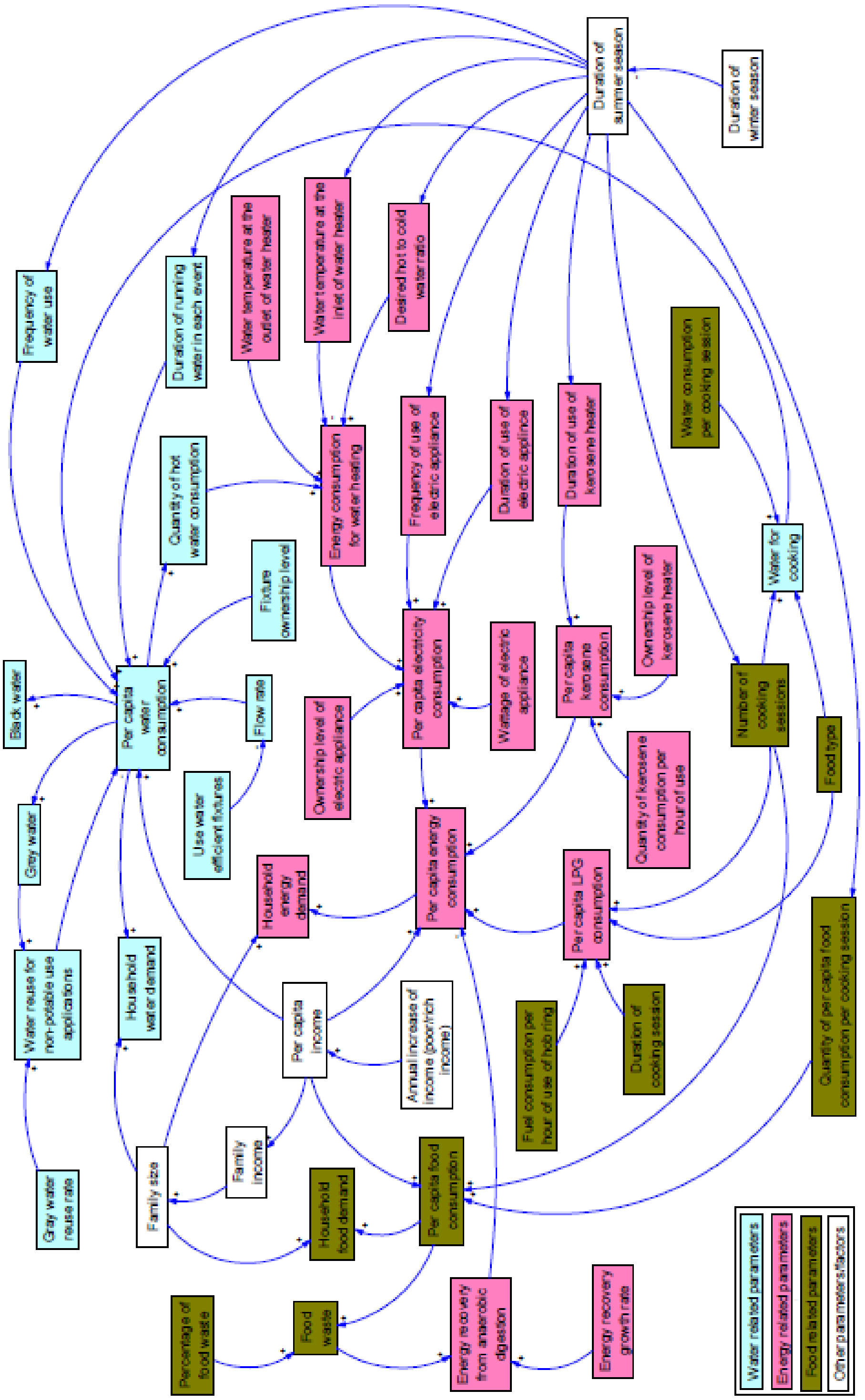

Fig. 2. Relationship between water-energy-food parameters and external drivers at a household scale.

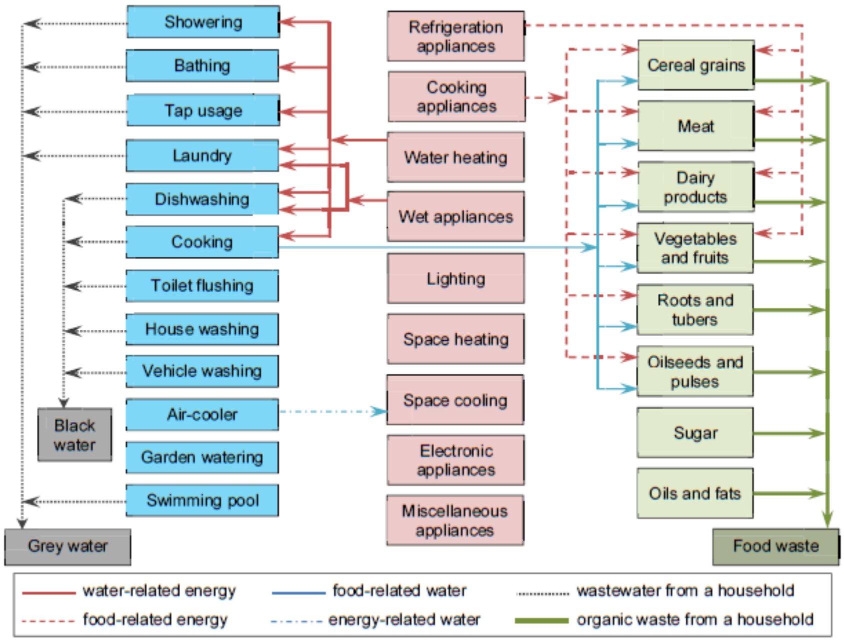

Fig. 3. Modelling the interactions between water, energy and food end-uses at a household scale.

Table 1
Summary of energy end-uses and the related appliances.

Energy end-use	Appliances
Space heating	Air-conditioner, electrical heater, kerosene heater, gas heater
Space cooling	Air-conditioner, evaporative air-cooler, fan
Lighting	Spot lights, tube lights
Wet appliances	Water pump, dishwasher, clothes washer
Refrigeration appliances	Chest-freezer, fridge-freezer
Electronic appliances	TV, radio, computer, video record, CD/DVD player, Video games
Miscellaneous appliances	Hair dryer, vacuum cleaner, sewing machine, iron
Cooking appliances	Electrical hob, electrical oven, electrical kettle, microwave oven, toaster, gas oven, gas hob

daily water heating can be calculated using a specific heat formula (Equation (5)) (Gettys et al., 1989) as given below.

$$E_h = Q_h \times \rho \times S \times (T_{out} - T_{in})/3600 \tag{5}$$

where:

E_h = daily per capita energy consumption for water heating (kWh/p/d),
Q_h = daily quantity of hot water consumption per capita (m^3/p/d),
ρ = density of water (1000 kg/m^3),
S = specific heat capacity of water = 4.186 kJ/kg °C,
T_{out} = water temperature at the heater outlet (°C),
T_{in} = water temperature at the heater inlet (°C), and
3600 = conversion factor (from kJ to kWh).

Swan (2010) assumed that the delivered water temperature, T_{out}, is 55 °C and T_{in} is equal to the annual average soil temperature. In order to achieve the preferred tap water temperature (40 °C), it is assumed that 50% of the water used requires heating (i.e., for bathing, showering, taps, dishwashing, laundry and cooking) (Kenway et al., 2008; Fidar, 2010). For the case study in this paper, the same proportion has been assumed for each indoor end-use requires heating to calculate the average per capita hot water consumption. The average temperature of water supply (T_{in}) for the case study is approximately 12 °C during the cold season (Duhok Directorate of Seismology and Meteorology, 2015). The average water temperature at the outlet of heater (T_{out}) is taken as 62 °C, based on the survey findings. Using the quantity of per capita hot water consumption and Equation (5), the per capita electricity consumption for water heating can be calculated. The model is flexible to accommodate any hot to cold water ratio (components no. 1 in Fig. 1) considering various climatic conditions in different regions of the world.

2.2.2. *Energy consumption of electric appliances*

To calculate the energy consumption of electric appliances, the energy consumption of each appliance is assumed to remain constant throughout its entire operating hours. The energy consumption of each appliance in use in a household is modelled as a function of ownership level (e.g., number of air-conditioners in use in a household), duration of use and wattage (components no. 1 in Fig. 1). Using these parameters and Equation (6), the energy consumption of each appliance presented in Table 1 can be calculated as below.

$$Ea_i = Na_i \times Da_i \times Wa_i \quad (6)$$

where:

Ea_i = daily per capita average energy consumption of appliance i (kWh/p/d),
Na_i = average ownership level of appliance i per household,
Da_i = daily per capita average duration of use of appliance i (hrs/p/d), and
Wa_i = average wattage of appliance i (Watt),

In the developed WEF model, wattage values for appliances in Table 1 are based on the survey findings.

2.2.3. Kerosene and LPG consumption

In addition to the electricity consumption, the WEF model calculates household consumption for other types of energy uses, such as kerosene and LPG. Equation (7) is used to calculate per capita kerosene and LPG consumption for space heating. The energy consumption for food preparation is explained in Section 2.3.2.

$$E_s = N_s \times D_s \times Q_s \quad (7)$$

where:

E_s = daily per capita average kerosene/LPG consumption for space heating (l/p/d),
N_s = average number of kerosene/LPG heaters in use in a household,
D_s = daily per capita average duration of use of kerosene/LPG heater (hrs/p/d), and
Q_s = quantity of kerosene/LPG consumption by each heater per hour (l/heater/hr).

2.3. Modelling of household food consumption

Household food consumption is disaggregated into several groups: cereal grains, meat, dairy products, vegetables and fruits, roots and tubers, oilseeds and pulses, oils and fats, and sugar. Each food group comprises various commodities as shown in Table 2. The food commodities presented in this table are included in the WEF model. The daily per capita consumption of each of these food commodities is modelled as a function of the number of cooking sessions per day and the quantity of food consumed per cooking session (components no. 3 in Fig. 1) as shown in Equation (8).

Table 2
Summary of food groups and related food commodities.

Food groups	Commodity
Cereal grains and products	Wheat flour, rice, burgul & jareesh, buns, cake, biscuits, macaroni & vermicelli
Meat	Chicken & turkey, sheep & goat, bovine, fish & seafood
Dairy products	Yogurt, cheese, egg, milk, butter
Roots and tubers	Potato, onion, carrots, garlic, radish
Vegetables	Tomato, cucumber, aubergine, courgette, okra, lettuce, sweet pepper, celery
Fruits	Water melon, orange, apple, melon, grape, pumpkin, banana
Oilseeds and pulses	Bean, chick pea, lentil
Oils and fats	Vegetable oils, animal fats
Sugar	Sugar

[a] Milk and oil consumption is modelled in l/p/d.

$$F_i = (Nc_i/7) \times Fc_i \quad (8)$$

where:

F_i = daily per capita consumption of food commodity i (g/p/d),
Nc_i = number of cooking sessions of food commodity i per week (cs/w), and
Fc_i = average quantity of per capita consumption of food commodity i per cooking session (g/p/cs).

In order to calculate the energy and water consumption for food preparation (Fig. 3), the model included some other parameters, such as, the quantity of water and energy consumption per cooking session of each food commodity (components no. 3 in Fig. 1). The calculation of water and energy consumption for food preparation and generated food waste is explained in the following Sections (2.3.1–2.3.3).

2.3.1Water use for food preparation

The quantity of water consumption for food preparation is modelled as a function of number of cooking sessions per week and water consumption per cooking session (components no. 3 in Fig. 1). The model requires these parameters for each food commodity presented in Table 2. Using these parameters in Equation (9), the daily per capita water consumption for cooking each type of food can be calculated.

$$W_i = (Nc_i/7) \times Wc_i \quad (9)$$

where:

W_i = daily per capita average water consumption to prepare food commodity i (l/p/d),
Nc_i = average number of cooking sessions of food commodity i per week (cs/w), and
Wc_i = per capita average water consumption in each session of washing and cooking food commodity i (l/p/cs).

2.3.2. Energy use for food preparation

The required parameters to calculate the energy consumption for food preparation are the duration of cooking session and fuel consumption per hour for using a hob ring (components no. 3 in Fig. 1). Using these parameters for each food commodity (Table 2) in Equation (10), the energy consumption for food preparation can be calculated in the WEF model. In order to calculate the energy use for food preparation, the size of the hob ring used for cooking every type of food is assumed to be the same in all households.

$$E_i = (Nc_i/7) \times (Dc_i/60) \times E_h \quad (10)$$

where:

E_i = daily average fuel consumption to prepare the food commodity i (l/d).
Dc_i = duration of cooking session of the food commodity i (min/cs), and
E_h = fuel consumption per hour of using hob ring for cooking (l/hr).

2.3.3. Food waste from household

In each step of the food supply chain (production, processing, distribution and consumption), the percentage of food waste for each type of food is estimated by FAO (2011), for different world regions. Table 3 shows the percentages of food waste for each type of food during the consumption step of food supply chain in different regions. The table shows that food waste at a consumption step in Sub-Saharan Africa, South and Southeast Asia is very low, compared to the other regions of the world. Using these percentages in Equation (11), the quantity of food waste from a household can be calculated in the WEF model. The calculated food waste is influenced by the quantity of per capita food consumption, which is a function of household income and seasonal variability. The values in Table 3 can be used in the developed model to quantify food waste in the regions of interest.

$$FW_i = PFW_i \times F_i \tag{11}$$

where:

FW_i = quantity of waste from food commodity i (g/p/d), and
PFW_i = percentage of waste from food commodity i (%).

2.4. Impact of income on water, energy and food

Income and wealth can be a major factor influencing per capita water, energy and food consumption. Kriström (2008) stated that income is the key driver for household energy consumption, reflecting increased affordability with an increase in income. Per capita water consumption also increases with an increase in household income (Willis et al., 2013). Although, other factors, such as occupant's age, education level and house size can have a marginal impact on resources consumption (Hewitt and Hanemann, 1995; Grafton et al., 2011), the major consumption influencing factors are household income and seasonal variability (Anker-Nilssen, 2003; Okutu, 2012; Palmer et al., 2013). Therefore, the developed model investigates the impact of these factors on water, energy and food consumption.

The households are divided into three income groups (i.e., low, medium and high) based on the classification of CSO and KRSO (2012) (Table 4). Based on this classification, the parameters relating to water, energy and food end-uses (components no. 1, 2 and 3 in Fig. 1), which are presented in Sections 2.1–2.3, are classified and defined in the model for each income group, individually. The values assigned to these parameters are derived from the two surveys conducted as discussed in Section 4.2. The input parameter values to quantify water demand in the model can be found in Hussien et al. (2016). Consequently, the model estimates water, energy and food consumption for low, medium and high income households.

2.5. Impact of seasonal variability on water, energy and food

The household energy consumption varies seasonally due to changes in the energy requirements for space heating and cooling (Lam et al., 2008). Svehla (2011) showed a significant seasonal variation in refrigeration, cooking and the use of some other appliances. Most studies assumed that indoor water consumption, except for evaporative air-cooling, remains unchanged throughout the year (Rathnayaka et al., 2015). However, in addition to garden watering, swimming pool and evaporative air-cooling, indoor water end-uses do vary seasonally. An example is showering, which increases in summer (Rathnayaka et al., 2015).

Table 4
Income groups classification for Iraq (CSO and KRSO, 2012).

	Income range in each income group in Iraqi Dinar (ID)		
	Low	Medium	High
Per household	$<1 \times 10^6$	1×10^6–2×10^6	$>2 \times 10^6$
Per capita	$<15 \times 10^4$	15×10^4–30×10^4	$>30 \times 10^4$

The WEF model captures the impact of seasonal variability on the consumption of water, energy and food at a household scale. In order to achieve this, modifications were made for different end-uses.

To estimate water consumption during the summer season, evaporative air-cooler end-use is added to the other water end-uses which are presented in Section 2.1. Consequently, the annual per capita average water consumption can be calculated using Equation (12).

$$TW = d_w \times \sum_{i=1}^{n} [We_i]_w + d_s \times \sum_{i=1}^{m} [We_i]_s \tag{12}$$

where:

TW = annual per capita total water consumption (l/p/year),
$[We_i]_w$ = daily per capita water end-use i during winter season (l/p/d),
$[We_i]_s$ = daily per capita water end-use i during summer season (l/p/d),
d_w = duration of winter season (d), and
d_s = duration of summer season ($=365- d_w$) (d).

In terms of energy consumption during the summer season in the WEF model, the space heating appliances are replaced with space cooling appliances (i.e., fan, evaporative air-cooler and air-conditioner) (Table 1). Equation (13) is used in the WEF model to calculate the annual per capita energy consumption for each income group.

$$TE = d_w \times \sum_{i=1}^{n} [Ee_i]_w + d_s \times \sum_{i=1}^{m} [Ee_i]_s \tag{13}$$

where:

Table 3
Percentage of waste from various types of food within the consumption step of food supply chain (FAO, 2011).

Region	Cereal grains	Meat	Fish and sea food	Dairy products	Roots & tubers	Vegetable & fruits	Oilseeds & pulses
Europe including Russia	25	11	11	7	17	19	4
North America and Oceania	27	11	33	15	30	28	4
Industrialised Asia	20	8	8	5	10	15	4
Sub-Saharan Africa	1	2	2	0.1	2	5	1
North Africa, west and central Asia	12	8	4	2	6	12	2
South and Southeast Asia	3	4	2	1	3	7	1
Latin America	10	6	4	4	4	10	2

TE = annual per capita total energy consumption (kWh/p/year),
$[Ee_i]_w$ = daily per capita energy end-use i during winter season (kWh/p/d), and
$[Ee_i]_s$ = daily per capita energy end-use i during summer season (kWh/p/d).

Similarly to Equation (12) for water and Equation (13) for energy, the model calculates the seasonal variability of food consumption and also the water and energy use for food preparation. This is achieved by using the parameters of each food commodity for each income group during winter and summer seasons. The survey data analysis indicates that in general terms WEF increases with the household income. The water consumption is 270 l/p/d in winter and increases to 334 l/p/d in summer. The energy consumption increases in winter (15.5 kWh/p/d) compared to that in summer (12.1 kWh/p/d). Food consumption broadly remains same in winter and summer. The parameters influencing consumption and their respective values for different seasons and income groups are available in supplementary material as given in Table A1 to A3.

2.6. Family size

The analysis of our conducted survey (Hussien et al., 2016) strongly suggests that Duhok family size is influenced by family income. Therefore, in the WEF model, the impact of a family size (FS) is addressed as a function of increase/decrease in the family income (Equation (14)).

$$FS = \sum_{j=1}^{3} P_j \times FS_j \tag{14}$$

where:

P_j = percentage of households in income group j (j = *low, medium and high*), and
FS_j = average family size of the income group j. FS_j values are constant as derived from the conducted survey and are shown in Table 5.

3. Model assumptions

The key assumptions include:

1) Although, some electric appliances operate on different power ratings, the model reports an average energy consumption of each appliance throughout its entire operating hours rather than capturing short time scale variability.
2) Electricity is the main source for water heating at a household level. This is based on the household survey findings.
3) The hot to cold water ratio is assumed to be 1:1 for each end-use that required hot water in Duhok households. However, the model is flexible to accommodate any hot to cold water ratio considering various climatic conditions in different regions of the world.
4) The average temperature of water supply (T_{in}) is approximately 12 °C during the cold season (Duhok Directorate of Seismology and Meteorology, 2015). The average water temperature at the outlet of heater (T_{out}) is taken as 62 °C, based on the survey findings.
5) The size of hob ring used for cooking every type of food is the same in all income households.
6) The capacity of LPG cylinder is assumed as 26.2 l. This is the predominant cylinder size in Iraq (Kurdistan Ministry of Natural Resources, 2014).
7) There is no leakage in the household.
8) The survey results indicated that bath and swimming pool ownership is very low. It is assumed as zero.

Table 5
Impact of income on average family size in Duhok, Iraq.

	Low income	Medium income	High income
Average family size	4.82	7.10	8.45

4. Model application

The developed WEF model has various applications that can support appropriate policy formation and analyse future consumption related implications:

1) Specify the highest end-use of water/energy in terms of consumption. This can assist to find the suitable strategy to reduce that end-use and the related waste.
2) Estimate the consumption of each food commodity at a household scale, which can help to plan for the future land-use for agricultural crops.
3) Evaluate the impact of new technologies and efficiency enhancement programs on water (e.g., use recycled grey water for non-potable applications), energy (e.g., use anaerobic digestion for energy recovery from food waste) and food when they are applied to a household.
4) Enable the decision-makers and stakeholders to compare between different scenarios and their respective resource requirements to find the preferable management policy.

4.1. Model input parameters

A summary of model input parameters is given in Table 6. Each input parameter, labelled with an asterisk (*), could have six different values depending on weather (summer or winter) and household income (low, medium and high). The input parameter values for water, energy and food demand estimation are provided as supplementary material for this paper. The values for these parameters have been derived from a detailed survey conducted for the chosen case study city, Duhok, Iraq, which is described in the following section. The non-survey-based data used in the WEF model and their spatial resolution are provided in Table 7.

4.2. Case study

The developed model was applied using the data collected from the city of Duhok located in the Kurdistan region in Iraq. Duhok has a population of around 295,000 inhabitants with 4.9% fertility rate (CSO et al., 2006). The average family size in Duhok is 6.7 (2.47 child, 2.01 adult female, 1.96 adult male and 0.25 elder) with monthly average family income 1664.9 × 10^3 ID (CSO and KRSO, 2012). The city has seen considerable urbanisation and changes in land use patterns resulting in additional demand for water, food and energy (Kurdistan Regional Statistics Office (KRSO), 2014).

Energy supply to Duhok households increases annually with a rate of 9% (General Directorate of Duhok Electricity, 2014). Per capita meat consumption has also increased in Duhok households to 24 kg/p/y in 2014 (Kurdistan Ministry of Agriculture and Water Resources, 2014). Due to the increase in Duhok household's consumption for WEF, it is selected as a case study in this paper. A detailed survey on water, energy and food consumption was carried

Table 6
Summary of model input parameters.

Input parameters	Key driver/end-use
Average family size of low, medium and high income households (FS_j)	Key drivers
Proportion of low, medium and high income households (P_j)	
Duration of summer and winter seasons	
Frequency of use of water end-use (Fe_i) *	Showering, hand wash basin tap use, manual dishwashing, cooking, house floor
Duration of use of water end-use (De_i) *	washing, vehicle washing and garden watering
Flow rate of water end-use (Re_i) *	
Frequency of use of water end-use (Fe_i) *	Bathing, toiler flushing and clothes washing
Quantity of water consumption during each event of water end-use (Ve_i) *	
Ownership level of electric appliance (Na_i)	Air-conditioner, electric heater, evaporative air-cooler, fan, spot lights, tube lights,
Duration of use of electric appliance (Da_i) *	water pump, dishwasher, clothes washer, chest-freezer, fridge-freezer, TV, radio,
Wattage of electric appliance (Wa_i)	computer, video record, CD/DVD player, Video game, hair dryer, vacuum cleaner, sewing machine, iron, electric hob, oven, kettle, microwave, and toaster
Ownership level of kerosene and gas use appliance (N_d)	Kerosene heater, kerosene hob, gas heater, gas hob and gas oven
Duration of use of kerosene and gas use appliance (D_s) *	
Quantity of kerosene/gas consumption by the appliance (Q_s)	
Water temperature at inlet of water heater (T_{in})	Water heating uses
Water temperature at outlet of water heater (T_{out})	
Desired ratio of hot to cold water for water uses	
Number of cooking sessions of a food commodity (Nc_i) *	Wheat flour, burgle & jareesh, buns, cake, biscuits, macaroni & vermicelli, chicken &
Quantity of consumption of the food commodity per cooking session (Fc_i) *	turkey, sheep & goat, bovine, fish & sea food, yogurt, cheese, egg, milk, butter,
Average water consumption per cooking session of the food commodity (Wc_i) *	potato, onion, carrots, garlic, reddish, tomato, cucumber, aubergine, courgette, okra,
Duration of cooking session of the food commodity (Dc_i) *	lettuce, sweet pepper, celery, water melon, orange, apple, melon, grape, pumpkin,
Fuel consumption per hour of using hob ring for cooking (E_h) *	banana, bean, chick pea, lentils, vegetables oils, animal fats and sugar.
Percentage of waste of food commodity	

Table 7
Summary of non-survey based data.

Parameters	Unit	Value	Spatial resolution	Reference
Water temperature at inlet of water heater	°C	12 °C during the cold season	Local	Duhok Directorate of Seismology and Meteorology (2015)
Classification of household income groups	ID	Table 4	National	CSO and KRSO (2012)
Capacity of LPG cylinder	l	26.2	National	Kurdistan Ministry of Natural Resources (2014)
Waste from each type of food	%	Table 3	Regional	FAO (2011)
Average wattage of spot lights	Watt	40	National	Iraqi Ministry of Electricity (2010)
Average wattage of tube lights	Watt	60	National	Iraqi Ministry of Electricity (2010)

*l = litres of LPG, ID=Iraqi Dinar.

out for representative sample (i.e, 419 households) of the city population during winter and summer season. Further details on the case study site are given in Hussien et al. (2016).

5. Model results

Using the case study of Duhok, the sensitivity of the WEF model estimations to the input parameters is analysed. The model validity is tested using uncertainty assessment analysis. Then the model results are compared with the historical data. Finally, the WEF model is used to investigate the impact of future scenarios on the household demand for water, energy and food.

5.1. Model sensitivity

In order to calculate the sensitivity of the model output to the input parameters, one-at-a-time analysis method has been used. This method considers the range of variation in input parameters as its standard deviation below and above its average value (i.e., average ± standard deviation) (Hamby, 1995). Then, the change in model output (water and energy demand) is quantified by using the upper and lower value of each input parameter individually, while holding all other input parameters at their base-case value (Cullen and Frey, 1999). This method does not account for interactions between the input parameters (Frey and Patil, 2002; Saltelli and Annoni, 2010), but provides a clear indication how a single parameter influences the overall outcome.

Fig. 4 shows the sensitivity of water demand estimation to the input parameters. The highest sensitivity is attributed to the frequency and duration of each session of garden watering. Their contribution to the sensitivity of water demand estimation accounts approximately to ±1.5% of the base-case estimated demand (i.e., the estimated demand when all input parameters set to their mean).

The sensitivity of electricity demand estimation to the model input parameters is shown in Fig. 5. It is clear from this figure that the estimation of electricity demand is highly sensitive to the ownership level and the duration of the use of air-conditioners in a household (±4% of the base-case estimated demand). This may be due to the high variation in ownership level (average = 1.36, variance = 0.98) and the duration of the use of air-conditioners (average = 10 h/hh/d, variance = 7.3 h/hh/d) between Duhok households. However, the other input parameters have less impact on the electricity demand estimation (±1% of the base-case estimated demand).

Overall, for the parameters obtained from the survey, the model has shown reasonable predictions. In order to increase confidence in the results, a formal uncertainty assessment was performed as discussed below.

5.2. Uncertainty analysis

The uncertainty of model output is analysed using the Monte Carlo technique. This technique has been used by Kenway et al.

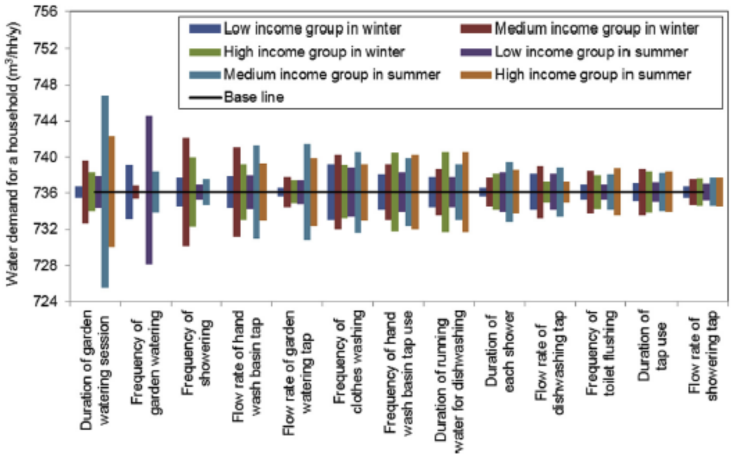

Fig. 4. Sensitivity analysis of household water demand estimation to the input parameters.

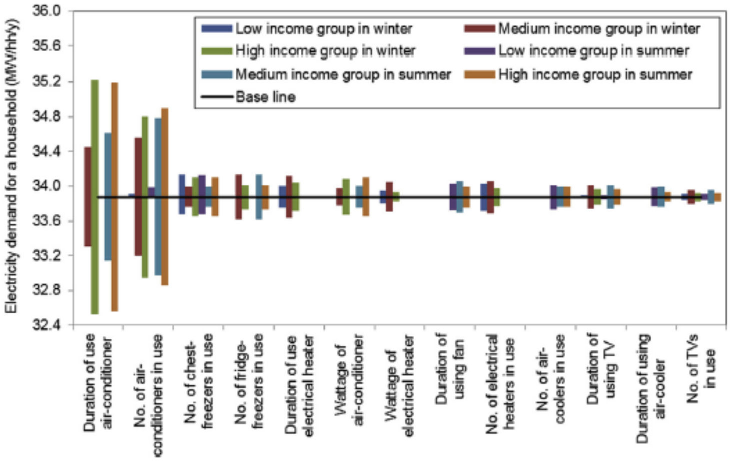

Fig. 5. Sensitivity analysis of household electricity demand estimation to the input parameters.

(2013) and Schaffner et al. (2009) to test the uncertainty of their models. For each input parameter into the WEF model, random values are selected from the distribution of possible values for input parameter under consideration. The random values of input parameters are used in the developed model and the expected value of the output is calculated to evaluate the impact of multiple uncertain parameters. The process is repeated for a number of iterations. Then, the probability distribution of the calculated outputs is plotted as shown in Fig. 6. The analysis shows that the uncertainty for water demand estimation is lower than that for energy. This is because the relative width (standard deviation/average (Schaffner et al., 2009)) of estimated demand for water (0.03) is less than that for electricity, kerosene and LPG (0.04, 0.04 and 0.05, respectively). The relative width of estimated demand for food types in Fig. 6 is less than 0.04.

5.3. Comparison of WEF model results with historical data

The results of the developed model are compared against the available historical data which are published in reports or collected from local directorates (KRSO, 2014; COSIT et al., 2010; General Directorate of Duhok Electricity, 2014) in Duhok for the business as usual scenario (i.e., current family size, demographic and household characteristics). The comparison between the model results and the available historical figures for water, energy, food consumption and waste generation is presented in Table 8. The results show that the estimated values of the WEF model are close to the measured historical data. However, the simulation results of food consumption are slightly higher than the historical data. This is probably because the historical data of food consumption in Table 8 are based on daily per capita average calorie intake (2580kcal/p/d) in Iraq, which is less than that in Duhok (2910kcal/

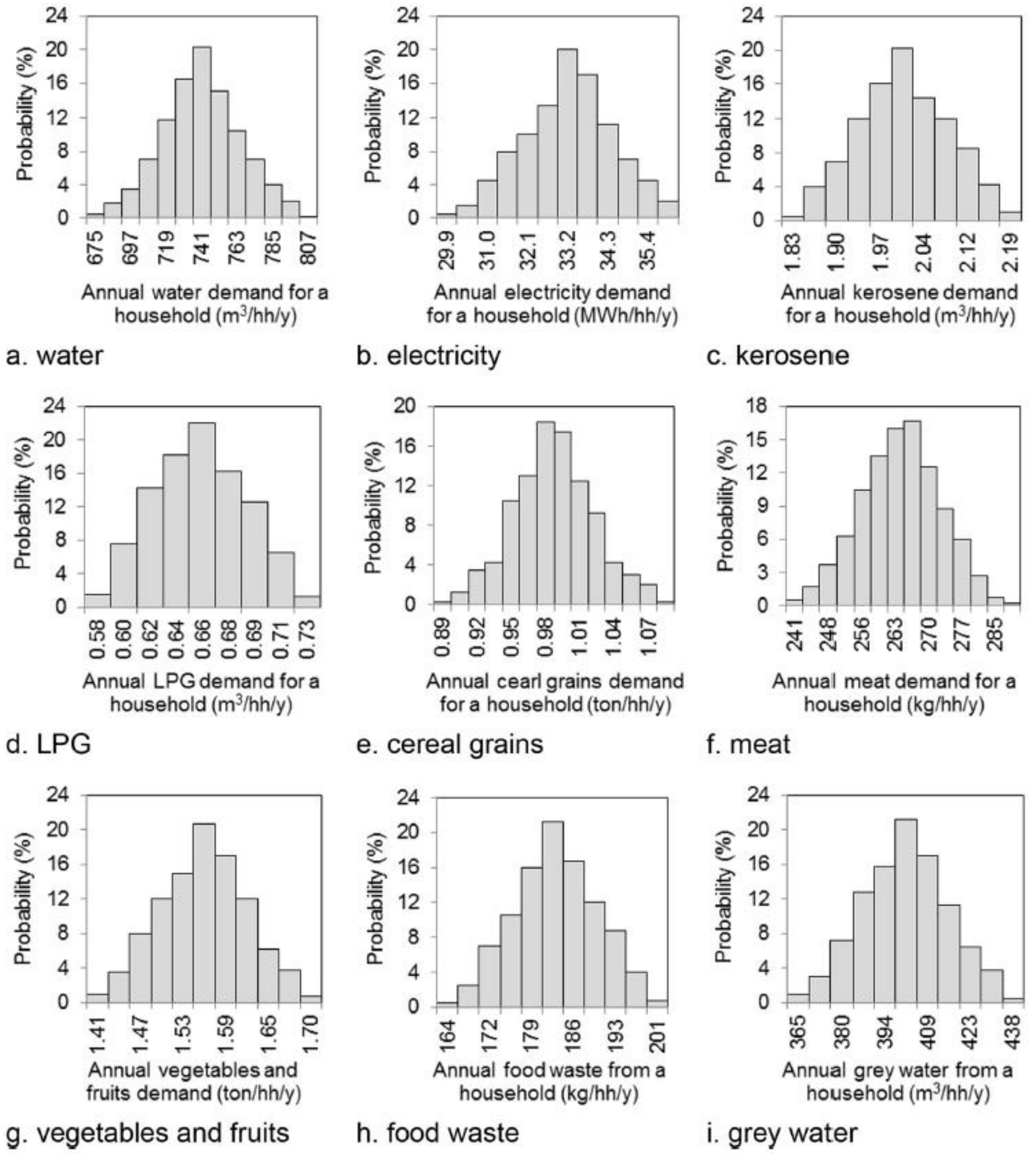

Fig. 6. Probability distributions of Monte Carlo simulations.

p/d) (COSIT et al., 2010).

To prove the validity of the model results of food consumption, the simulation results of the quantity of daily per capita average food consumption are converted into calories using the conversion factors given by COSIT et al. (2010). These factors are based on FAO (2004) and have been adapted to take into account the specifications of available food commodities in Iraq. The results show that the daily per capita average calorie intake is approximately 2880kcal/p/d in Duhok. The detailed comparison at end-use level is not possible because water, energy and food consumption at micro-level have not been addressed for Duhok households.

5.4. Scenarios analysis

The implications of Global Scenario Group[1] scenarios on water, energy and food demand are investigated in this paper. The scenarios are explained in Table 9.

[1] http://gsg.org.

Table 8
Comparison of model results with historical measured data at a household level.

Description	Unit	Model results	Historical data	Reference
water consumption in winter	l/hh/d	1816	1896	KRSO (2014)
water consumption in summer	l/hh/d	2238	2298	
energy consumption in winter	kWh/hh/d	102	97	General Directorate of Duhok Electricity (2014)
energy consumption in summer	kWh/hh/d	79	74	
cereal grains consumption	g/hh/d	2702	2620	COSIT et al. (2010)
meat consumption	g/hh/d	728	639	Kurdistan Ministry of Agriculture and Water Resources (2014)
dairy consumption	g/hh/d	605	607	COSIT et al. (2010)
roots and tubers consumption	g/hh/d	933	529	
vegetables consumption	g/hh/d	2888	2396	
fruits consumption	g/hh/d	1416	1175	
oilseeds and pulses consumption	g/hh/d	350	241	
oils and fats consumption	g/hh/d	240	241	
sugar consumption	g/hh/d	505	489	
food waste	g/hh/d	969	1005	Duhok Directorate of the Municipalities (2014)
average family size	no.	7.04	6.7	CSO and KRSO (2012)

Table 9
Summary of GSG scenarios (Kemp-Benedict et al., 2002).

Scenario	Definition	Implications
Market force (MF)	the globalized governance, trade liberisation and consumerist values lead to free market behaviour.	high growth in population, productivity, economy, GDP and income and also inequality between rich and poor countries, and within each country. The consumption for water, energy and wastes will increase.
Fortress world (FW)	the powerful world forces, faced with a dire systemic crisis, impose an authoritarian order where elites retreat to protected enclaves, leaving impoverished masses outside.	rapid deterioration in environmental conditions, pollution, climate change, water scarce, food insecurity and health crisis with a large socio-economic divide between rich and poor.
Policy reform (PR)	the world establishes the necessary regulatory, economic, social, technological, and legal mechanisms to meet social and environmental sustainability goals, without major changes in the state-centric international order, modern institutional structures, and consumerist values.	achieve internationally recognized goals for poverty reduction, climate change stabilisation, ecosystem preservation, freshwater protection, and pollution control. As a result, greenhouse emissions decline, growth continues in developing countries for two decades as redistribution policies raise incomes of the poorest regions and most impoverished people.
Great transition (GT)	social values move toward internationalism rather than localism and also concerned with environmental conservation, which leads to high growth and development, and service directed change.	increase in wastewater reuse and a decline in fossil fuel energy use and intensive agriculture leading to a reduction in the leakage and water demand.

Numerous studies and assessments have relied on GSG scenarios, such as OECD (2001), WWV (2000) and UNEP (2002). According to GSG, water, energy and food consumption and poor/rich income ratio are assumed to vary from region to region. For the case study located in Iraq, values associated with the Middle East have been used as given in Table 10. The growth rates in this table reflect percentage change in consumption. The model initially used to calculate the base consumption, based on parameter values obtained from the survey. The consumption in each scenario is then calculated by the household WEF model using respective values for poor/rich income ratio in Table 10. The annual demand for water, energy and food has been simulated for 35 years ahead. The time horizon of 35 years is the most often considered timeline in scenarios (Hunt et al., 2012; Ercin and Hoekstra, 2014) and also recommended for socioeconomic planning (Simonovic and Fahmy, 1999).

Fig. 7 shows the impact of GSG scenarios on the future demand for water, energy and food and the generated waste. In this figure, the simulated future changes in the household demand are presented as a percentage of the current demand. The results show that within these scenarios, the highest increase in the household demand is attributed to the fortress world scenario. This is mainly due to the increase in high income households which leads to increase the family size.

The impact of GSG scenarios on the interactions between water, energy and food is also simulated as shown in Table 11. The results in this table show that the food-related energy in fortress world scenario is higher than the other scenarios. The water-related energy in market force scenario is slightly higher than that in the fortress world scenario. At a household level, the impacts of different scenarios are marginal (Table 11). However, when extrapolated to a city level, noticeable differences and resources

Table 10
Summary of annual growth rate (%) of indicators of GSG scenarios for Middle East region.

Indicators	Market force		Policy reform		Fortress world		Great transition	
	2005–2025	2025–2050	2005–2025	2025–2050	2005–2025	2025–2050	2005–2025	2025–2050
Poor/rich income ratio	0.03	0.03	0.2	0.15	−0.1	−0.3	0.6	0.5
Meat consumption	0.7	0.6	0.9	0.7	0.7	0.2	0.9	0.3
Crop consumption	2.1	1.4	2.0	1.2	2.2	1.3	1.9	0.9
Household energy	3.8	3.1	3.0	1.6	3.9	2.4	2.6	0.1
Domestic water	3.4	2.6	1.9	0.6	3.5	2.0	1.8	0.4
Domestic fuel	3.6	2.2	3.1	1.0	3.4	1.6	2.9	−0.4

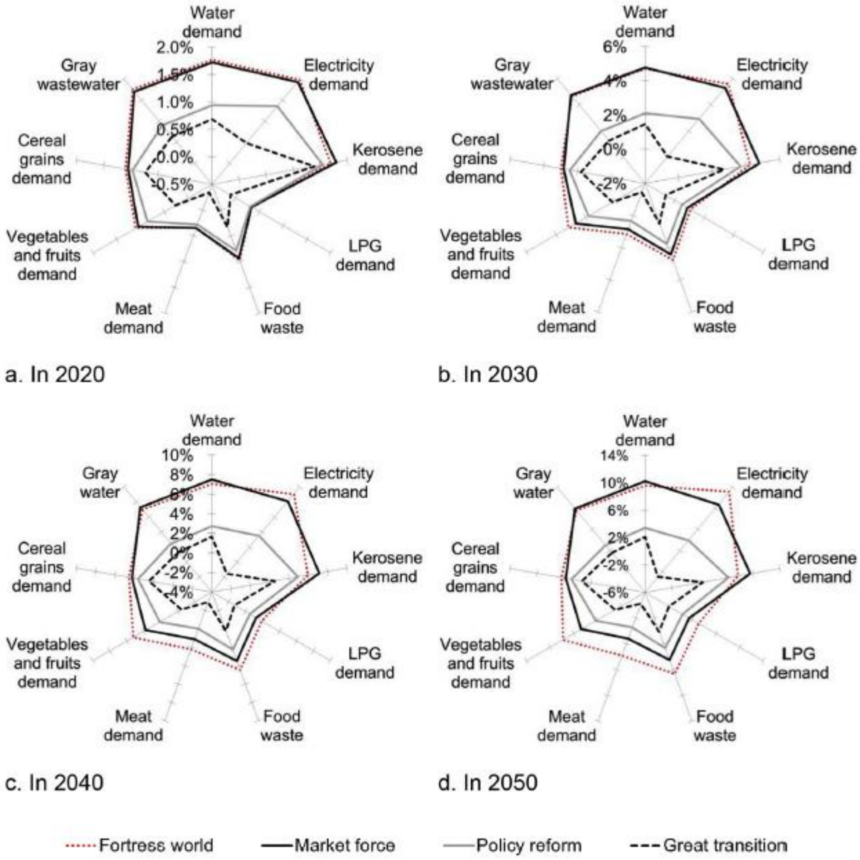

Fig. 7. The impact of GSG scenarios on water-energy-food at a household level.

Table 11
The impact of GSG scenarios on the interactions between water, energy and food at a household level.

Future scenarios	Energy for water (GJ/hh/y)			Energy for food (GJ/hh/y)			Water for food (m^3/hh/y)		
	2030	2040	2050	2030	2040	2050	2030	2040	2050
Business as usual	24.3	24.3	24.3	20.9	20.9	20.9	35.7	35.7	35.7
Market force	25.5	26.2	26.9	21.1	21.2	21.2	36.4	36.7	37.0
Policy reform	24.9	25.1	25.3	21.0	21.0	21.0	36.2	36.3	36.5
Fortress world	25.4	26.0	26.6	21.1	21.3	21.6	36.5	37.0	37.6
Great transition	24.7	24.9	25.1	20.8	20.7	20.5	35.8	35.6	35.5

implication were observed.

The developed WEF model at a household level can be improved to include the greenhouse gas emissions and the impact of other socioeconomic variables on the consumption. The model can also be expanded to include the demand for other sectors (agricultural, industrial and commercial) in the city. This is to forecast the demand for water, energy and food for the whole city.

6. Conclusion

The purpose of the current study was to present the structure of a developed integrated model for water, energy and food consumption at a household scale. The developed model addresses the impact of lifestyle change (user behaviour), family size, household income, appliances efficiency and climate change (increase/decrease the duration of summer season) on the future demand for water, energy and food. The availability of the WEF model may assist the decision-makers and stakeholders to investigate nexus problems at a household level and the implications of management policy for water, energy and food. The model can also be expanded to include the demand for water, energy and food and their interactions in the other sectors (agricultural, industrial and commercial) in the city. This is to forecast the demand for water, energy and food for the whole city.

Two seasonal surveys were conducted in 419 households in the city of Duhok, Iraq, to collect data on water, energy and food consumption during the winter and summer seasons. The survey data were used with the developed model to simulate the demand for water, energy and food and the generated food waste and wastewater streams. The model sensitivity to the input parameters is analysed. Additionally, the simulation results were compared with the measured historical data to test the model validity. The model results show a good agreement with the measured historical profiles. The model was applied to investigate the impact of four possible scenarios: market force, fortress world, great transition and policy reform. The results suggest that the fortress world scenario has the highest negative impact on household water, energy and food consumption.

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Software, WEF model and data availability

Software name Simile (i.e., modelling software for scientific research projects in the earth, environmental and life sciences)
Software developer and contact address Simulistics (a spin-out company from the University of Edinburgh). Address: Simulistics Ltd., 2B Pentland Park, Loanhead, Midlothian, UK. Tel: +44 (0)131 448 2982. Fax: +44 (0)131 448 2982. Email: info@simulistics.com
Software availability and cost Simile software full version requires licence and can be downloaded at http://www.simulistics.com/simile-version-67-released
Software size 27 MB
Operating system required for software 32-bit Windows: Windows 95 or later.
Name of the developed model WEF model
WEF model developer and contact address Wa'el A. Hussien, Fayyaz A. Memon and Dragan A. Savic. University of Exeter, Exeter, Devon, UK. E-mail: wahh201@exeter.ac.uk
WEF model data availability provided as supplementary material

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.envsoft.2017.03.034.

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