



Assessment of the effectiveness and economic efficiency of selected support options for UK

D13 of WP4 from the RES-H Policy project

**A Working Document prepared as part of the IEE project
"Policy development for improving RES-H/C penetration in
European Member States
(RES-H Policy)"**

January 2011 (with amendment in April 2011)

Written by:

Tom Richardson, University of Exeter

Lei Xie, (L.Xie@exeter.ac.uk) University of Exeter

Peter Connor (P.M.Connor@exeter.ac.uk) University of Exeter

With contributions from:

Lukas Kranzl, Andreas Müller

Energy Economics Group, Vienna University of Technology

Luuk Beurskens and Pieter Kroon, Energy research Centre of the Netherlands, ECN

The project "Policy development for improving RES-H/C penetration in European Member States (RES-H Policy)" is supported by the European Commission through the IEE programme (contract no. IEE/07/692/SI2.499579).

The sole responsibility for the content of this report lies with the authors. It does not represent the opinion of the European Communities. The European Commission is not responsible for any use that may be made of the information contained therein.

© University of Exeter, January 2011

Content

1	Impacts of RES-H policies on capacities, emissions, costs (about 10-15 pages)	10
1.1	Methodology	10
1.1.1	<i>Invert Model: Methodology</i>	10
1.2	Characteristics of investigated policies and scenarios	12
1.3	Results from Policy Set 1	14
1.3.1	<i>Growth in RES-H/C capacities</i>	15
1.3.2	<i>Costs</i>	16
1.3.3	<i>Avoided fuel costs</i>	17
1.3.4	<i>Reduction of GHG emissions</i>	18
1.4	Policy set 2	18
1.4.1	<i>Growth in RES-H/C capacities</i>	19
1.4.2	<i>Costs</i>	20
1.4.3	<i>Avoided fuel costs</i>	20
1.4.4	<i>Reduction of GHG emissions</i>	21
1.5	Comparison and synthesis (Amended April 2011)	21
2	Employment effects	24
2.1	The EmployRES project	24
2.2	Methodology used in this paper	26
2.3	Results	27
2.3.1	<i>Bottom-up results for Policy Set 1 based on INVERT</i>	27
2.3.2	<i>Bottom-up results for Policy Set 2 based on INVERT</i>	27
2.3.3	<i>Comparison of top-down results and bottom-up results</i>	28
3	Transaction costs	30
3.1	Methodology	30
3.2	Assumptions	31
3.3	Results	32
4	References	34
5	Annex 1	36
5.1	Heat generation costs	36
6	Annex 2: Modelling assumptions	39
7	Annex 3 Industry Modelling	41
7.1	Modelling of industrial process heat using the RESolve-H/C model	41
7.2	Determining the realisable potential of RES-H in industry	41
7.3	Determining the penetration of RES-H in industry	44
7.4	Fuel price scenarios	45

7.5 Conclusions Concerning the RHI modelling for Industry Uptake of RES-H..... 62
7.6 Levels of Subsidy Informing the Industry Models..... 63

List of tables

Table 1:	<i>Levels of subsidy available under the RHI, as used in the models. Based on figures in DECC RHI Consultation document (DECC 2010).</i>	14
Table 2:	<i>Results of using the March 2011 DECC figures in the INVERT model</i>	22
Table 3:	<i>Overview of the Industry Modelling Approach (part 1)</i>	42
Table 4:	<i>Matching of RES-H/C technologies to temperature levels</i>	43
Table 5:	<i>Overview of the Industry Modelling Approach (part 2)</i>	44
Table 6:	<i>Levels of support available to industry under the RHI (As of April 2011) (DECC 2011)</i>	63

List of figures

Figure 1:	Overview structure of Invert-Simulation-Tool.....	10
Figure 2:	Development of RES-H in the building sector, policy set 1, low energy prices (left) and high energy prices (right)	15
Figure 3:	Public budget requirement in the building sector, policy set 1, low energy prices (left) and high energy prices (right)	17
Figure 4:	Avoided fuel costs in the building sector under policy set 1, low energy prices (left) and high energy prices (right)	17
Figure 5:	Reduced annual GHG emissions in the building sector, policy set 1, low energy price scenario (left) and high energy price scenario (right).....	18
Figure 6:	Development of RES-H in the building sector, policy set 2, low energy prices (left) high energy prices (right).....	19
Figure 7:	Public budget requirement in the building sector, policy set 2, low energy prices (left) and high energy prices (right)	20
Figure 8:	Avoided fuel costs in the building sector, policy set 2, low energy prices (left) and high energy prices	21
Figure 9:	Reduced GHG emissions in the building sector: policy set 2, low energy prices (left) and high energy prices (right)	21
Figure 10:	Overview of the modelling steps realised in the EMPLOY RES project (Ragwitz et al. 2009).....	25
Figure 11:	Calculation of employment effects with a top-down and bottom-up approach.....	26
Figure 12:	Annual employment effects 2010 to 2030, high energy price scenario (left) and low energy price scenario (right)	27
Figure 13:	Annual employment effects 2010 to 2030, high energy price scenario (left) and low energy price scenario (right)	28
Figure 14:	Overview of bottom-up results for all policy sets as well as top-down results	29
Figure 15:	Transaction costs for both policy sets in both energy price scenarios.....	33
Figure 16:	Range of heat generation costs in the building sector (low-price scenario)	36
Figure 17:	Range of heat generation costs in the building sector (high-price scenario)	37
Figure 18:	Fuel Price Scenarios, low energy price scenario (left), high energy price scenario (right) (Source: PRIMES).....	45
Figure 19:	Overview of bottom-up results for all policy sets as well as top-down results	47

Figure 20: Penetration of RES-H into Industry, low energy price scenario, no RES-H Policy	47
Figure 21: RES-H fuel costs, low energy price scenario, no RES-H Policy.....	48
Figure 22: Avoided costs, low energy price scenario, no RES-H Policy.....	48
Figure 23: Net avoided costs, low energy price scenario, no RES-H Policy.....	49
Figure 24: Avoided industry CO ₂ emissions, low energy price scenario, no RES-H Policy	49
Figure 25: Industry supply curve in 2020, low energy price scenario, no RES-H Policy	50
Figure 26: Penetration of RES-H into Industry, high energy price scenario, no RES-H Policy.....	51
Figure 27: RES-H fuel costs, high energy price scenario, no RES-H Policy	51
Figure 28: Avoided costs, high energy price scenario, no RES-H Policy	52
Figure 29: Net avoided costs, high energy price scenario, no RES-H Policy	52
Figure 30: Avoided industry CO ₂ emissions, high energy price scenario, no RES-H Policy	53
Figure 31: Industry supply curve in 2020, high energy price scenario, no RES-H Policy	53
Figure 32: Penetration of RES-H into Industry, low energy price scenario, RHI implemented	54
Figure 33: RES-H fuel costs, low energy price scenario, RHI implemented.....	54
Figure 34: Avoided costs, low energy price scenario, RHI implemented.....	55
Figure 35: Cost of the RHI, low energy price scenario, RHI implemented.....	55
Figure 36: Net avoided costs, low energy price scenario, RHI implemented.....	56
Figure 37: Avoided industry CO ₂ emissions, low energy price scenario, RHI implemented	56
Figure 38: Industry supply curve in 2020, low energy price scenario, RHI implemented	57
Figure 39: Penetration of RES-H into Industry, high energy price scenario, RHI implemented	58
Figure 40: RES-H fuel costs, high energy price scenario, RHI implemented.....	59
Figure 41: Avoided costs, high energy price scenario, RHI implemented	59
Figure 42: Cost of the RHI, low energy price scenario, RHI implemented.....	60
Figure 43: Net avoided costs, high energy price scenario, RHI implemented	60

Figure 44: Avoided industry CO₂ emissions, high energy price scenario, RHI implemented 61

Figure 45: Industry supply curve in 2020, high energy price scenario, RHI implemented 62

The RES-H Policy project

The project "Policy development for improving RES-H/C penetration in European Member States (RES-H Policy)" aims at assisting Member State governments in preparing for the implementation of the forthcoming Directive on Renewables as far as aspects related to renewable heating and cooling (RES-H/C) are concerned. Member States are supported in setting up national sector specific 2020/2030 RES-H/C targets. Moreover the project initiates participatory National Policy Processes in which selected policy options to support RES-H/C are qualitatively and quantitatively assessed. Based on this assessment the project develops tailor made policy options and recommendations as to how to best design a support framework for increased RES-H/C penetration in national heating and cooling markets.

The target countries/regions of the project comprise Austria, Greece, Lithuania, The Netherlands, Poland and UK – countries that represent a variety in regard of the framework conditions for RES-H/C. On the European level the projects assesses options for coordinating and harmonising national policy approaches. This results in common design criteria for a general EU framework for RES-H/C policies and an overview of costs and benefits of different harmonised strategies.

This Working Document

This Working Document summarises the results of the assessment of the effectiveness and economic efficiency of different support instrument options to foster the market penetration of RES-H/C in the UK. For two selected policy options related costs (mainly public transfer costs) and benefits (e.g. growth in RES-H/C capacities, avoided fuel costs, reduced GHG emissions) will be assessed. In addition it will be analysed how the different policy options will influence the development of different RES-H/C technologies. Moreover, this working step covers an estimation of the transaction costs (in particular those resulting on the authorities' side) and the direct (gross) employment effect that can be linked to the two analysed support policy options.

This Working Document is based on the description and qualitative assessment of selected support instrument options as described by Working Document D9. Similar documents have also been prepared relating to the other countries/regions targeted within this project.

1 Impacts of RES-H policies on capacities, emissions, costs (about 10-15 pages)

1.1 Methodology

The RES-H Policy project aims to apply two separate models to produce results indicating the impacts of RES-H support policies selected by stakeholder consultation. This report details the application of the INVERT model to data concerning the impact of two selected policies on the installation of RES-H technologies in the domestic and commercial sectors.

1.1.1 Invert Model: Methodology

The INVERT Model is a comprehensive, dynamic bottom-up simulation tool that evaluates the effects of different promotion schemes (investment subsidies, feed-in tariffs, tax exemptions, subsidy on fuel input, CO₂ taxes, soft loans, and additional aside premium) on the energy carrier mix, CO₂ reductions and costs for society promoting certain strategies. Furthermore, the INVERT Model is designed to simulate different scenarios (price scenarios, insulation scenarios, different consumer behaviours, etc.) and their respective impact on future trends of renewable as well as conventional energy sources on a national and regional level. An overview is shown in Figure 1.

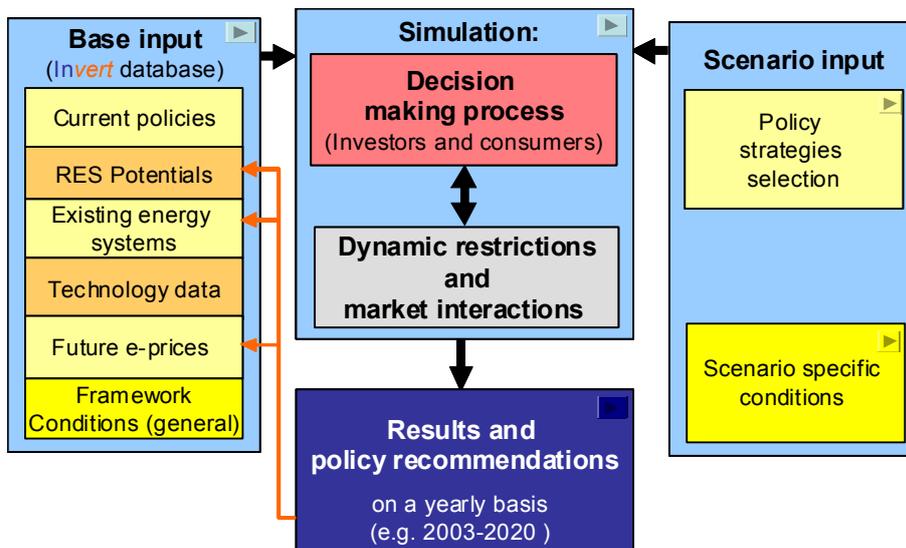


Figure 1: Overview structure of Invert-Simulation-Tool

The Invert simulation tool was originally developed by Vienna University of Technology/EEG in the framework of the Altener project Invert (Investing in RES&RUE technologies: models for saving public money). During several projects and studies the model has been extended and applied to different regions within Europe, see e.g. (Biermayr et al., 2007), (Haas et al., 2009), (Kranzl et al., 2006), (Kranzl et al., 2007), (Nast et al., 2006), (Schriefl, 2007), (Stadler et al., 2007). The last modification of the

model in the year 2010 included a re-programming process and accommodation of the tool, in particular taking into account the inhomogeneous structure of decision makers in the building sector and corresponding distributions (Müller, 2010). The current state of the model relies on this new calculation-core (called EE-Lab) leading to the current version of the model Invert/EE-Lab506 which has been used in this project.

The core of the tool is a myopic, multinomial logit approach, which optimizes objectives of “agents” under imperfect information conditions and by that represents the decisions maker concerning building related decisions. Invert/EE-Lab models the stock of buildings in a highly disaggregated manner. Therefore the simulation tool reflects some characteristics of an agent based simulation.

The basic decision algorithm

The basic decision/selection process works on an annual basis and is defined as follows:

For each year of the simulation period INVERT decides for each building segment if the system (regarding building shell and heating / dom. hot water system) remains as it is or if a new heating technology respectively a measure to improve the building shell has been chosen. The share of buildings applying changes is calculated based on the age of the considered building element using a Weibull distribution. The share on the actual installation of available types is calculated based on adjusted heat generation costs using the multinomial logit approach. This incorporates, that low-cost options (based on adjusted heat generation costs) get the largest market share, but more expansive options hold some share too. The necessary distribution parameters are calibrated in order to meet historic development

In order to put the basic model represented by the basic decision algorithm in a realistic frame work the model is extended with the consideration of three different categories of restrictions:

- restrictions concerning resource potentials (e.g. maximum amount of biomass used for heating)
- restrictions concerning technology penetration rates (defining the maximum share of a technology, especially relevant for new / unconventional technologies, technologies where low acceptance can be expected)
- restrictions concerning replacement rates (maximum number of buildings per year where a certain measure may be carried out, e.g. windows may be changed in only x% of all buildings for one year)

After the calculation of replacement rates for the current year of the simulation period for each building segment where a change occurs according to the basic algorithm it is

decided if all the buildings of this building segment are subjected to this change or if it has to be split up in two parts (one part containing the changed buildings, the other part containing the unchanged buildings). Restrictions are exogenously defined for each year of the simulation period.

The following variables are defined via distribution rather than single values.

- Resource availability for each building segment
- Technical life for equipment
- Investment and operating & maintenance costs and running costs for measures

Modelling the energy demand

Energy demand is modelled depending on service demand and efficiency. The two energy services under investigation are space heating and water heating. Behavioural aspects in the case of space heating (such as level of indoor temperature, ventilation habits) are considered through the service factor. This parameter describes the relation between actual and theoretically calculated energy consumption for space heating. The model calculates the service factor as a function of thermal quality (specific heat load) of the building and degree of automation of the heating system (central heating system vs. single stove heating system) as well as the specific building size. Final energy demand for space heating is computed based on the specific heat load of a building ($\text{W/m}^2\text{K}$) and the average outdoor temperature using a monthly balance approach.

Final energy demand for water heating is modelled as dependent on the number of people living in the dwelling under consideration and the service demand for domestic hot water (volume of hot water with 50°C) per person and day, or the average hot water demand per square meter when it comes to non residential buildings, and annual efficiency of the water heating system. The model incorporates the ageing of heating systems and domestic hot water systems; this means that their annual efficiency is modelled as decreasing from year to year.

Database of building stock

The currently implemented buildings represent a detailed, disaggregated image of the buildings stock. Residential buildings are distinguished by their size (number of dwellings per buildings) and construction period as well as type of location (urban or rural). This holds for non residential buildings as well. Yet, since less information about these types of buildings is available, the distinction is less accurate.

1.2 Characteristics of investigated policies and scenarios

Informed by the stakeholder consultation two policy options are modelled (Connor 2010). It is clear that the UK will be adopting the RHI as an important instrument in driving forward the use of RES-H technology. Those stakeholders consulted were largely

happy with the instrument and it is effectively inevitable at this stage in the policy process. As such, all of the stakeholders agreed that it made sense to model the RHI in the next stage of the project. The second policy mechanism to be modelled is a modified form of Supplier Obligation, as detailed in the UK-D9 document (Xie & Connor, 2009). The potential impact of these mechanisms are modelled as part of two designated 'policy sets'; with policy set 1 consisting of the RHI only, and policy set 2 consisting of the RHI plus the modified Supplier Obligation. Within each of these two core policy sets, two scenarios are modelled: one using a high energy price and the other a low energy price.

Specific to the pricing, we apply the Eurostat price relations for 2007-2009 and we take into account the growth rates of the medium and the high energy price scenario based on Capros *et al* (2008) and Resch *et al* (2009), to inform the high and a low energy price scenario. Moreover, country specific energy taxes and value added taxes (VAT) are taken into account.

1.2.1 Policy Set 1: The Renewable Heat incentive (RHI)

The UK government legally introduced the Renewable Heat Incentive (RHI) in the 2008 Energy Act, though without providing any level of detail as to its operational qualities. The UK Government has since published a consultation document outlining initial proposals for the operation of the mechanism and the level of subsidy available (DECC 2009). The RHI will provide fixed payments for heat generated from eligible technologies. Eligibility of technologies for payment from the mechanism is cast quite widely, with eligible technologies including: air, water and ground source heat pumps, other geothermal energy, solar thermal, biomass boilers, biogas, bioliquids, biomethane and combined heat and power using renewable fuel stuffs. Generally, payments are to be made on a metered basis for large-scale applications and on a deemed basis, a form of estimation, for small- and medium- scale applications. Table 1 describes the level of support afforded to different technologies in the modelling process in p/kWh. The UK Government has stated that while depreciation will not apply to the tariffs available under the RHI initially, that it is likely to apply following a review which will take place after the RHI has been introduced. It is currently unknown as to exactly when depreciation will be initiated and what the rate of tariff reduction will be specific to each technology. We have chosen to assume that it will begin from April 1st 2014 and that the rate of reduction will apply at 3% per annum across all technologies.

It was assumed for initial modelling purposes that the costs associated with the RHI would be paid by all energy consumers, as an addition to their bills, with oversight by an appointed body, assumed to be the current UK energy regulator, Ofgem. Ofgem were also assumed to have oversight for all issues relating to compliance with the RHI be it by suppliers, installers and developers.

Due to restrictions relating to the specifics of the tariffs available across all scales of RES-H applicable within the RHI, we have simplified the levels of support suggested in the actual RHI consultation document. Costs used within the model shown in Table 1.

Technology	RHI (p/kWh heat)
Wood log	8
Wood chips	8
Wood pellets	8
Heat pump air/water	5
Heat pump brine/water	6.5
Biomass district heating	2
Solar thermal	17.5

Renewable heat incentive^(b) (according to): Decentralised biomass systems 6.2-8.6 p/kWh, Heat pumps 5.5-7.1 p/kWh, Solar thermal systems 16.4-17.5 p/kWh, biomass district heating 2.5 p/kWh, Biogas 4 p/kWh, Liquid biofuels 6.5 p/kWh

Table 1: Levels of subsidy available under the RHI, as used in the models. Based on figures in DECC RHI Consultation document (DECC 2010).

1.2.2 Policy Set 2: The RHI + Supplier Obligation

The UK currently operates a form of supplier obligation known as the Carbon Emission Reduction Target (CERT), which compels large utilities to act to reduce carbon emissions amongst their consumers. While in principle the obligation includes support for both RES-E and RES-H microgeneration, in practice it primarily drives energy efficiency measures. It is proposed that this mechanism could be extended to compel utilities to assist in the installation of microgeneration technologies including RES-H technologies.

Following stakeholder consultation (Xie & Connor, 2009), the decision was taken to model a modified form of the CERT mechanism, with an assumption made that utilities were compelled to develop microgeneration and could claim the subsidies available in the RHI mechanism also being modelled. The supplier obligation is modelled as a 'strong type' of obligation. It is assumed that suppliers will consider all building types (i.e. new, renovated and not renovated) when fulfilling their obligation. Given that actual obligation would in practice only cover new and buildings undergoing substantial renovation, estimating the quota levels used in the modelling exercises is not straightforward. However, adjusting for these discrepancies, obligation levels can be assumed as equating to about 13% for 2020 and 24% for 2030. The penalty for not achieving these quota levels was set to 60€/m².

1.3 Results from Policy Set 1

This section sets out the results of the modelling exercises for domestic and commercial buildings under policy set 1, the Renewable Heat Incentive. The figures used in the model are based on those published in the Renewable Heat Incentive consultation

document (DECC 2010). The models assume that the RHI will be introduced from 2011 as stated in the consultation document. The consultation document also states that while the RHI will not initially be subject to digression it is likely that digression will be adopted following a review. For this reason we have adopted an assumed rate of digression of 3% to apply to all tariffs suggested in the consultation document, with application from 2014.

1.3.1 Growth in RES-H/C capacities

Figure 2 shows the simulated development of RES-H in the building sector under policy set 1. In both scenarios, the RES-H technologies achieve significant market penetration. From a baseline of 1% in 2007, under the low-price scenario, the share of RES-H in the building sector increases to around 6% (~28.2TWh) in 2020 and 10% (~42.2TWh) in 2030. Under the high-price scenario RES-H penetration reaches 10% (~49.4TWh) in 2020 and 21% (~86.8TWh) by 2030. While both scenarios show similarly shaped growth curves, the low price scenario shows a flattening in RES-H market post 2025; this is absent in the high cost scenario.

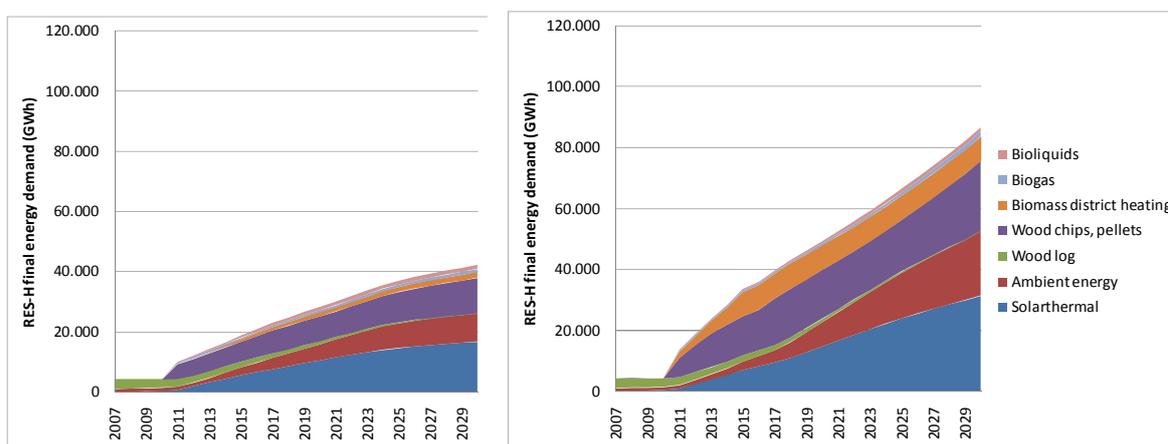


Figure 2: *Development of RES-H in the building sector, policy set 1, low energy prices (left) and high energy prices (right)*

In the short term, both scenarios see a rapid uptake of woodchip and pellet technologies. In the high price scenario, this is also accompanied by a rapid uptake of biomass district heating systems. However, the majority of growth in the mid to long-term is, in both scenarios, supplied by heat pump technology and solar thermal. In particular in the high energy price scenarios (which increase biomass prices, too) it turns out to be more attractive to fulfil the obligation with solar thermal or ambient heat than with biomass. In 2030, the market is dominated by wood chip and pellet, heat pumps, and solar thermal technology. While representing the largest market share in 2030, in the low price scenario and in the high price scenario, solar thermal becomes the dominant technology by 2017 and 2021 in these scenarios respectively.

Significant scaling up of RES-H seems likely to be limited in some regards by the absence of a district heating system. The evidence suggests this to be questionable economically in the UK at the moment (See, for example Pöyry/Faber Maunsell (2009) and there is little evidence that the UK government will provide the political support that will be needed to facilitate the development of district heating networks. However, it should be noted that a number of scenarios for delivery of energy in the UK up to 2050 suggest that district heating will play the part of a transition technology, prior to a shift to heat provision through electrification (largely through the use of heat pumps in typical scenarios). It is not clear how this transition might occur in practice. Scenarios including this transition are highlighted by Speirs, Gross et al. (2010).

A question that turned out to be crucial for the modelling task is the potential role of modern wood log heating systems. With the RHI support levels for solid biomass heating systems, wood log boilers would be an extremely economically attractive system. However, the tradition of wood log boilers in UK is low and it is basically a question of acceptable comfort conditions. Therefore, we excluded wood log systems from this simulation. If these systems would be widely accepted, their economic potential could be substantial.

The biomass price that maintains throughout the period will have a highly significant impact on the total RES-H adopted and on the technology mix. While we have chosen a relatively high price, it is quite possible that the actual figure will be higher still, with implications for uptake of biomass. This will be dependent on the demand for biomass in the UK, as well as across Europe, on the availability of biomass via international trade and on any limitations placed on importation by the UK and the EU in response to concerns about the potential impacts on sustainability of large-scale energy crop production outside the EU and its implications for the societies in which it might occur.

Other limiting factors impacting the scenarios are the rate at which new technologies are taken up. This will stem from demand but can also be limited by factors such as the availability of trained personnel, the rate at which new personnel are trained and the rate at which the supply of systems can be expanded to meet growing demand.

1.3.2 Costs

Figure 3 shows the public budget requirement in the building sector under policy set 1. Given that the tariff rates for technologies remain constant in the modelling process, the cost curves for the two scenarios show a similar shape to those describing the development of RES-H (figure 2). Assuming that support under the RHI remains constant, under the low price scenario, total annual costs would be forecast to reach ~€2.6 billion by 2020 and ~€3.4 billion by 2030. These expenses are almost double under the high price scenario (~€4.1 billion in 2020 and €6.3 billion in 2030). In 2030, support for solar thermal represents 78% and 76% of total annual costs for the low cost and high cost scenarios respectively. For the two scenarios, total costs by 2030 are ~€48.7 billion and ~€80.3 billion respectively. In both cost scenarios, 2025 sees a dip in public budget requirements as RHI support for the first non-grid biomass systems is ending. Typically, the systems will still be in operation, but are not subsidised any longer.

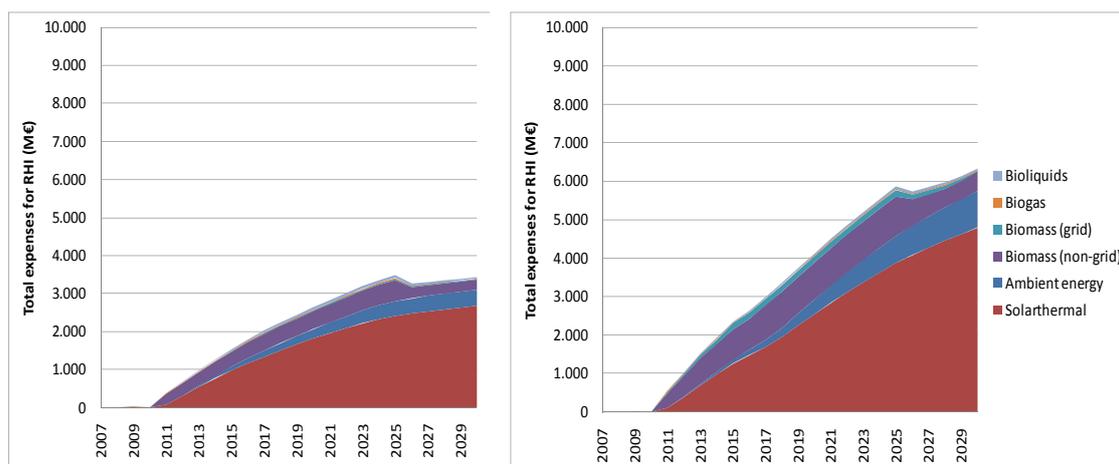


Figure 3: Public budget requirement in the building sector, policy set 1, low energy prices (left) and high energy prices (right)

1.3.3 Avoided fuel costs

Figure 4 shows the avoided fuel costs associated with the building sector in policy set 1. The blue area represents total fuel costs associated with uptake of RES-H technology in policy set 1, while the red area represents total fuel costs under the reference scenario (based on the mix of fossil fuels in the year 2007). The difference between the red and blue areas represents the net avoided fuel costs. The fossil reference scenario assumes that 100% of the heat demand is covered by fossil fuels. Thus, avoided fuel costs are calculated include consideration of RES-H systems in place in 2007 and others adopted before the introduction of the RHI.

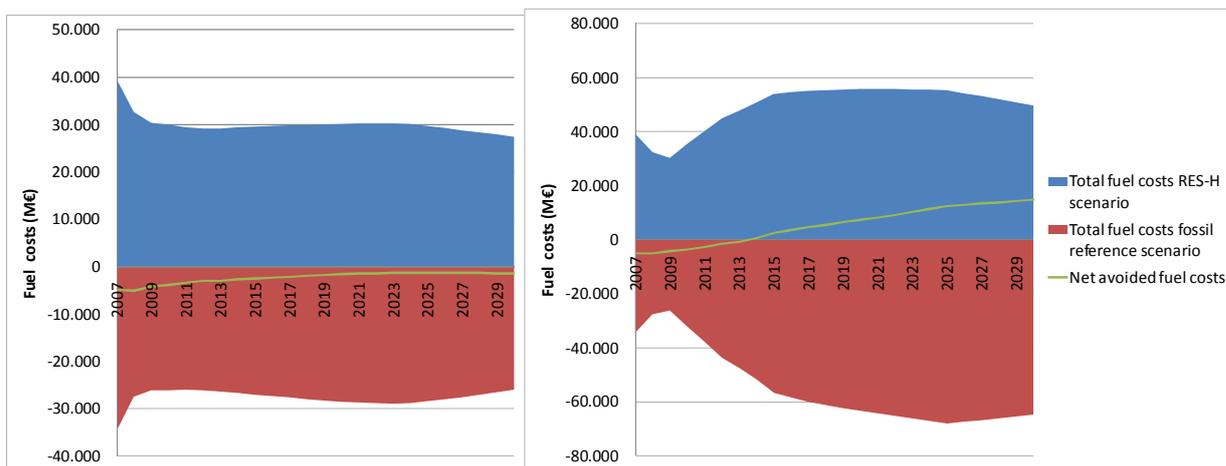


Figure 4: Avoided fuel costs in the building sector under policy set 1, low energy prices (left) and high energy prices (right)

In the low energy price scenario avoided fuel costs stay marginally negative throughout the period to 2030, indicating that increasing the penetration of heat technologies in-

curs added fuel costs. However, in the high price scenario fuel cost savings are made from 2013 onwards. In 2030 the net avoided fuel costs amount to almost €15 billion per year. The avoided fuel costs for policy set 1 show that where overall energy prices are low that there is no net saving on fuel costs at any point up to 2030. However, the model is much more favourable in the high energy price scenario, with a very rapid shift to a net benefit to avoided fuel costs and a substantial benefit in the period to 2030.

It must be emphasised that these results are highly dependent on the level of biomass prices. To reiterate, the calculations assumed relatively high biomass prices.

1.3.4 Reduction of GHG emissions

Figure 5 shows the potential reduction of greenhouse gas (GHG) emissions in the building sector under the two price scenarios for policy set 1. GHG savings are calculated against a reference system with no RES-H technology and based on the fossil fuel mix used for heating in 2007. Thus, both scenarios show savings prior to 2011.

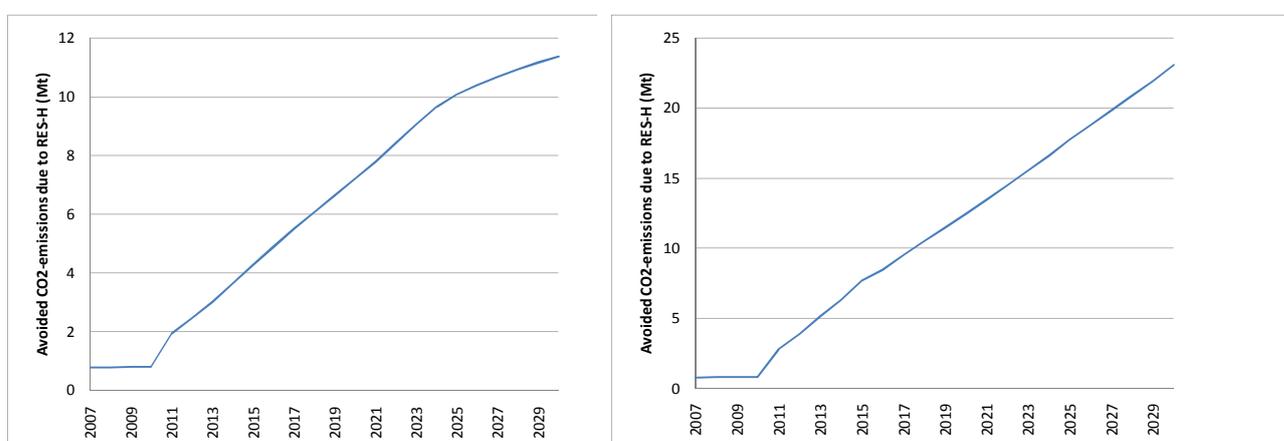


Figure 5: Reduced annual GHG emissions in the building sector, policy set 1, low energy price scenario (left) and high energy price scenario (right)

GHG emission savings correlate with technology deployment under the two scenarios. Savings under the high price scenario are therefore roughly double those under the low price scenario. Under the low price scenario, GHG savings are expected to be 7.2 Mt CO₂ equivalent (e) by 2020, rising to 11.4 Mt CO₂e by 2030. Under the high price scenario the figures are 12.5 Mt CO₂e by 2020, rising to 23.1 Mt CO₂e by 2030.

1.4 Policy set 2

Policy set 2 is based on the Renewable Heat Incentive combined with a Supplier Obligation. Again, both policies are assumed to come into practice in 2011.

1.4.1 Growth in RES-H/C capacities

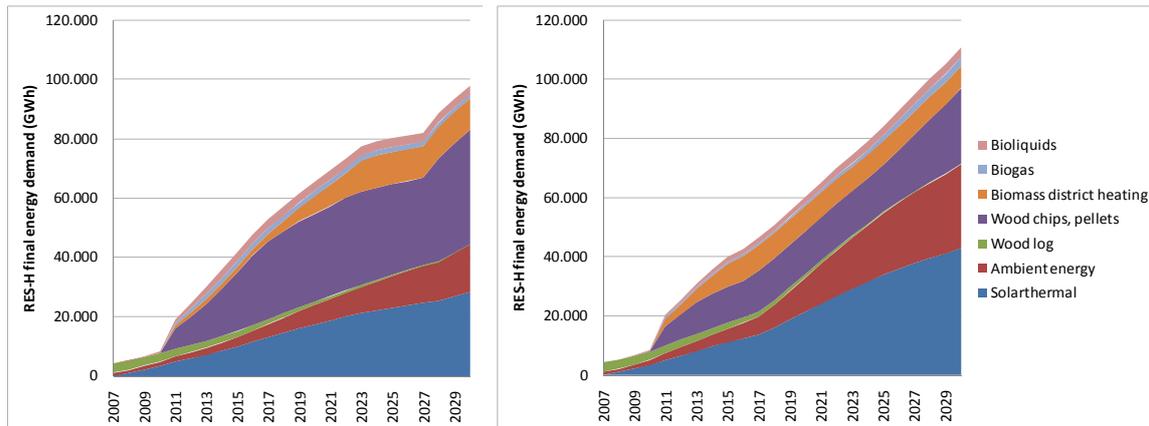


Figure 6: Development of RES-H in the building sector, policy set 2, low energy prices (left) high energy prices (right)

This represents an increase in the RES-H share in the building sector in the low-price and the high-price scenario from 1% (2007) to 14% (2020), 24% (2030) and to 13% (2020), 27% (2030), respectively.

Compared to the pure RHI-policy setting the supplier obligation is less dependent on the energy price level (if the penalties for not fulfilling targets for suppliers are sufficiently high). In particular, the uptake of biomass could be lower in the high price scenario and partly be replaced by heat pumps. However, as with the results from policy set 1, the breakdown of technologies will be heavily dependent on the price of biomass and this is difficult to predict given the potential for variation in development of international biomass markets and the impact this will have on biomass prices.

Specific to policy set 2, it is not possible for the models we are using to allow for different strategic responses by the obligated supply companies. Different responses may have significantly different implications for technology uptake.

Because of the obligatory nature of this policy set the difference between the levels of total deployment in the low and high energy price scenarios is low. It is notable however that solar thermal is far more significant in the high energy price scenario, while some forms of biomass combustion are significantly reduced. This is likely to reflect the additional pressure that rising general energy prices will place on biomass in the high price scenario, and the comparative advantage that solar thermal will enjoy, rooted in the absence of necessity for fuel.

1.4.2 Costs

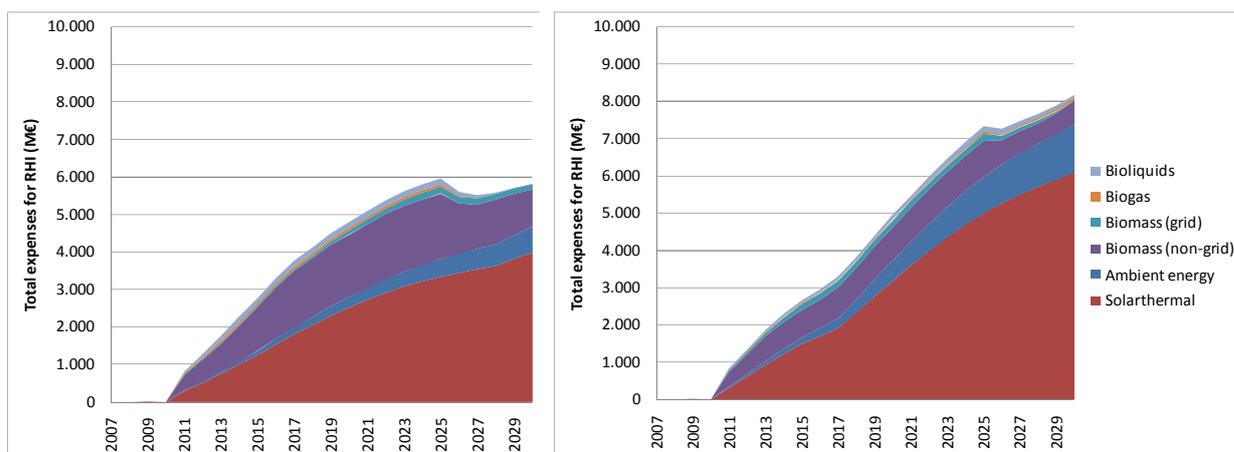


Figure 7: Public budget requirement in the building sector, policy set 2, low energy prices (left) and high energy prices (right)

It is inevitable that the obligation built into policy set 2 implies higher uptake of RES-H technologies and that thus a higher public budget is required in the high price scenario (given that the specific level of RHI as a support per kWh heat output remains constant).

1.4.3 Avoided fuel costs

The following figures show the avoided fuel costs due to RES-H systems for the low- and the high-price case. The blue area shows the total fuel costs that occur in the scenario that has been presented above. The red area shows the total fuel costs that would have occurred in the case that all RES-H systems would be provided by a fossil fuel mix (based on the mix of fossil fuels in the year 2007). The difference of the total fuel costs in the pure fossil reference scenario and in the scenario presented above represent the net avoided fuel costs. In particular for high-price periods, the net avoided fuel costs can amount to almost €20 billion per year. In low price periods (in particular in the low-price scenario), net additional costs can occur, which is mainly due to the fact that biomass heating systems show lower efficiencies than natural gas boilers. Moreover, this result is highly dependent on the level of biomass prices. Our calculations assume relatively high biomass prices.

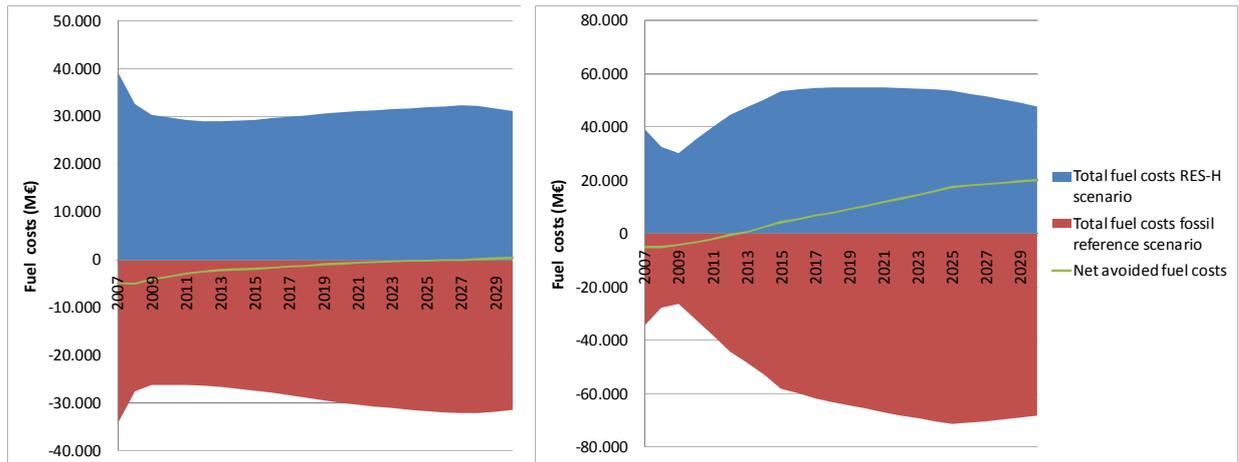


Figure 8: Avoided fuel costs in the building sector, policy set 2, low energy prices (left) and high energy prices

1.4.4 Reduction of GHG emissions

The following figures show the reduced GHG emissions associated with the two energy price scenarios for policy set 2. For the calculation of this indicator we assumed that in the fossil reference system all RES-H systems would be replaced by a fossil heating system mix (fossil energy mix from 2007).

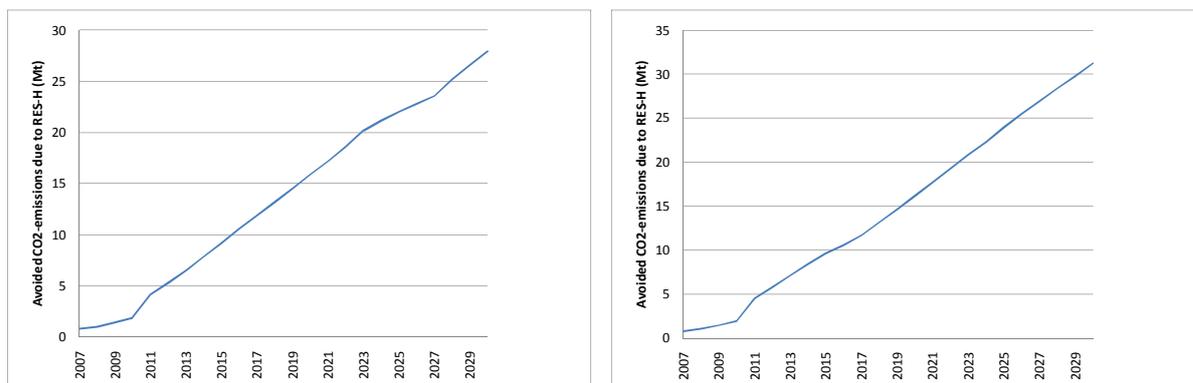


Figure 9: Reduced GHG emissions in the building sector: policy set 2, low energy prices (left) and high energy prices (right)

It is apparent that the GHG emissions reduction is similar under both scenarios, again reflecting the obligatory nature of the instruments applied in policy set 2. It can also be noted that the increase in total emissions reductions from policy set 1 to policy set 2 is substantial, rising from 11.4 Mt CO₂e in 2030 to ~28 Mt CO₂e by 2030.

1.5 Comparison and synthesis (Amended April 2011)

The results of the modelling for the building sector (comprising the domestic and commercial sectors) for the 2 policy instruments (1: RHI, 2: RHI +SO) across two energy price scenarios suggests a number of conclusions, and warrant greater consideration.

Our results suggest the adoption of the RHI has the potential to drive significant growth in Res-H technologies, but that the level of this growth will be dependent on ongoing market conditions throughout the period of operation. Our figures suggest however that the level of the RHI as originally proposed by DECC (2010) may have been too high and that substantial savings could be made without severely impinging on the ability of the mechanism to deliver capacity. Following the publication of further figures for the level of support likely to be available for commercial and industrial installations under the RHI in March 2011 (DECC 2011) the model was amended to produce figures which suggest that the new lower levels of support should still be able to drive a substantial amount of new RES-H capacity (See section 7.6 for these figures). It should be noted that we have used these figures for domestic premises as well to show the impacts with these figures. The key outputs for the new figures are in Table 2.

	RHI, low energy price		RHI, high energy price		RHI + SO, low energy price		RHI + SO, high energy price		
	Year	2020	2030	2020	2030	2020	2030	2020	2030
RES-H Total (TWh)		20.4	34.7	37.4	68.9	72.1	95.8	62.3	99TWh
Share RES-H		4%	9%	8%	17%	15%	23%	13%	24%
Billion € (annually)		1.7	2.7	2.9	5.0	4.7	6.9	4.6	7.6
Avoided GHG Emissions (Mt)		4.8	8.4	9.4	18.2	19.4	29.9	16.9	30.0

Table 2: Results of using the March 2011 DECC figures in the INVERT model

It can be noted that the influence of high overall energy prices continues to be a key driver of RES-H deployment and will significantly impact uptake as well as factors like reduction of overall energy use. It seems likely that should energy prices behave as in the low energy price scenario then the RHI alone would not deliver the kind of volume of RES-H that is essential to meeting the UK's targets under the 2009 Renewables Directive. Even in the high energy price scenario the RHI does not appear to drive enough capacity to make the UK's self imposed RES-H target of 12%. If the UK does not hit this target for RES-H it is unlikely to reach the overall 15% target for RE in 2020.

This suggests then that there is a case for another mechanism to drive deployment of RES-H alongside the RHI. A mechanism like the SO, because it compels deployment, and hopefully does so at minimum cost would be useful in ensuring that targets are actually met. While this would mean increased costs, it would provide much greater likelihood of the UK meeting its national target while driving significant contributions to reducing UK greenhouse gas emissions.

Looking beyond the instruments aiming to provide financial support, it is essential to note the need for non-financial instruments alongside those providing a subsidy. The models produced here rely on assumptions about the upper rate of expansion of deployment. Experience in promoting RES-H outside the UK suggests that programmes to provide training of relevant personnel and to raise awareness amongst industry actors and consumers facilitate more rapid expansion. Failure to address these elements within a policy framework may strongly influence the rapidity with which RES-H deployment occurs. Given the extremely ambitious nature of the UK's targets for RES-H, equal to over 1000% in the next 9 years, anything which can slow growth now must be addressed urgently.

2 Employment effects

As one of their main political tasks, governments strive for constant economic growth and high employment. Assessing the expansion of RES-heating and cooling (RES-H/C) in terms of the effect on employment forms an essential part of a quantitative analysis in allowing fully realised decisions to be made about the full benefits and costs of investment. The results presented in this section are based on the research project *EmployRES*¹ which was directed by Fraunhofer ISI. Specific gross employment effects are derived from the *EmployRES* results which serve as the input data for the two approaches (top-down and bottom-up) applied to calculate the total gross employment effects.

The gross employment effects of RES-H/C result from the economic impact of the renewable heating industry and the industries indirectly depending on it. The latter are mainly suppliers of inputs needed in the production process or of capital goods. In this gross perspective, negative employment effects – e.g. in industries linked to conventional energy generation – are not included.

The following paragraphs introduce the modelling approach and the main assumptions made in the *EmployRES* project and then describe the methodology of calculating the employment effects using the top-down and the bottom-up approach. Subsequently, the results are presented followed by a comparison of the outcomes of the two approaches.

2.1 The *EmployRES* project

The research project *EmployRES* was carried out on behalf of the *Directorate-General for Energy and Transport* of the European Commission and completed in April 2009. The calculations of gross employment effects are based on the annual turnovers deriving from enhanced RES market penetration.

This study combines different models – including two macroeconomic models (Astra, Nemesis), a RES sector model (GREEN-X) and an input-output (IO) model (MULTIREG) – in order to determine the economic and technological impacts of RES expansion. The IO model MULTIREG is used to calculate the current value added of RES activities and the employment effects. The technology classification and the cost structures of RES technologies are based on the GREEN-X database. The Green-X model delivers scenarios for the future development of RES activities and their corresponding expenditures and investments. This output data then serves as the input for

¹ “Employ RES The impact of renewable energy policy on economic growth and employment in the European Union” carried out by Fraunhofer ISI (Germany), Ecofys (the Netherlands), Energy Economics Group (Austria), Rütter + Partner Socioeconomic Research + Consulting (Switzerland), Lithuanian Energy Institute (Lithuania) and Société Européenne d’Économie (France).

the macroeconomic models, which determine the economic effects. This modelling step is performed by two real-world macro models – NEMESIS and ASTRA.

With the input-output model, a demand-side approach is used, which subdivides expenditures for renewable energy use into the cost components investments, operation maintenance and fuel expenditures and allocates them to economic activities. The resulting production vectors for each RES technology, differentiated by country and by economic sector, form the basis for calculating the direct gross value added and thus the direct employment effects. The indirect economic effects are determined by incorporating the RES production vectors as additional final demand in the input-output model.

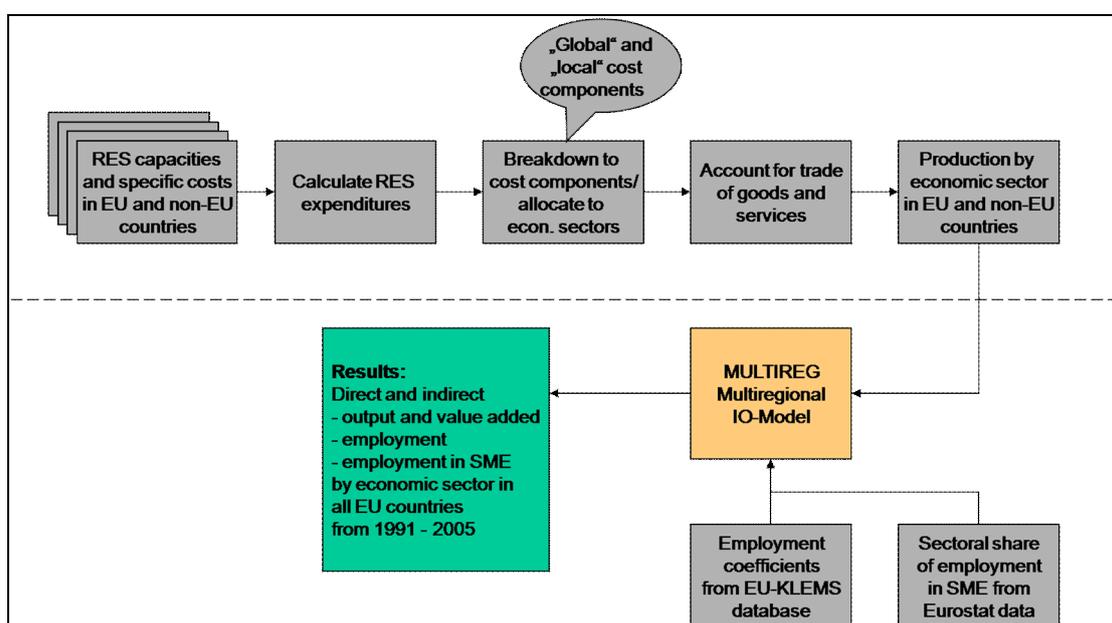


Figure 10: Overview of the modelling steps realised in the EMPLOY RES project (Ragwitz et al. 2009)

The MULTIREG model covers all the EU Member States and their main trade partners. It projects trade between the EU 27 and the rest of the world on a disaggregated, multi-sector level distinguishing 41 sectors. To calculate employment effects, the model is extended by sector- and country-specific employment data including working hours, employment as well as labour productivity and labour costs. These data are taken from the EU KLEMS database (EU Klems 2008). The EUROSTAT data on small and medium sized enterprises (SME) is another database used by MULTIREG in order to determine the economic impact of RES expansion on SMEs.

As a basis for the macroeconomic modelling, different scenarios of future global RES markets are defined. The scenarios depend on: (1) The deployment of RES technologies within the EU; (2) the deployment of RES in the rest of the world as well as (3) the world market shares of European economies, and the export shares. Different projec-

tions are derived for each element resulting in five scenarios. In this way, RES development within the EU is outlined in different policy scenarios according to GREEN-X. The deployment of RES in the rest of the world is derived from the IEA World Energy Outlook scenarios (International Energy Agency 2007). Based on the present world market shares, three projections are made for the future RES-related export shares of the European economies. In this study, the ADP-ME scenario is used, which assumes a “moderate export share” and an “accelerated RES deployment policy” combined with the “IEA Alternative Scenario” (Ragwitz et al. 2009, p. 126).

For a detailed description of the scenarios and the methodology, see Ragwitz et al. (2009).

2.2 Methodology used in this paper

In this paper, the gross employment effects are calculated based on the modelling work described above as well as on the INVERT results presented in chapter X.XX. Thus, two approaches are adopted which are referred to as *top-down* and *bottom-up* in the following. The top-down approach conforms to the *EmployRES* method using Green-X results. The bottom-up approach applies the INVERT results in order to evaluate the different policy sets in terms of employment effects.

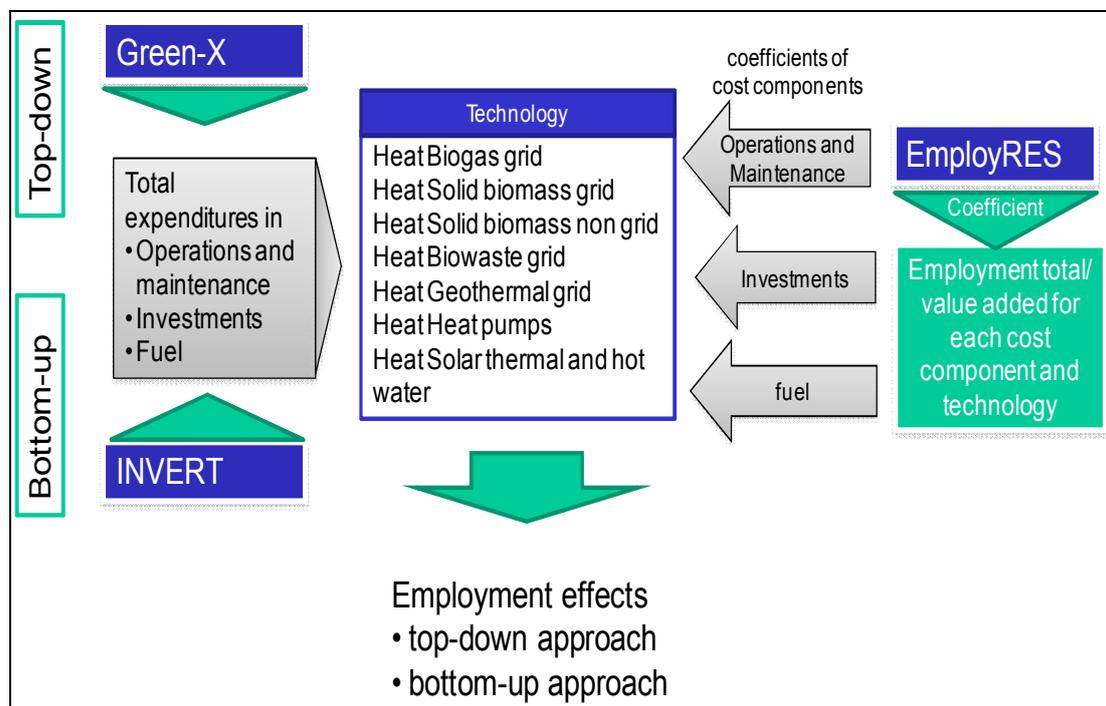


Figure 11: Calculation of employment effects with a top-down and bottom-up approach

Therefore, technology-specific employment coefficients are derived from the *EmployRES* results for each cost component – investments, operations maintenance and

fuel expenditures. The coefficients express the ratio of employment in full time equivalents (fte) to value added (million euro) for each RES-H reference technology. The total gross employment effects are calculated by multiplying the coefficients by the corresponding costs, or by the revenues of RES-H deployment, respectively (*Figure 11*). In the case of the *bottom-up* approach, the related costs are provided by the INVERT model. Since the specific employment coefficients account for future change in productivity, overall employment effects are likely to decrease in the future; even if there is a further expansion of RES-H.

2.3 Results

2.3.1 Bottom-up results for Policy Set 1 based on INVERT

The policy is as described in section 1.2.1.

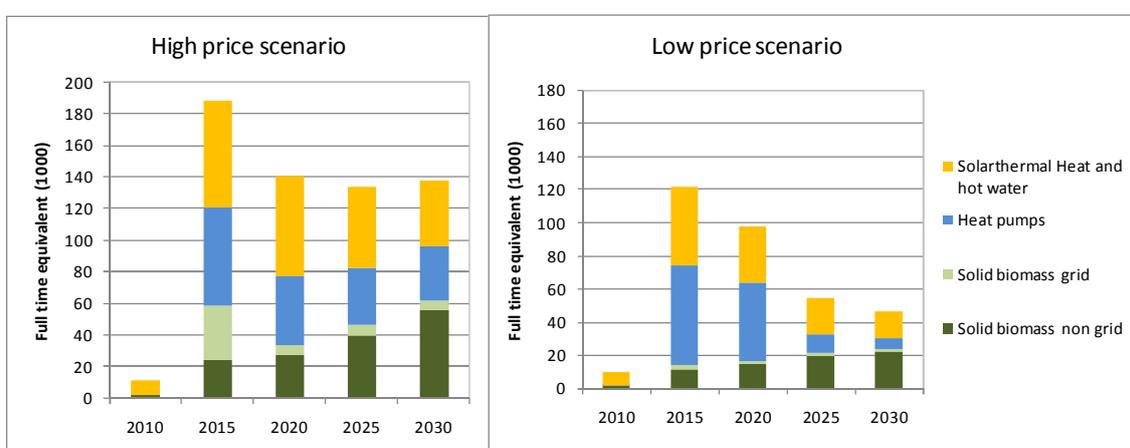


Figure 12: Annual employment effects 2010 to 2030, high energy price scenario (left) and low energy price scenario (right)

It is apparent that adoption of the RHI from 2011 (as proposed in the RHI consultation document (DECC 2010) would see a sharp increase in employment up to 2015, as companies gear up for installation and demand increases sharply. It is expected that the jobs associated with installation will then drop off in as companies become more proficient and the amount of full-time equivalent jobs associated with installing a particular capacity of RES-H/C devices reduces. The initial increase in jobs is predicted to be higher in the case of the high price scenario, reflecting the more rapid uptake of RES-H in circumstances where the alternative is more expensive. It is notable that while a decline follows a 2015 peak in employment, this occurs at a considerably lesser rate in the high price scenario than in the low price scenario.

2.3.2 Bottom-up results for Policy Set 2 based on INVERT

The policy is as described in section 1.2.2.

The second policy set produces a much more sustained rate of employment in both the low price and high price scenarios, reflecting that the mechanism effectively compels

significant levels of changeover, even where this might not be economic in all cases. It can be noted that the difference in the total level of employment is much less in the two scenarios for the second policy set, for similar reasons.

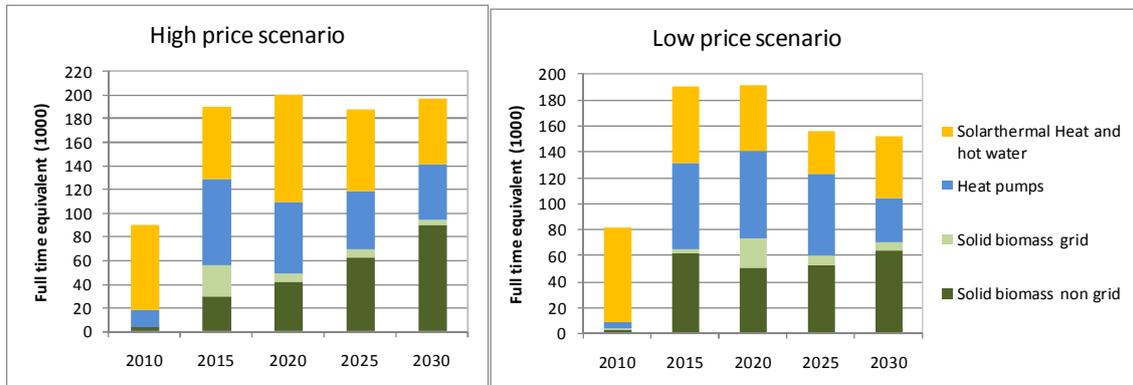


Figure 13: Annual employment effects 2010 to 2030, high energy price scenario (left) and low energy price scenario (right)

2.3.3 Comparison of top-down results and bottom-up results

Figure 14 show a comparison of the employment estimates for the two policy sets in both high and low price scenarios.

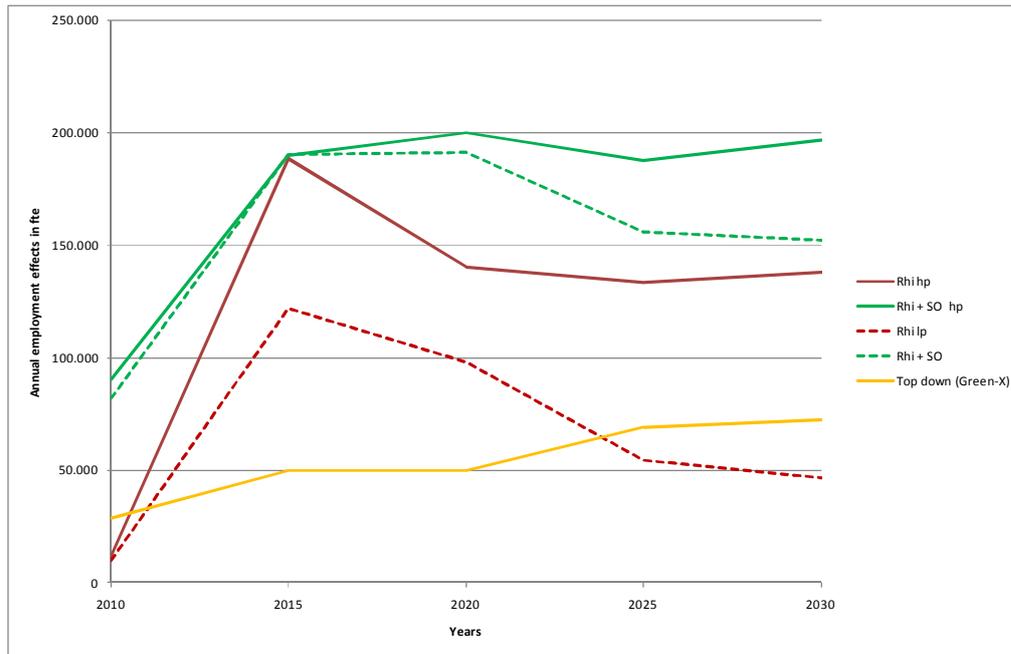


Figure 14: Overview of bottom-up results for all policy sets as well as top-down results

It applies the top-down Green-X model as a check against the validity of the bottom-up INVERT model presents significant variations in results. As noted, the higher results for policy set 2 again reflect that it is additional to policy set 1.

It is notable that the Green-X results trail significantly behind the Invert model outputs, and additionally have a different profile, with a steady increase in employment under the former, and a 2015 peak followed by a decline at different rates. However, it must be noted that the Green-X results were preliminary and apply a grant subsidy policy instrument, which was rejected for modelling under INVERT as a result of stakeholder consultation in the UK. Thus in this instance there is little value to this comparison.

3 Transaction costs

3.1 Methodology

Transferring the general concept behind the term "transaction costs" to policy instruments that aim at motivating, incentivising or obliging people to use renewables for space heating or warm water production, such costs involve several elements:

- Search and information costs: E.g. costs for building owners for gathering information about funding options or requirements/compliance options, about the best technical solution in a specific environment etc.
- Implementation costs: In most cases the main part of the implementation costs consists of the differential costs that reflect the cost difference between the renewable (e.g. solar collector) and a reference (e.g. gas boiler) option (including e.g. capital costs, installation costs, maintenance, fuel costs). If subsidies are involved, they would also belong to the implementation costs. In our project these costs are partly determined by our modelling activities (e.g. avoided fuel costs, required volume of a public subsidy scheme in order to achieve a certain target, see above). But also the costs that incur households for filling in applications to a funding programme, costs for involving authorised experts for e.g. confirming that certain technical requirements are met would fall under this category.
- Public administration costs: E.g. costs that arise public authorities or experts who act on behalf of a public authority from the execution of a political measure (e.g. for administering a use obligation or a subsidy scheme). The costs for such an enforcement scheme typically rise with the complexity of an instrument and the degree to which different levels of administration are involved.

Our quantitative assessment of transaction costs focuses on the public administration costs. These involve mainly the costs that incur authorities for executing a support program. Public administration costs are an important element in the discussion about policy instruments as

- often an estimation of the expected public administrative costs needs to be reported to the policy sector before adopting a regulatory norm for implementing a new instrument
- generally public administrative costs have to be covered by public budgets

Costs that incur the private sector (e.g. the costs linked to filling in applications, gathering information about funding options or requirements/compliance options, involvement of experts) have only be determined qualitatively.

Regarding the RHI the values reflect the number of the yearly supported heating systems under the RHI, and since the RHI is an element of both policy sets then this applies across both policy sets and in each scenario.

- Policy Set 1: This policy set is concerns the RHI only, and the total costs reflect more or less the administration work done in support of providing eligible applicants with the appropriate subsidy.
- Policy set 2: RHI plus supplier obligation. This combination requires additional work load would occur, largely stemming from increased oversight of supply companies that would be required. This might include controlled and random inspections in households where installations have been supported and which are now eligible for support. It has proven difficult to produce a model which produces meaningful results for the supplier obligation.

3.2 Assumptions

Public administration costs were estimated for both modelled policy sets. This estimation was based on some basic assumptions for each of the assessed policy sets. The following parameters and instrument design features have been considered.

The Renewable Heat Incentive

The main input figure is the total number of RES-H/C installations support cases that apply for payments under the RHI each year and thus have to be dealt with by the executing authority. A distinction must be made between small scale and large scale installations. Whereas for small scale installations funding applications usually can be processed in a rather straightforward way, processing large scale installations might require a case to case assessment. We initially assumed that an administrative worker might be able to carry out the paperwork for 16 small transactions per day or 1 large transaction per day. Following consultation with stakeholders at the UK's Department of Energy and Climate Change (DECC) experienced in costing, these figures were changed to 30 small transactions per day or 0.5 large transactions per day.

To assess the costs associated with these transactions, we assumed staff costs of €40,000p.a.; this assumption was confirmed as reasonable via stakeholder consultation with DECC.

For the building sector the number of support cases results from the INVERT model runs (see above). Here it must be noted that INVERT distinguishes between 'small scale' and 'medium to large scale' installations. Medium to large scale installation encompass all installations in buildings with more than three apartments as well as buildings connected to district heating (with the assumption of one DH-installation per 50 buildings). Thus especially for large scale installations the "number of processed support cases per day and staff at the executing authority" has been estimated accordingly.

Other assumptions: The assumptions made concerning the RHI are informed by DECC's 2010 RHI consultation document and are laid out in section 1.2.1 of this report. More detailed assumptions are laid out in section 6.

RHI + Supplier Obligation

The main input figure is the total number of cases per year in which the supplier obligation has to be fulfilled and thus has to be dealt with by the executing authority. As with

the RHI alone, a distinction must be made between small-scale and large-scale installations and we have made an assumption in favour of a similar rate for administrative processing. For the building sector the number of support cases results from the INVERT model runs (see above). Here it must be noted that INVERT distinguishes between 'small scale' and 'medium to large scale' installations. Medium to large scale installation encompass all installations in buildings with more than three apartments as well as buildings connected to district heating (with the assumption of one DH-installation per 50 buildings). Thus especially for large scale installations the "number of processed obligation cases per day and staff at the executing authority" has been estimated accordingly.

The assumptions made concerning the RHI + SO are informed in the first instance by DECC's 2010 RHI consultation document as laid out in sections 1.2.1, 1.2.2 and in section 6 of this report, and extrapolated from the current operation of the Carbon Emission Reduction Target policy instrument currently in use in the UK.

As with the RHI alone, oversight would rest with the UK energy regulator, Ofgem.

It is possible that applying an SO alongside the RHI in this manner would require additional checks of installations and performance, in line with auditing of the Carbon Emissions Reduction Target as it is currently applied but there is little data to guide assumptions in this regard and we are thus reporting costs based on administrative oversight of payments based on the higher uptake that the second policy set would drive.

Non-compliance with the compulsory element of the applied Supplier Obligation would be based in the current methodology for dealing with compliance related to the Carbon Emissions Reduction Target with Ofgem having the power to issue penalties as deemed appropriate. (Ofgem 2009)

3.3 Results

Figure 15 presents the modelled transaction costs for both policy sets in both pricing scenarios.

As would be expected, the transaction costs for the second policy set are higher as a result of the compulsory element of that set. This represents the biggest distinction between the transaction costs in the four cases to be considered. The differences applicable to policy set 2 in the two different price scenarios are relatively small. The differences for policy set 1 in the two pricing scenarios starts small and grows more distinct, differentiating it from the comparative behaviour of the policy set 2 outputs.

Considering the RHI only, the models suggest that over time transaction costs declines significantly as a fraction of total RHI costs. Starting from 2011 (taken as the initial year in these model runs) transaction costs dip from around 0.75-0.80% of total RHI costs to a point where they account for only 0.15% of total transaction costs by 2030. This represents a huge comparative cost reduction and this level of transaction cost provides another justification of the RHI as a key mechanism for the support of RES-H in the UK.

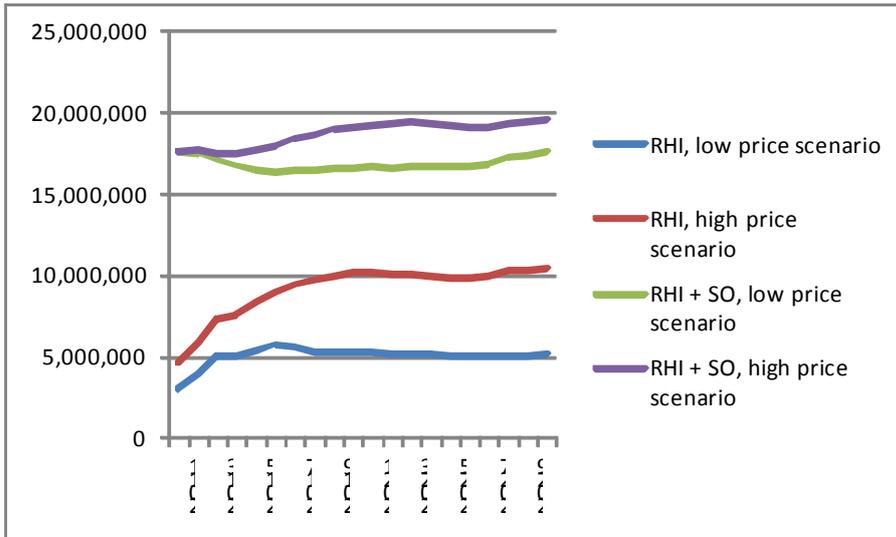


Figure 15: Transaction costs for both policy sets in both energy price scenarios

4 References

- Biermayr, P., Cremer, C., Faber, T., Kranzl, L., Ragwitz, M., Resch, G., Toro, F., 2007. Bestimmung der Potenziale und Ausarbeitung von Strategien zur verstärkten Nutzung von erneuerbaren Energien in Luxemburg. Endbericht im Auftrag des Ministeriums für Energie.
- Capros, P., L. Mantzos, et al. (2008). Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables. Athens, E3MLab/NTUA
- Connor, P. (2010). Documentation of consultation process on the proposed 2020/2030 RES-H targets in the United Kingdom. Penryn. A report prepared as part of the IEE 'RES-H Policy' project.
- DECC, 2009. Consultation on Renewable Electricity Financial Incentives 2009. Department of Energy and Climate Change. London.
- DECC (2010). Renewable Heat Incentive Consultation on the proposed RHI financial support scheme. Department of Energy and Climate Change, London.
- EU Klems. 2008. "EU KLEMS Growth and Productivity Accounts: March 2008 Release." Productivity in the European Union: A Comparative Industry Approach (EU KLEMS2003) funded by the European Commission, Research Directorate General <http://www.euklems.net/index.html> (Accessed March 24, 2010).
- Haas, R., Müller, A., Kranzl, L., 2009. Energieszenarien bis 2020: Wärmebedarf der Kleinverbraucher. Ein Projekt im Rahmen der Erstellung von energiewirtschaftlichen Input-parametern und Szenarien zur Erfüllung der Berichtspflichten des Monitoring Mechanisms. Im Auftrag der Umweltbundesamt GmbH. Wien.
- International Energy Agency. 2007. *World Energy Outlook 2007: China and India, Insights: India and China Insights*. 1. ed. Organization for Economic Co-operation and Development (OECD).
- Kranzl, L., Stadler, M., Huber, C., Haas, R., Ragwitz, M., Brakhage, A., Gula, A., Figorski, A., 2006. Deriving efficient policy portfolios promoting sustainable energy systems—Case studies applying Invert simulation tool. *Renewable energy* 31, 2393–2410.
- Kranzl, L., Brakhage, A., Gürtler, P., Pett, J., Ragwitz, M., Stadler, M., 2007. Integrating policies for renewables and energy efficiency: Comparing results from Germany, Luxembourg and Northern Ireland., in: . Presented at the eceee 2007 summer study, La colle sur Loup, France.
- Müller, A., 2010. Hat Heizen zukunfft? Eine langfristige Betrachtung für Österreich., in: . Presented at the Symposium Energieinnovation, Graz.
- Nast, M., Leprich, U., Ragwitz, M., Bürger, V., Klinski, S., Kranzl, L., Stadler, M., 2006. Eckpunkte für die Entwicklung und Einführung budgetunabhängiger zur Marktdurchdringung erneuerbarer Energien im Wärmemarkt“ Endbericht. Im Auftrag des deutschen Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit.

Ofgem (2009). Carbon Emissions Reduction Target (CERT) 2008-2011 Supplier Guidance - Version 2. London, Ofgem

Pöyry/Faber Maunsell (2009). The Potential and Costs of District Heating. London, Department of Business, Enterprise and Regulatory Reform.

Ragwitz, Mario et al. 2009. "EmployRES The impact of renewable energy policy on economic growth and employment in the European Union Final report." *European Commission, DG Energy and Transport*.

Resch, G., Panzer, C., Ragwitz, M., Faber, T., Huber, C., Rathmann, M., Reece, G., Held, A., Haas R. (2009): Scenario report "20% RES by 2020 – Scenarios on future European policies for RES-Electricity". Report of the European research project futures-e, Energy Economics Group (EEG), Vienna University of Technology, Austria

Schriefl, E., 2007. Modellierung der Entwicklung von Treibhausgasemissionen und Energieverbrauch für Raumwärme und Warmwasser im Österreichischen Wohngebäudebestand unter Annahme verschiedener Optimierungsziele.

Speirs, J., R. Gross, et al. (2010). Building a roadmap for heat: 2050 scenarios and heat delivery in the UK. London, CHPA.

Stadler, M., Kranzl, L., Huber, C., Haas, R., Tsioliaridou, E., 2007. Policy strategies and paths to promote sustainable energy systems—The dynamic Invert simulation tool. *Energy policy* 35, 597–608.

Xie, L. & Connor, P., 2009. Description of selected RES-H/C support instrument options including their qualitative assessment for the United Kingdom. A report prepared as part of the IEE project.

Xie, L. & Connor, P., 2010. Policy development for improving RES-H/C penetration in European Member States. A report prepared as part of the IEE 'RES-H Policy' project.

5 Annex 1

5.1 Heat generation costs

The heat generation costs of the different technologies included in the INVERT modelling runs are shown in the two following figures. For each technology the bandwidth of the heat generation costs, which is due to decreasing specific investment costs with rising system sizes, is indicated for the years 2010, 2020 and 2030.

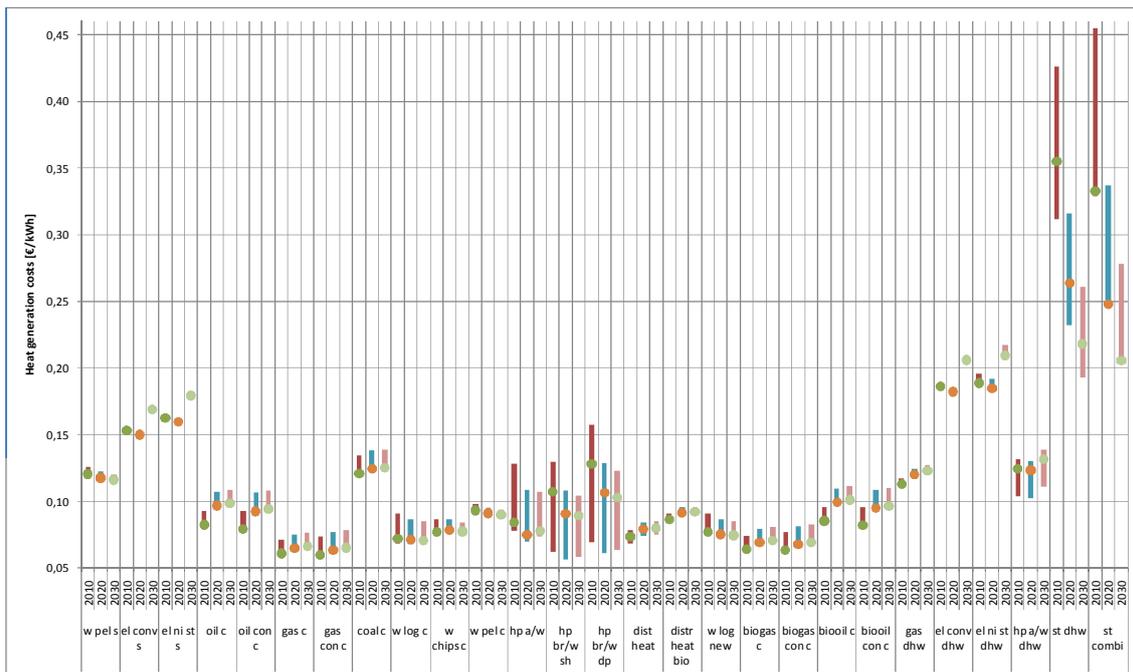


Figure 16: Range of heat generation costs in the building sector (low-price scenario)

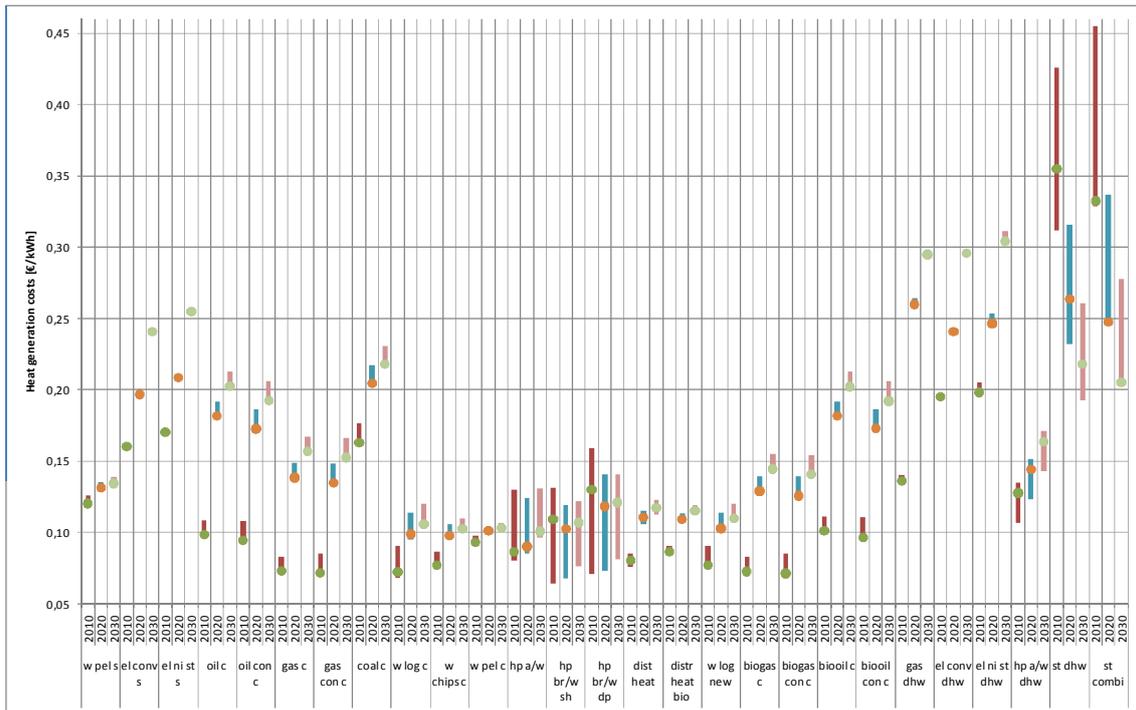


Figure 17: Range of heat generation costs in the building sector (high-price scenario)

w pel s	Pellets single
el conv s	Electrical converter single
el ni st s	Electrical night storage single
oil c	Oil central
oil con c	Oil condensing central
gas c	Gas central
gas con c	Gas condensing central
coal c	Coal central
w log c	Wood log central
w chips c	Wood chips central
w pel c	Wood pellets central
hp a/w	Heat pump air/water
hp br/w sh	Heat pump brine/water shallow
hp br/w dp	Heat pump brine/water deep
distr heat	District heating central

distr heat bio	District heat Biomass central
w log new	Modern wood log boiler
biogas c	Gas central (running with biogas)
biogas con c	Gas condensing central (running with biogas)
biooil c	Oil central (running with bio-oil)
biooil con c	Oil condensing central (running with bio-oil)
gas dhw	Gas boiler (Domestic hot water)
el conv dhw	Electrical converter single (Domestic hot water)
el ni st dhw	Electrical night storage single (Domestic hot water)
hp a/w dhw	Heat pump air/water (Domestic hot water)

6 Annex 2: Modelling assumptions

Growth of building stock from 2007 to 2030	10%
Decline in total final energy demand ² for space heating and hot water from 2007 until 2030	24%-26%
Interest rate	Residential: 5.2% Non-residential sector: 10.4% For a depreciation time of 15 years.
General preferences and barriers for heating systems and energy carriers	<ul style="list-style-type: none">• Very high barrier for coal heating systems due to comfort reasons• No wood log systems as new heating systems due to comfort reasons and lack of tradition• Moderate barrier for wood chips, wood pellets and biomass district heating systems due to lack of tradition and information• Small preference to install solar thermal systems.
Energy carrier change ³	<ul style="list-style-type: none">• High preference to keep the old type of heating system in case of district heating• High preference to keep the old type of heating system or switch to blendings with biogenous energy carriers in case of natural gas and heating oil• Strong barrier to switch from natural gas and heating oil to coal and biomass.• Moderate preference to keep the old type of heating systems for all other heating systems
Regional distinction	A distinction between urban and rural areas has been carried out: <ul style="list-style-type: none">• In urban areas biomass have a strong barrier, heat pumps a moderate barrier.• In rural areas district heating is not available (except biomass district heating).

² Final energy demand including solar thermal and ambient energy. This decline in energy demand takes place due to exogenously given thermal renovation and endogenously determined mix of more efficient heating systems.

³ These parameters determine to which extent people have a preference for a certain heating system depending on their old heating system that they were used to in the past.

Diffusion restrictions

- Moderate maximum diffusion restriction of pellets.
- Strong maximum diffusion restriction of other biomass heating systems
- Moderate maximum diffusion restrictions for natural gas and heating oil blending.
- Strong diffusion growth restriction for solar thermal systems due to low current market development.
- Moderate diffusion growth restriction for all other systems

7 Annex 3 Industry Modelling

The outputs of the Green-X model became available too late in the project process to be included in the stakeholder consultation. Details of the model with some initial outputs have been amended to the UK report here for reference purposes. (April 2011)

7.1 Modelling of industrial process heat using the RESolve-H/C model

The RESolve-H/C model⁴ consists of numerous consecutive steps, which can all be attributed to two main loops:

1. Determining the *realisable potential* of RES-H in industry, resulting in a time series of energy data for the selected renewable heat technologies
2. Determining the *penetrations* of RES-H in industry under various policy assumptions, resulting in a time series of energy data for the selected renewable heat technologies, expected policy and fuel expenses and impacts on CO₂-emission

These two loops will be briefly explained in the following sections.

7.2 Determining the realisable potential of RES-H in industry

This section describes the consecutive steps applied to evaluate the potential of renewable heating and cooling sources (RES-H/C) and technologies. Starting point for the modelling work is based on EU-wide data sources. The advantage is that the modelling can take place based on generic datasets combined with relatively few country-specific data (or assumptions when specific data are lacking). The result of the modelling train described in this annex is realisable potentials (or targets) for RES-H/C penetrations in industry.

In a few words, the modelling approach can be summarised as follows:

- A. Based on several data sources, non-electric and non-feedstock energy use in industry is decomposed into energy use per energy carrier, per temperature level and per industry subsector and extrapolated to the year 2030. A breakdown into the three required steps is provided in table 3, below (step 1 to 3).
- B. For the base year 2005, each of the abovementioned decomposed energy uses are assigned energy conversion technologies, based on statistical information. A breakdown into the two required steps is provided in table 3, below (step 4 and 5).
- C. By applying a series of substitution and exclusion rules, a set of constraints is compiled which indicates which share of the industrial energy use is available

⁴ The RESolve-H/C model has been designed by the Energy research Centre of the Netherlands (ECN).

for RES-H/C: the potential of target. A breakdown into the three required steps is provided in table 3, below (step 6 to 9).

An more detailed outline of the A to C described above is provided in the overview below:

A.	Calculate energy use per energy carrier, temperature level and industry subsector and extrapolation to 2030	Step 1: Energy use per energy carrier and per subsector Step 2: Future development of the industry subsectors Step 3: Decomposing heat demand into temperature levels
B.	Assign energy conversion technologies to historic final energy data (fuel use)	Step 4: Conversion technologies and efficiencies Step 5: Match existing biomass technologies to projections
C.	Apply a series of substitution and exclusion rules to find constraints to RES-H/C penetration	Step 6: Match RES-H/C technologies to temperature levels Step 7: Limiting the number of technologies Step 8: Define constraints to RES-H/C potential in industry Step 9: Amending the potential by applying expert's view

Table 3: Overview of the Industry Modelling Approach (part 1)

Firstly, the heat demand in process industry has been decomposed into temperature levels for heating and cooling requirements: five heating categories H1 to H5 have been defined, and three cooling levels C1 to C3. These temperature ranges then are to be matched to the RES-H/C technologies, as each renewable energy source for heating and cooling performs best in a window of temperature ranges. Table 4 below shows in general terms which RES-H/C technology can serve which temperature level.

Level	Temperature range	Biomass	Deep geothermal	Heat pumps	Solar thermal	Underground heat/cold storage
H5	Above 600°C	x				
H4	Between 200 and 600°C	x				
H3	Between 100 and 200°C	x	x		x	
H2	Between 65 and 100°C	x	x		x	
H1	Below 65°C	x	x	x	x	x
C3	Between +10 and +15°C			x	x	x
C2	Between -30 and +10°C			x		
C1	Below -30°C					
Losses	Several temperature levels					

Table 4: *Matching of RES-H/C technologies to temperature levels*

For heat pumps only heating is considered as defined by Article 5.5 in the Directive 2009/28/EC). The leading principle for filling out table 4 has been to use standard technology configurations, ready for uptake. Exotic configurations thus haven't been listed; for example concentrating solar thermal for the highest temperature level is not considered.

Applying a set of constraints (step 8) results in a 'realisable potential', corresponding to the terminology in the Green-X and INVERT modelling approach: it represents the maximum achievable potential assuming that all barriers can be overcome and all driving forces are active. The realisable potential quantifies in a time dependent manner to what extent renewables can penetrate in a sector.

The realisable potential takes into account the following limiting factors:

1. Constraints on fuel supply (mainly relevant for biomass technologies)
2. Constraints on equipment supply (relevant for all manufactured technologies)
3. Constraints on the demand side (relevant for most options; this regards for example maximum market growth rates and planning constraints)
4. Constraints because of competition (some technologies compete for delivering the same energy service)

The four above factors all limit the realisable potential. If required, experts may modify the resulting potentials (step 9).

This potential is then further reduced to calculate the penetrations under fuel price and policy assumptions (see next section).

7.3 Determining the penetration of RES-H in industry

Once the realisable potential has been defined, an additional constraint determines the extent to which renewable options effectively penetrate into the market. This means that on top of A to C as introduced in the previous section an item D can be defined:

- D. Applying a series of constrains in order to evaluate the price effect of substitution of non-renewable energy sources, policy measures, and stakeholder behaviour. A breakdown into the three required steps is provided in table 5 below (step 10 to 12).

D.	Add information that allows to simulate market behaviour from industrial stakeholders in RES-H/C investment decisions	<p>Step 10: Determine costs and benefits of renewables</p> <p>Step 11: Determine effects of policy measures</p> <p>Step 12: Project stakeholder behaviour</p>
----	---	---

Table 5: Overview of the Industry Modelling Approach (part 2)

The result of the series of A to D results in projected RES-H penetrations in process industry, and derived indicators such as required budget for investments and impact on CO₂-emission.

The profitability of investment in a renewable heat technology can be determined once the costs and avoided costs are known. For each possible investment, and Internal Rate of Return (IRR) is calculated. The IRR is a measure to compare the profitability of investments: the higher the internal rate of return for a project is, the more desirable it is to invest. The IRR represents the interest rate at which the net present value of all project costs (investment, fuels costs, operation and maintenance) of the investment equals the net present value of the benefits (avoided fuel costs, electricity sales (for CHP technologies)) of the investment. The cash flows are based on perfect foresight. Future energy prices are assumed to be known. Also subsidies, CO₂-costs, taxes, and exploitation subsidies can be taken into account.

Modelling policy measures can be performed for various (country-specific) options:

1. An investment subsidy of a certain percentage
2. An exploitation subsidy
3. Cheap loans

Implementing these measures will modify the cashflows and likewise the value of the IRR in every renewable energy project, making the generation of renewable energy ‘as perceived by the investor’ more profitable. Once a project becomes more beneficial, this impacts the internal rate of return, which is decisive in estimating the penetration for each technology.

The stakeholder behaviour, i.e. whether to invest or not in a renewable heat project, finally is modelled assuming penetration levels that match the anticipated level of the IRR based on an s-curve approach: the higher the IRR is, the more investments are being simulated and the higher the resulting penetration of renewable heating in industry will be. In this step all previous inputs have been considered.

7.4 Fuel price scenarios

An important aspect in modelling the penetrations of the renewable technologies is the fuel price assumed. This section presents the assumptions.

Two price scenarios have been used, based on PRIMES data and for some countries adjusted in order to match with country-specific projections. The scenarios are indicated by ‘moderate’ and ‘high’ price scenario.

A crucial determinant is the price of biomass. In the two price scenarios mentioned above relatively low biomass prices were used in both scenarios. It should be noted that in the case of the high price scenario, a decoupling between the fossil energy carriers and biomass can be observed.

The price developments are displayed below. Note that for the calculation processes the prices after 2030 are relevant as well; these have all been assumed equal to the prices for the year 2030.

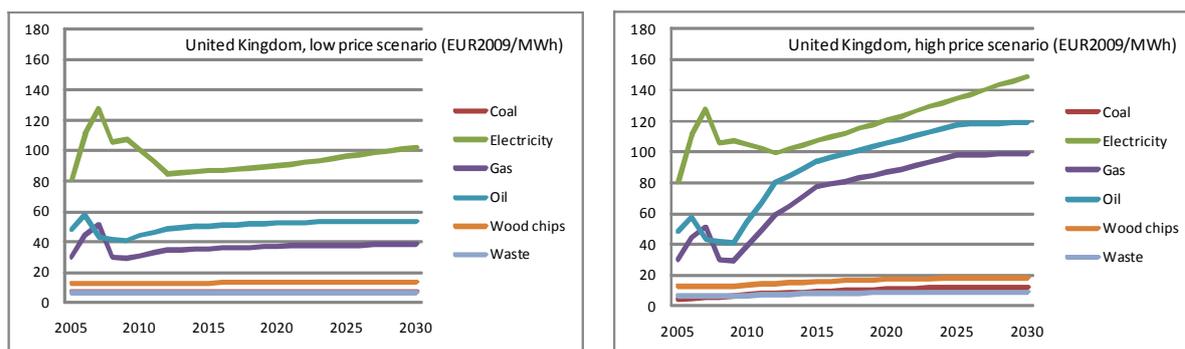


Figure 18: Fuel Price Scenarios, low energy price scenario (left), high energy price scenario (right) (Source: PRIMES)

Note that ‘waste’ prices are not available from PRIMES. In order to be able to model lower-quality and cheaper fuels, by default the price of waste is assumed to be half of the wood price. This can be changed for individual countries if experts suggest so.

Regarding the fuel prices the following remarks can be made.

- Fuel prices determine to a large extent the competitive force of renewables. Therefore, the outcomes of any modelling exercise is to be regarded in the light of the assumed inputs, notably the fuel prices.
- Comparing the projected prices of the various fossil energy carriers to the renewable energy carriers makes one issue crystal clear: even in the moderate scenario, the fossil fuel prices (especially electricity, oil and gas) in most countries are much higher than the biomass prices (wood, waste).
- It can be foreseen that the biomass technologies will be competitive because of the assumed fuel prices. In reality, the fuel price of biomass, and notably uncertain future development of it, makes that the biomass penetration might be overestimated.

In situations of biomass scarcity it is likely that the wood and waste fuel prices strongly increase. The current modelling environment assumes the prices to be fixed according (but varying between two price scenarios), which means that such dynamic behaviour cannot be modelled.

Simulating RHI in the UK industry sector

The RHI is an exploitation subsidy, providing a subsidy per energy unit generated for a range of renewable energy technologies. The tariffs have been implemented at the same level as published by DECC (shown in section 7.6).

The following sections highlight various types of output from the ECN industry model (RESolve-H/C).

Potential for RES-H/C in UK industry

The chart below indicates that the cumulative realisable potential of RES-H/C could amount to more than 90 PJ (25TWh) in 2030.

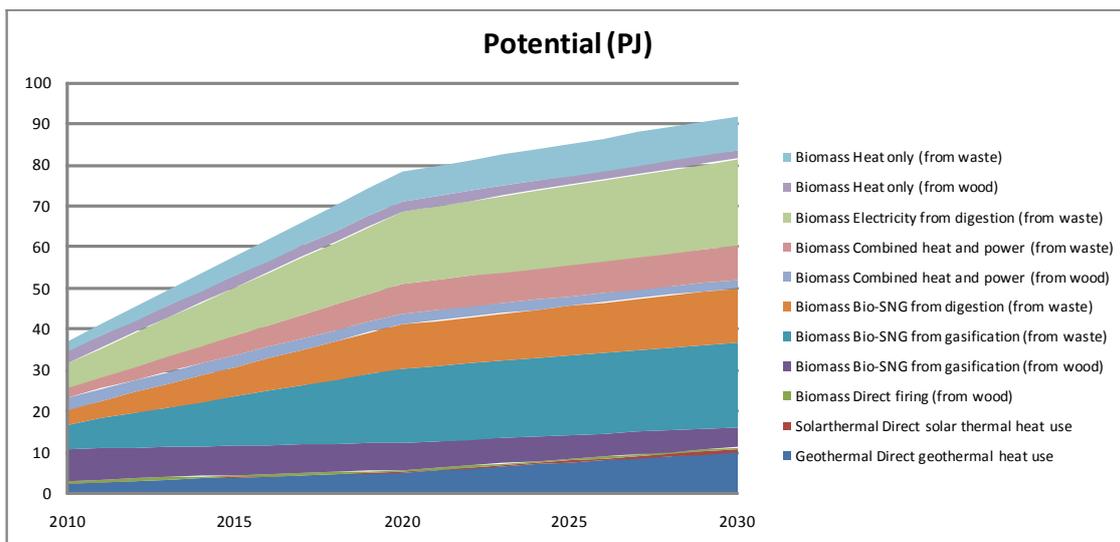


Figure 19: Overview of bottom-up results for all policy sets as well as top-down results

Cases available for RHI in UK

The following cases have been simulated and are presented in this document:

- Low price – no policy
- High price – no policy
- Low price – RHI implemented
- High price – RHI implemented

Low price – no policy

In the low fuel price scenario, the projected penetration is around 20 PJ (5.6 TWh) in 2020 and 25 PJ (7 TWh) in 2030.

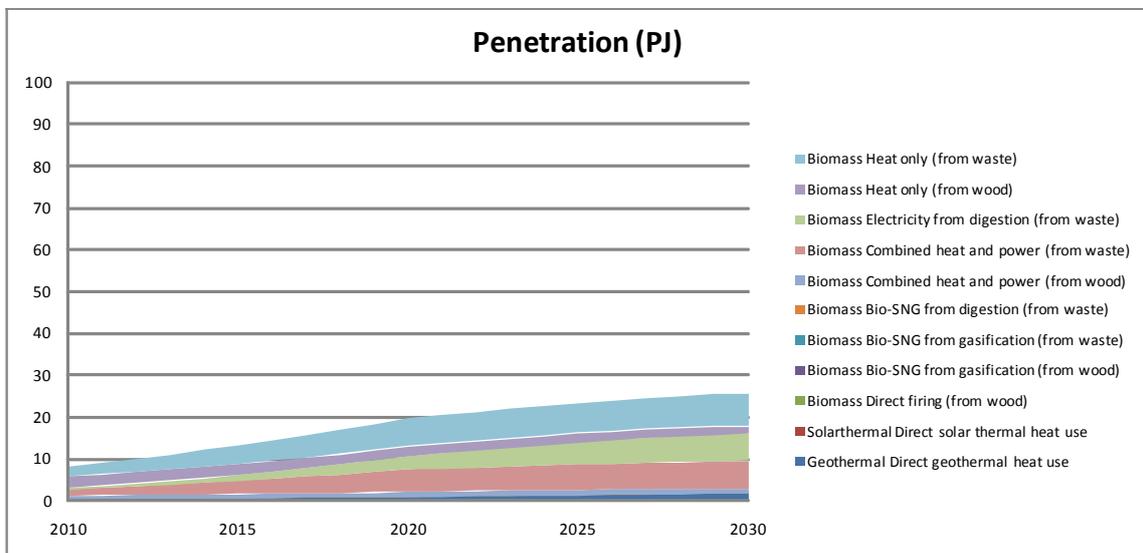


Figure 20: Penetration of RES-H into Industry, low energy price scenario, no RES-H Policy

Low price – no policy

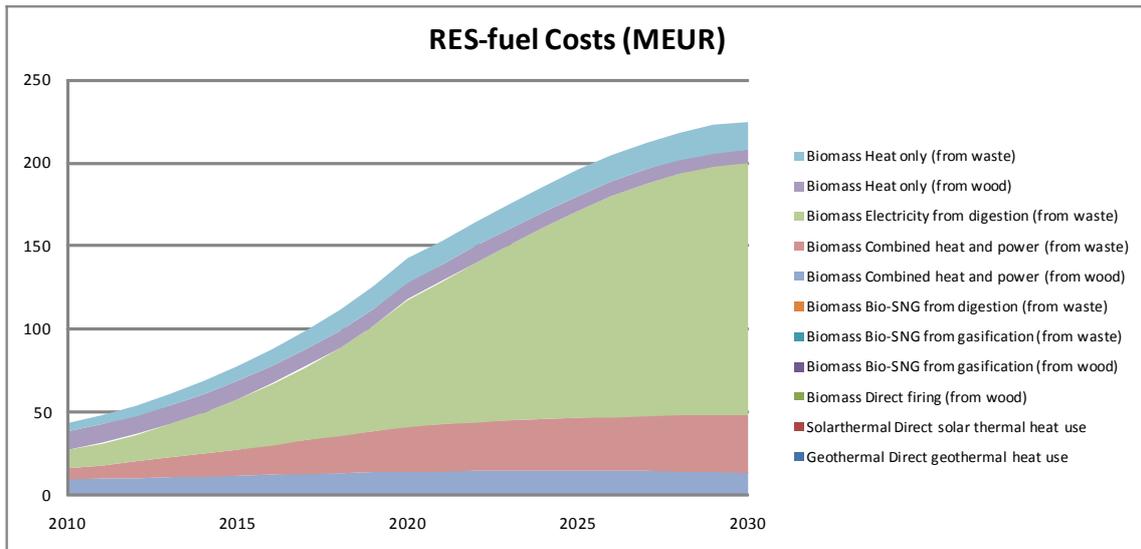


Figure 21: RES-H fuel costs, low energy price scenario, no RES-H Policy

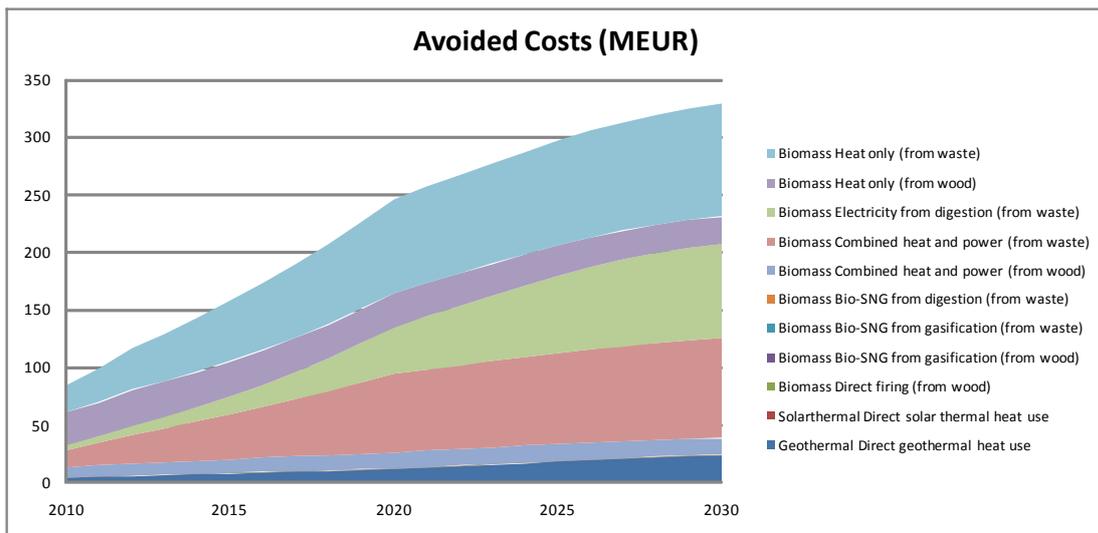


Figure 22: Avoided costs, low energy price scenario, no RES-H Policy

Low price – no policy

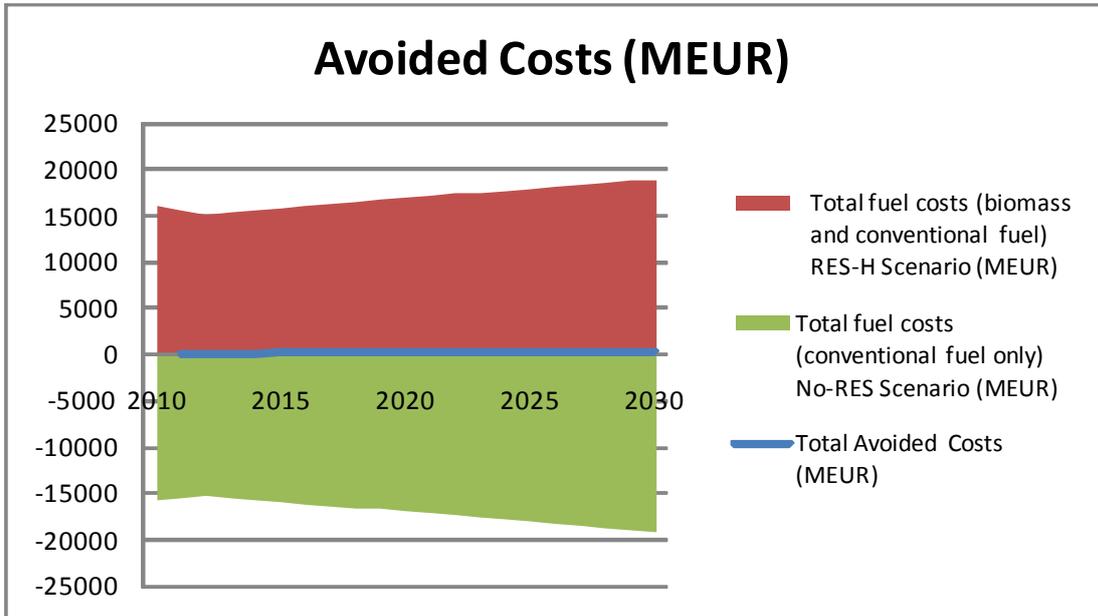


Figure 23: Net avoided costs, low energy price scenario, no RES-H Policy

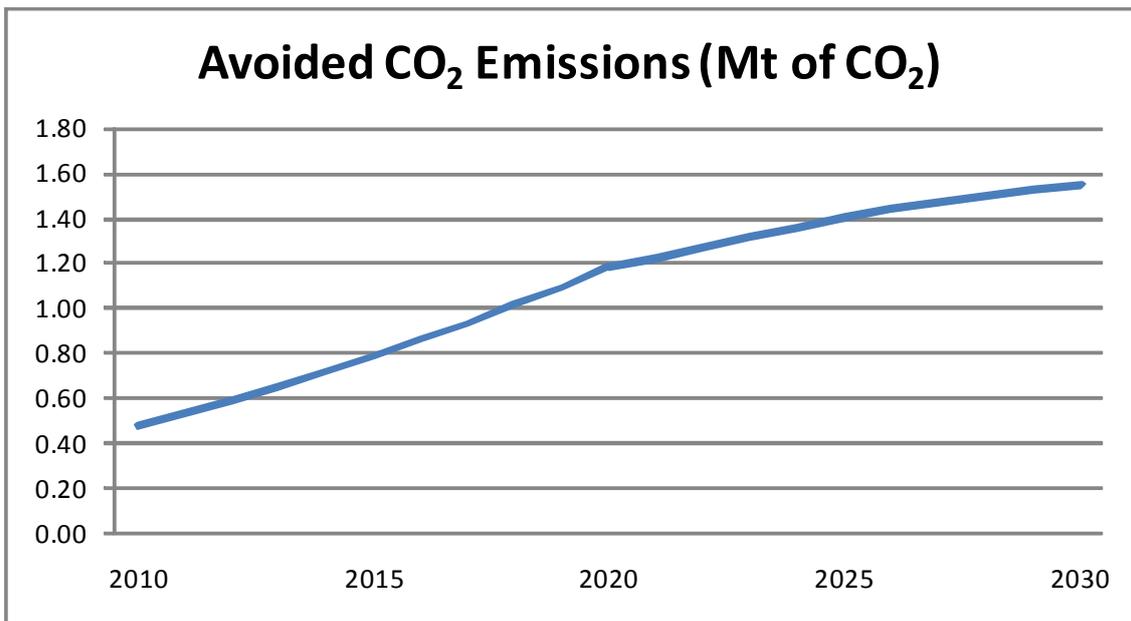


Figure 24: Avoided industry CO₂ emissions, low energy price scenario, no RES-H Policy

Low price – no policy

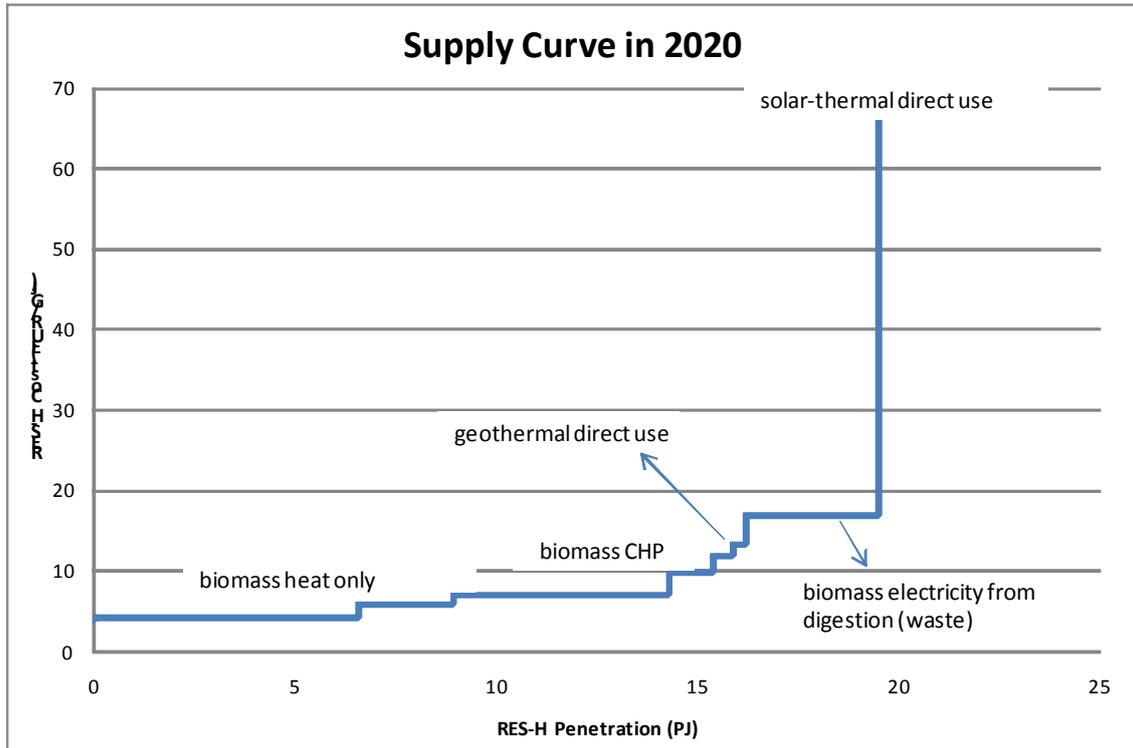


Figure 25: Industry supply curve in 2020, low energy price scenario, no RES-H Policy

High price – no policy

In the high fuel price scenario, the projected penetration is almost 40 PJ (11.1 TWh) in 2020 and almost 50 PJ (13.9 TWh) in 2030.

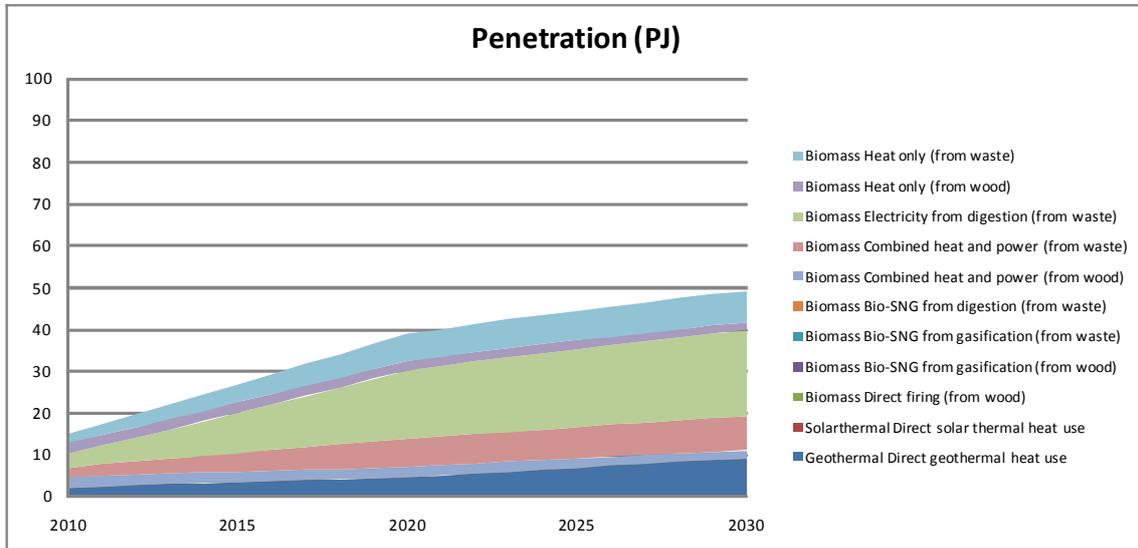


Figure 26: Penetration of RES-H into Industry, high energy price scenario, no RES-H Policy

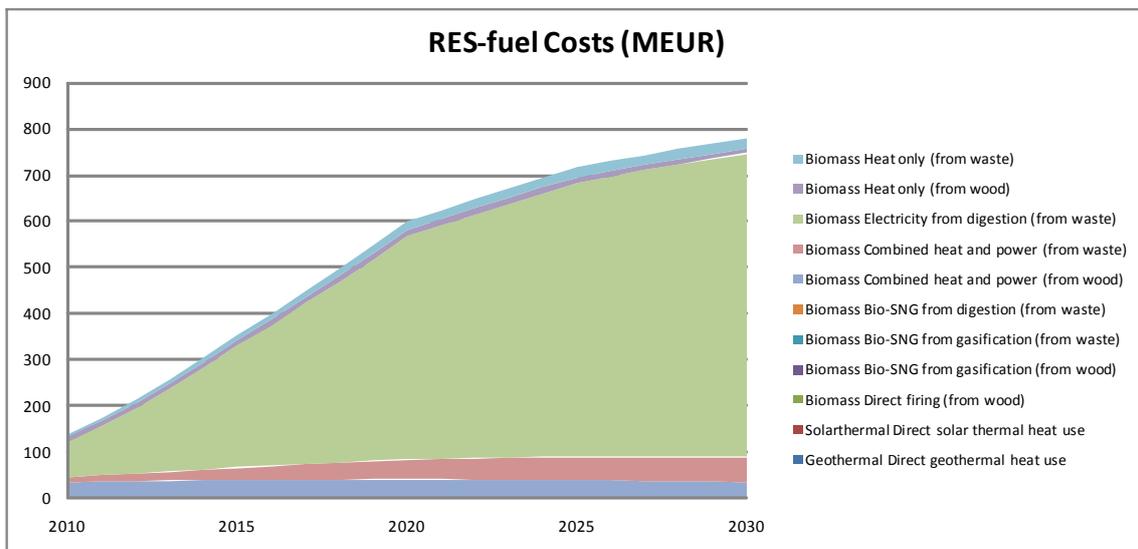


Figure 27: RES-H fuel costs, high energy price scenario, no RES-H Policy

It is clear that higher global (and thus national) energy prices, regardless of policy provision, will drive larger elements of industry to seek out RES-H options, as would be expected. The higher energy price scenario suggests roughly a doubling of generation from RES-H technologies.

High price – no policy

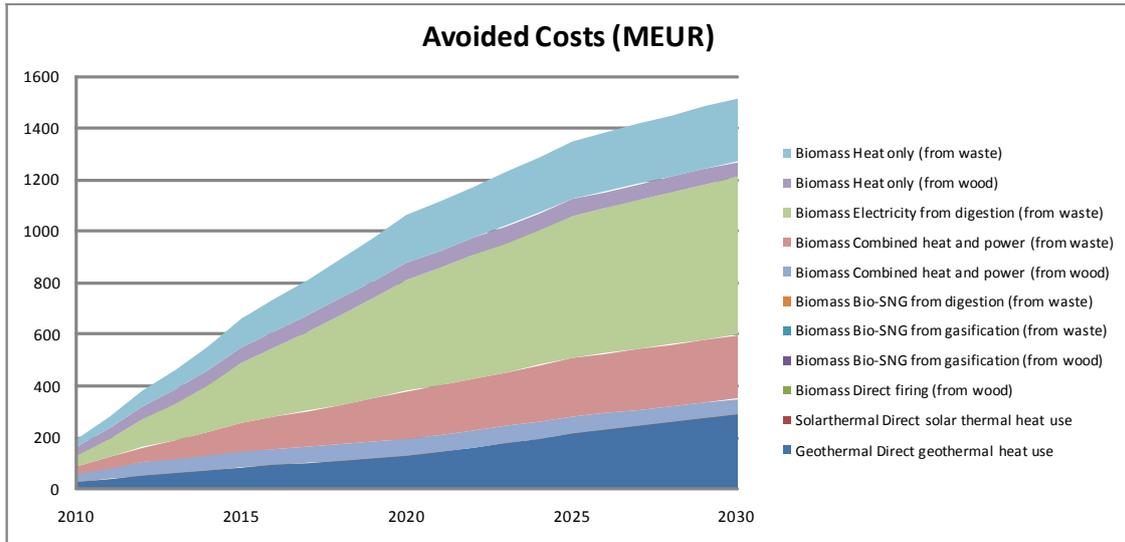


Figure 28: Avoided costs, high energy price scenario, no RES-H Policy

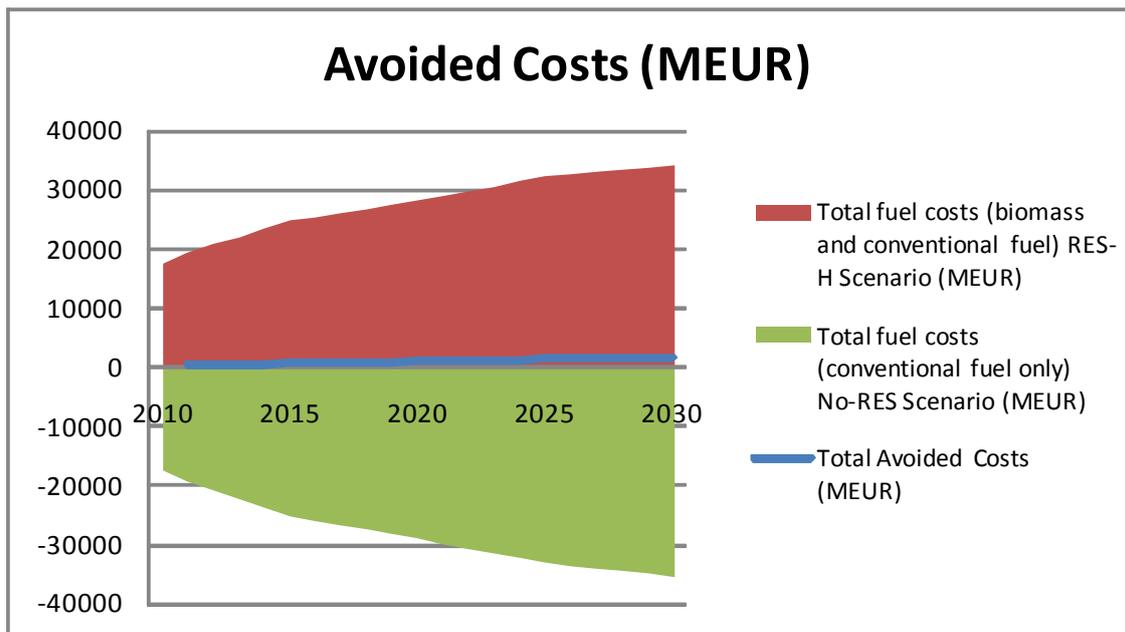


Figure 29: Net avoided costs, high energy price scenario, no RES-H Policy

Again as might be expected, the avoided costs benefit is greater under the high energy price scenario.

High price – no policy

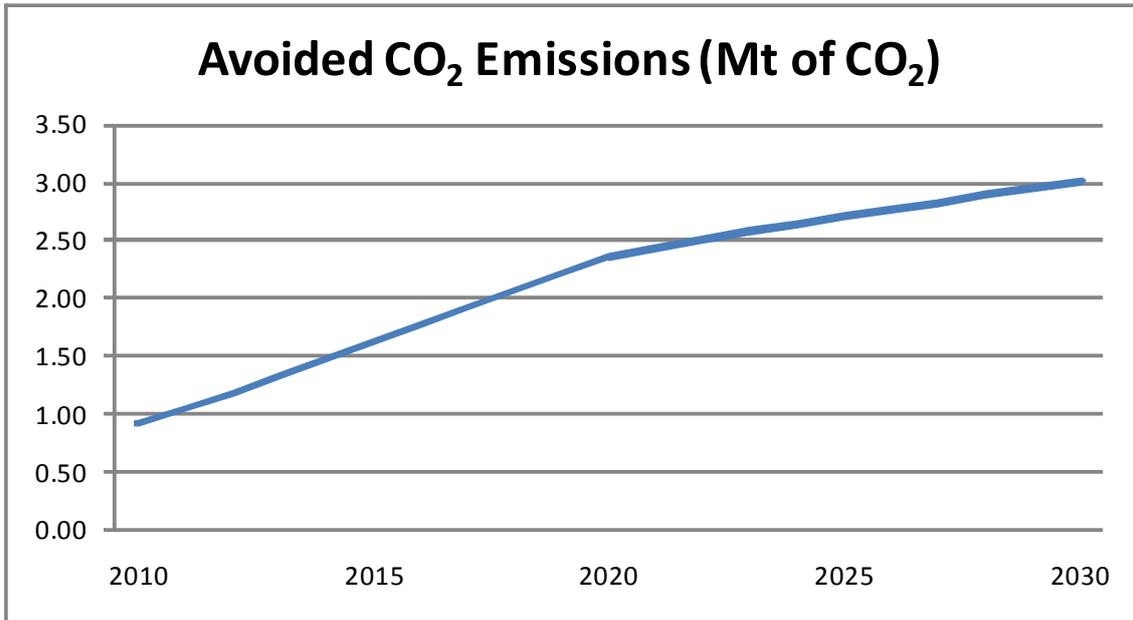


Figure 30: Avoided industry CO₂ emissions, high energy price scenario, no RES-H Policy

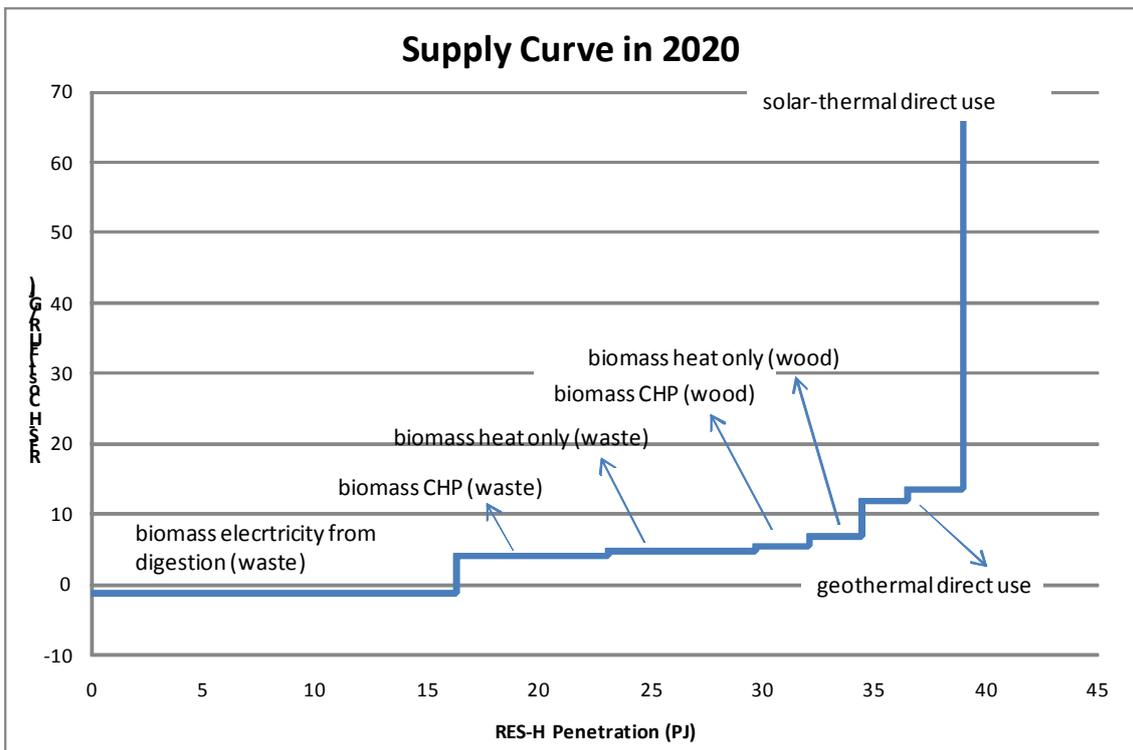


Figure 31: Industry supply curve in 2020, high energy price scenario, no RES-H Policy

Low price – RHI implemented

Implementing the RHI has the effect that projects become more beneficial for industrial parties, resulting in higher penetrations. The outcome of the simulation shows an increase, but still the projected penetration is less than in the ‘high price’ variant. In the low fuel price + RHI scenario, the projected penetration is approximately 27 PJ (7.5 TWh) in 2020 and almost 37 PJ (10.3 TWh) in 2030.

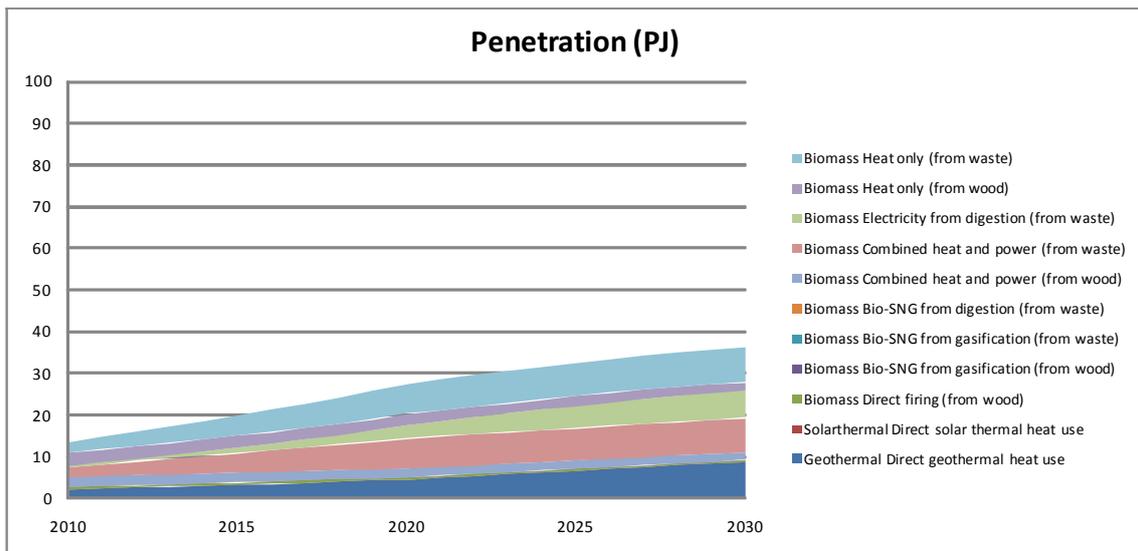


Figure 32: Penetration of RES-H into Industry, low energy price scenario, RHI implemented

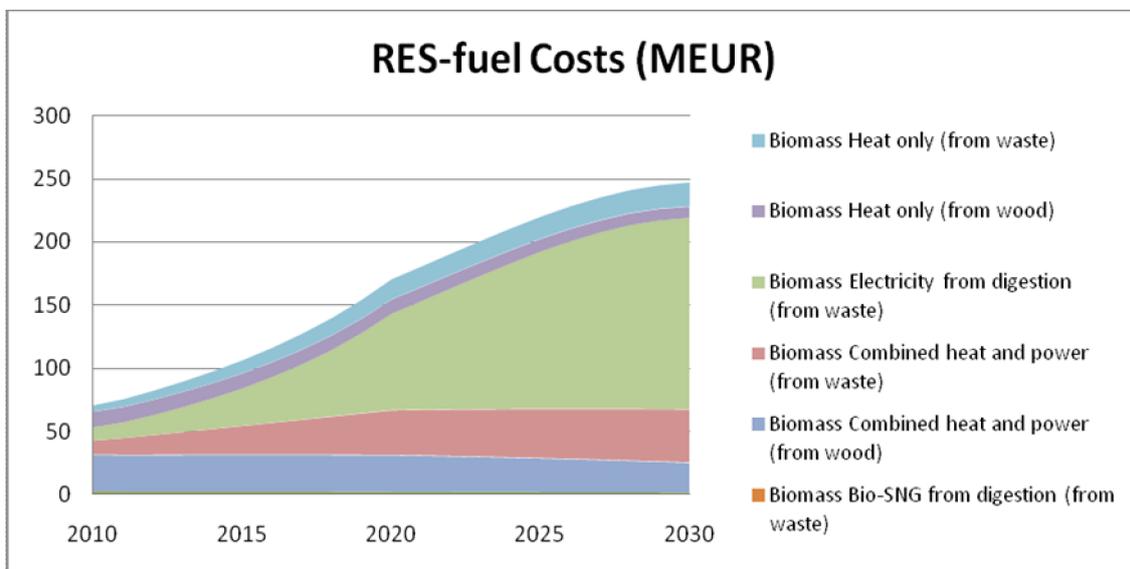


Figure 33: RES-H fuel costs, low energy price scenario, RHI implemented

Low price – RHI implemented

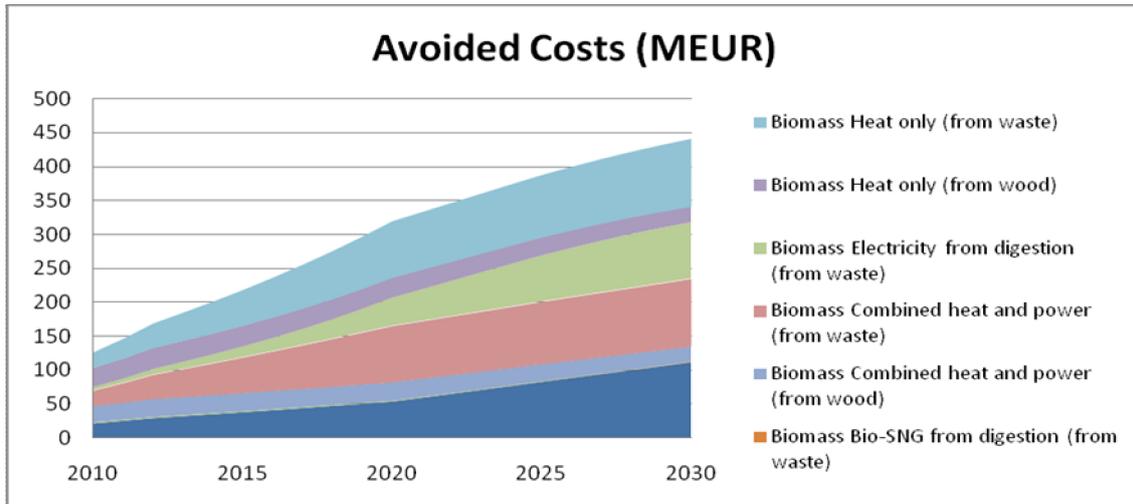


Figure 34: Avoided costs, low energy price scenario, RHI implemented

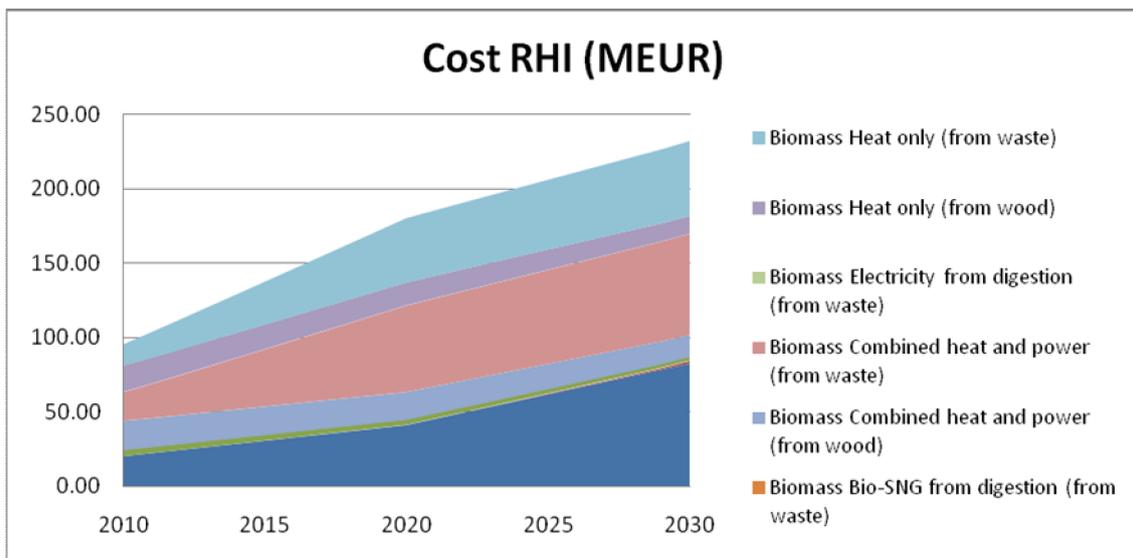


Figure 35: Cost of the RHI, low energy price scenario, RHI implemented

Low price – RHI implemented

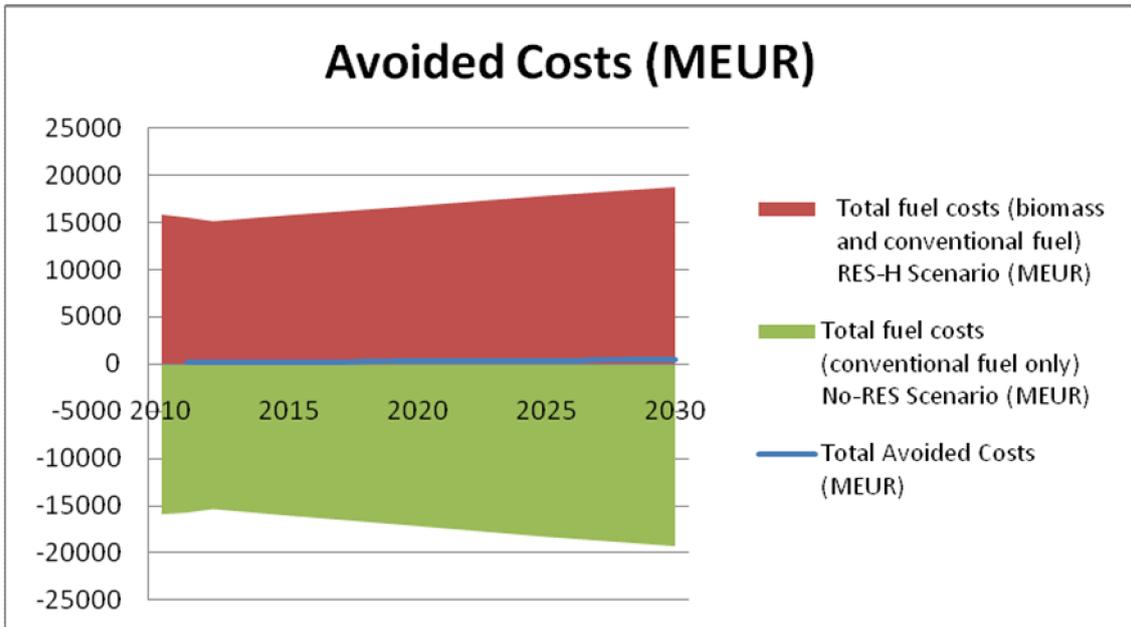


Figure 36: Net avoided costs, low energy price scenario, RHI implemented

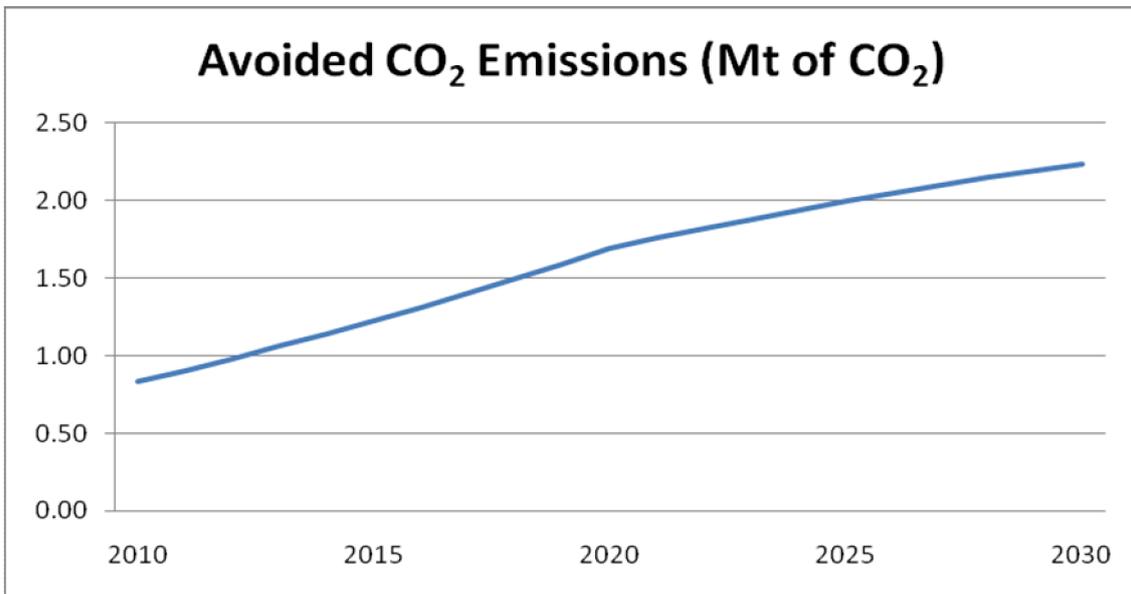


Figure 37: Avoided industry CO₂ emissions, low energy price scenario, RHI implemented

Low price – RHI implemented

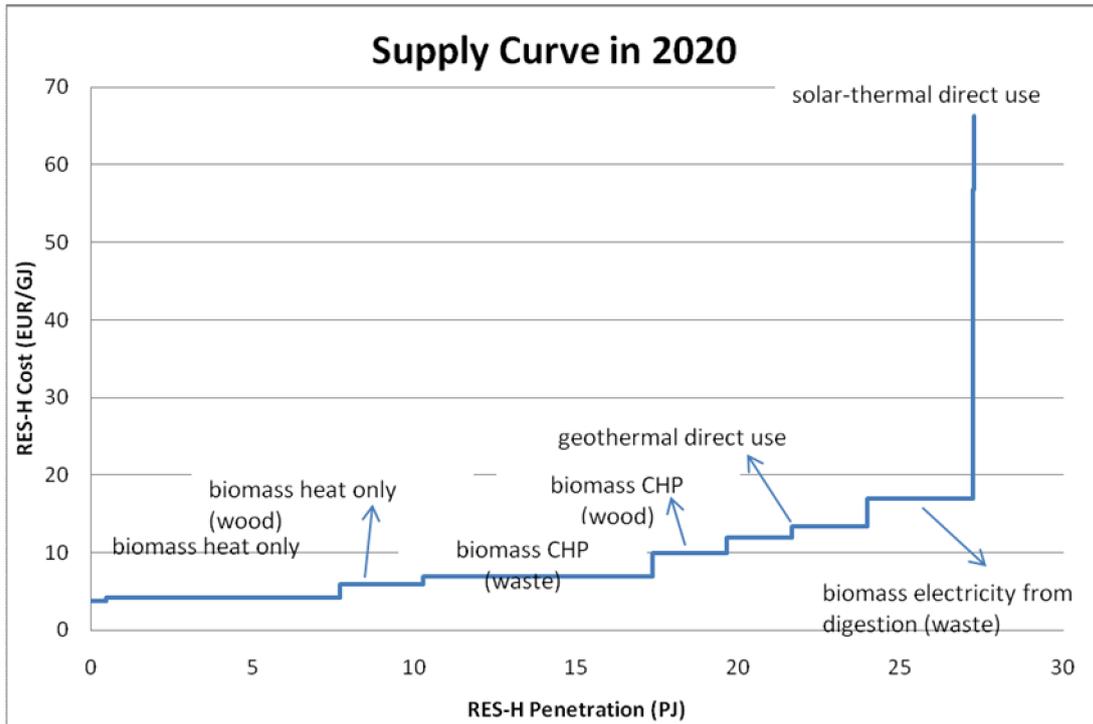


Figure 38: Industry supply curve in 2020, low energy price scenario, RHI implemented

High price – RHI implemented

Implementing the RHI has the effect that projects become more beneficial for industrial parties, but resulting in only slightly higher penetrations. The outcome of the simulation for the 'high price' variant shows only a minor increase, a slightly higher projected penetration than in the 'high price' variant. In the high fuel price + RHI scenario, the projected penetration is 41 PJ (11.4 TWh) in 2020 and almost 52 PJ (14.4 TWh) in 2030.

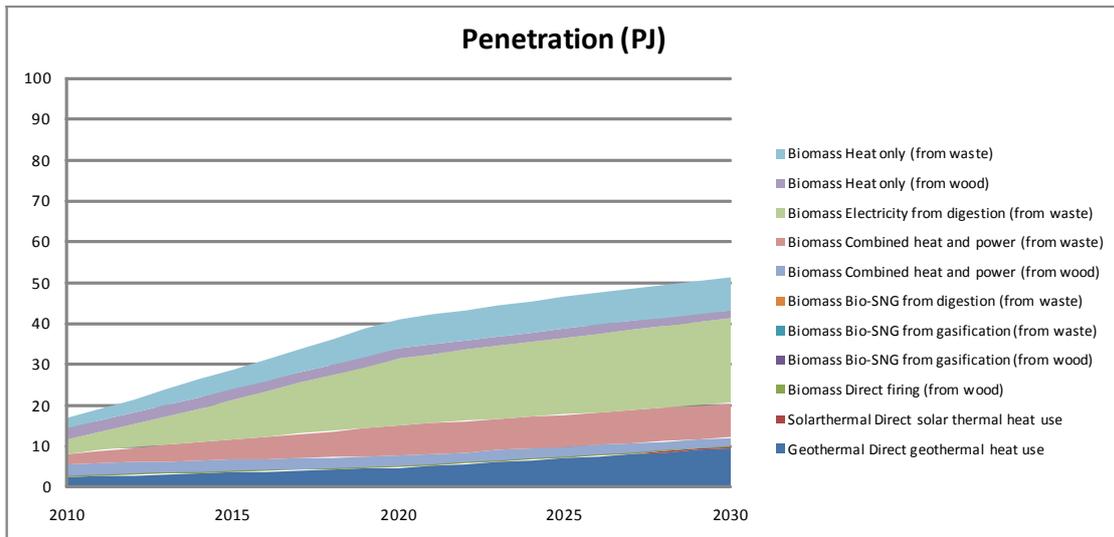


Figure 39: Penetration of RES-H into Industry, high energy price scenario, RHI implemented

It is apparent from our modelling that the application of the RHI has little impact on driving uptake of RES-H in the industry sector. In the high energy price scenario, the RHI is predicted to increase 2020 uptake of RES-H from 40PJ to 41PJ and to increase 2030 uptake from 50PJ to 52PJ. This suggests that much of the additional cost linked to the public funding of the RHI is not necessary if general energy prices are high. This is in line with the modelling for other countries carried out as part of the RES-H policy project. Essentially the models indicate that high energy prices alone drive exploitation of a large fraction of RES-H potential, leaving little scope for policy driven uptake.

High price – RHI implemented

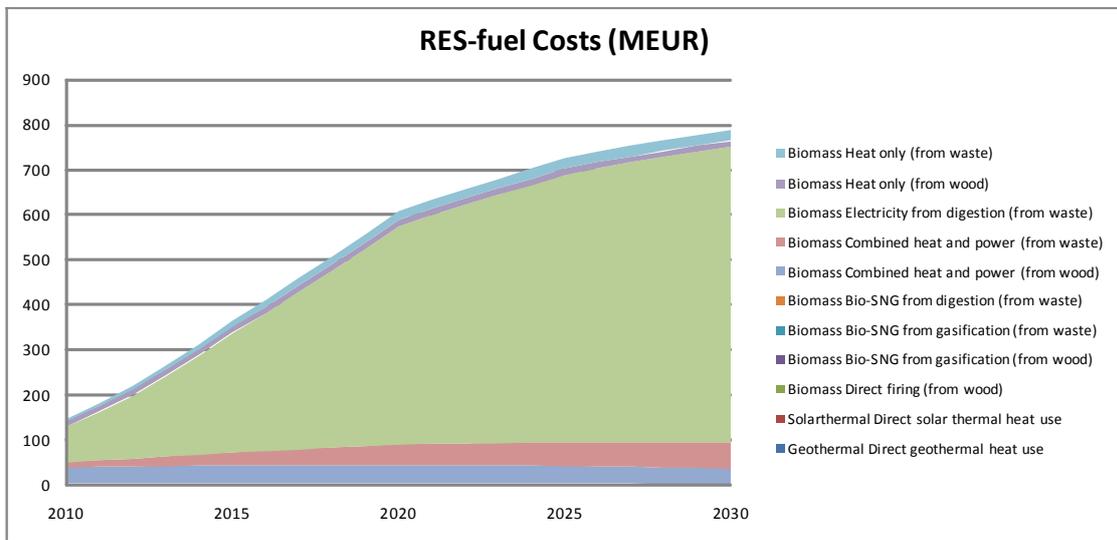


Figure 40: RES-H fuel costs, high energy price scenario, RHI implemented

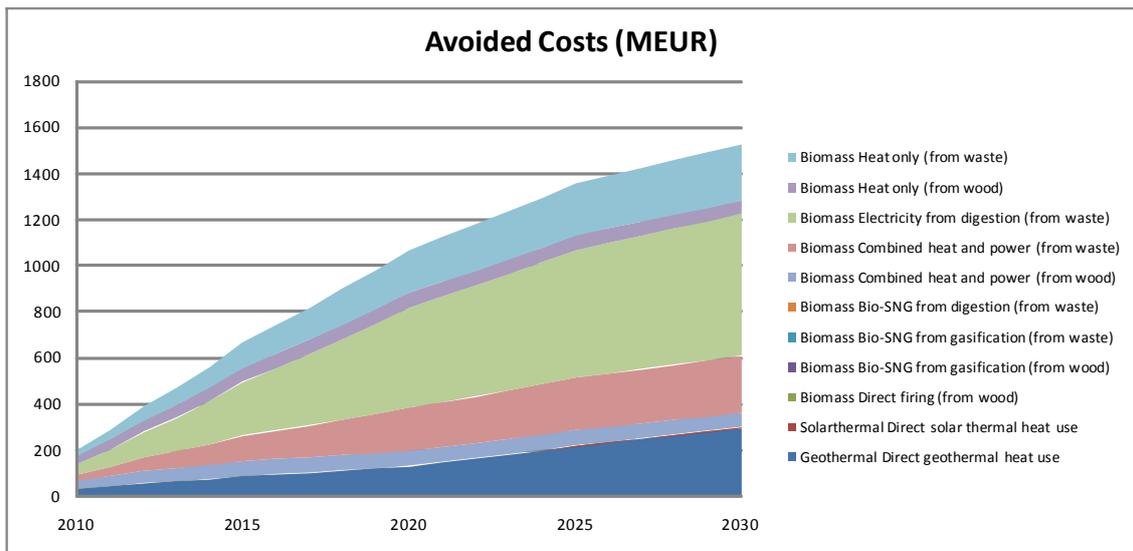


Figure 41: Avoided costs, high energy price scenario, RHI implemented

High price – RHI implemented

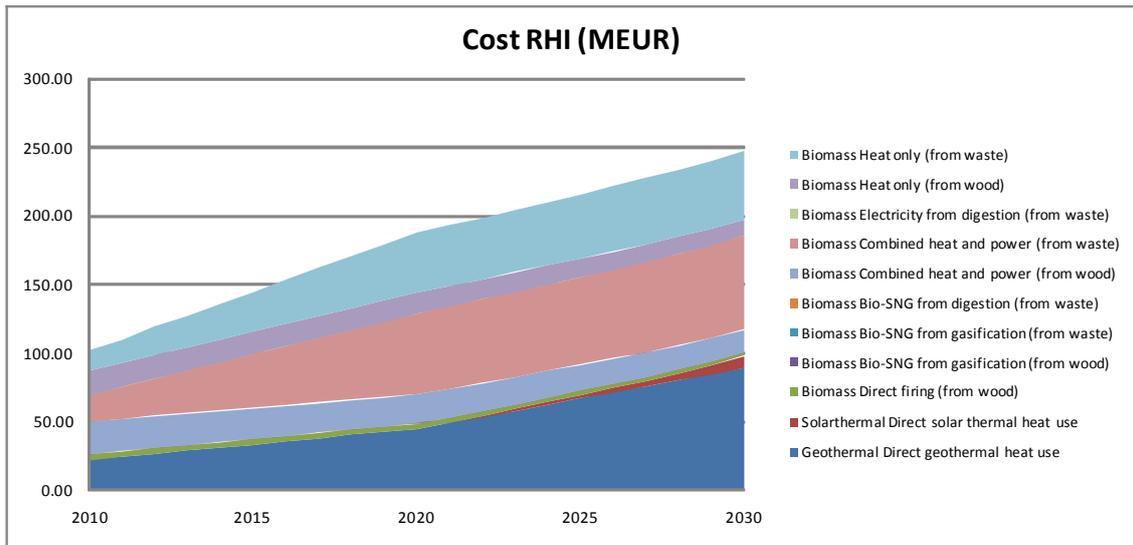


Figure 42: Cost of the RHI, low energy price scenario, RHI implemented

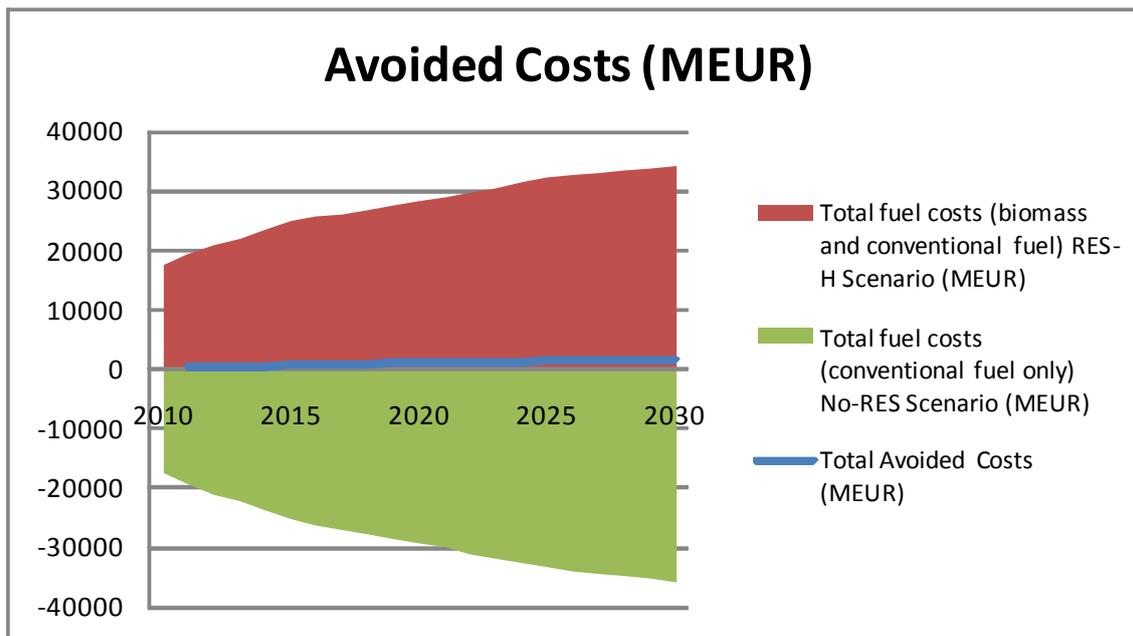


Figure 43: Net avoided costs, high energy price scenario, RHI implemented

High price – RHI implemented

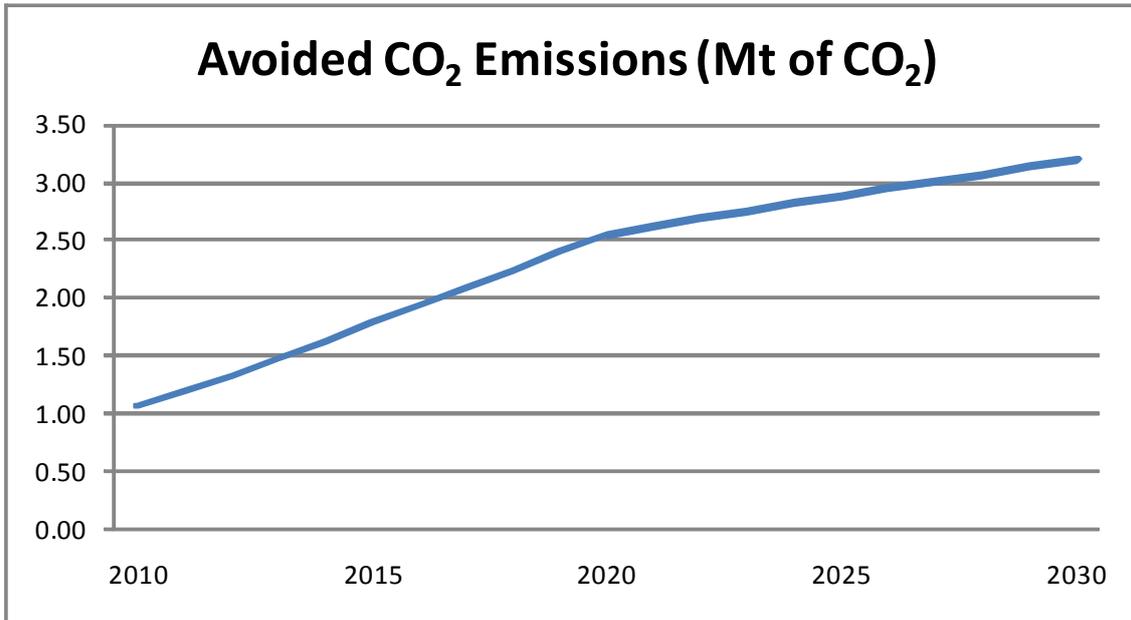


Figure 44: Avoided industry CO₂ emissions, high energy price scenario, RHI implemented

Given the comparatively small increase in uptake of RES-H predicted by the modelling, then the expected correlation with GHG emissions reductions sees a similarly small increase in emissions against the extra expenditure.

High price – RHI implemented

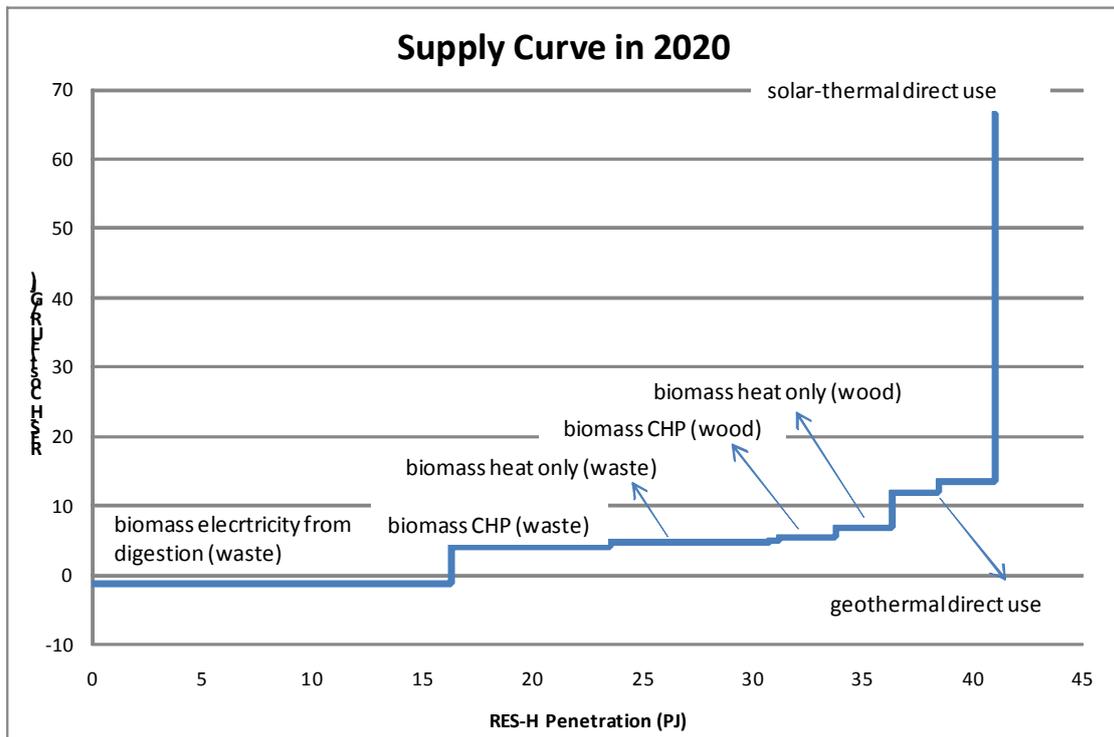


Figure 45: Industry supply curve in 2020, high energy price scenario, RHI implemented

7.5 Conclusions Concerning the RHI modelling for Industry Uptake of RES-H

The modelling for industry uptake of RES-H in the UK suggests that the key determinant of deployment is likely to be the price of energy on world and national markets. This is in line with the conclusions drawn concerning other EU Member States modelled within the RES-H project. Essentially, the model suggests that a high energy price will tend to drive enough demand for RES-H that an RHI makes only a very limited difference to the volume of RES-H that is incentivised. This is notable as it means that the public funds going into the RHI may not represent value for money where energy prices are high. The model suggests the RHI will have more influence on industry uptake of RES-H in the lower price energy scenario, with about a third more RES-H being generated in the industry sector by 2020 where the RHI is introduced, and about 50% more energy coming from RES-H by 2030 with the RHI than without.

This is at odds with our data for installation of RES-H in domestic and commercial buildings, where our models suggest the RHI will be a major driver for RES-H in both high and low energy price scenarios.

This does suggest that it will be worthwhile for Government to regularly review the level of RHI subsidy made available to industry, with a view to curtailing any excess

payments, particularly should energy prices rise towards the prices assumed in the high price scenario.

These scenarios do not rule out the potential benefits of adopting some or all of the 'flanking' policy measures that will be outlined by the RES-H Policy project. For example, it may be that initial uptake will be slow where government does not take action to overcome some of the initial barriers to use such as concerns about quality of installations, about the ability of technology to deliver, supply chain issues or simply where there is a lack of awareness of the technology.

7.6 Levels of Subsidy Informing the Industry Models

The simulations were run using the figures for levels of support provided in the UK Department of Energy and Climate Change document of March 2011 'Renewable Heat Incentive' available from www.decc.gov.uk/rhi

Levels of support					
Tariff name	Eligible technology	Eligible sizes	Tariff rate (pence/kWh)	Tariff duration (Years)	Support calculation
Small biomass	Solid biomass; Municipal Solid Waste (incl. CHP)	Less than 200 kWth	Tier 1: 7.6 Tier 2: 1.9	20	Metering Tier 1 applies annually up to the Tier Break, Tier 2 above the Tier Break. The Tier Break is: installed capacity x 1,314 peak load hours, i.e.: kWth x 1,314
Medium biomass		200 kWth and above; less than 1,000 kWth	Tier 1: 4.7 Tier 2: 1.9		
Large biomass		1,000 kWth and above	2.6		
Small ground source	Ground-source heat pumps; Water-source heat pumps; deep geothermal	Less than 100 kWth	4.3	20	Metering
Large ground source		100 kWth and above	3		
Solar thermal	Solar thermal	Less than 200 kWth	8.5	20	Metering
Biomethane	Biomethane injection and biogas combustion, except from landfill gas	Biomethane all scales, biogas combustion less than 200 kWth	6.5	20	Metering

Table 6: *Levels of support available to industry under the RHI (As of April 2011) (DECC 2011)*