Strengthening Momentum Towards a Flexible Renewable –based Electricity System

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Abstract (154)

Total global energy use is rising, and remains based on fossil fuels. Yet, the challenge of climate change requires a deep decarbonisation of our energy system. Here I argue that the global energy policy discourse is moving rapidly towards one of renewable, energy-efficient and flexible electricity systems. This is primarily because of a rapid take-up within a few countries of variable renewable electricity sources over the last decade, resulting from falling renewable electricity prices; new and more economic means of flexible system operation; and changing social preferences. Here I also argue that a 'no-regrets' energy policy is one that increases the energy system flexibility characteristics. This in turn has led to widespread and supportive public policy announcements .Whilst the changing discourse is welcome, it is not to say that the challenge of climate change has been met. Policy statements must be backed up by more effective governance support and pressure to speed up change.

Introduction

Global energy demand is rising and remains dominated by fossil fuels (1, seeFigure 1). Within the three principle domains of energy use – electricity, heat/cooling and transport – the global North maintains an almost steady use of electricity, but its energy consumption for heat and transport is declining. Meanwhile, the South is expected to increase its total energy use for some time in all three areas, and it is here that fossil fuels are expected to continue longest (1).

FIGURE 1

However, within this snapshot, a great deal of change is happening within electricity systems. Many countries have for a long time derived high proportions of their electricity from renewables – for example, hydro or biomass (2). However, there are two changes which are fundamentally altering both practice and mind-set within electricity systems around the world. The first is the rapid take-up of variable power renewables within a few countries or states. Denmark, Germany, Portugal, Spain, California, and Hawaii all derive 25-43% of their electricity generation from variable renewables sources (primarily wind and solar)(2).The second change, building on the first, is a greater understanding of the value of flexibility for the secure operation of energy systems. This knowledge has transferred to other countries, even if they do not yet have high proportions of variable power.

Public policy across the world has recently altered its position about energy and the use of fossil fuels to one that is more supportive of renewable electricity and energy efficiency mechanisms. This Perspective will argue that this is occurring because of: price reductions, particularly within wind and solar technologies; a growing understanding (and acceptance) of both the benefits of flexible system operation and the positive by-products of renewable electricity; changing social preferences; and more enabling governance. Past tensions between policies pursuing competitive and (often more expensive) decarbonisation goals are dissolving as costs and projections of renewable electricity technologies fall and as the economics of system integration alter and improve.

Given that energy systems are long lived, there is no contradiction in saying that while fossil fuels continue to be globally predominant , the overall momentum and frame of global public policy discourse towards energy provision has shifted .

The Conventional Energy System

Energy use – whether for electricity, heat or transport - over the last several hundred years has been mainly based on fossil fuels, large hydro electricity and traditional biomass (for example, wood), with the inclusion of nuclear power in the last 50-60 years (3).

Ownership of the global electricity infrastructure developed gradually from the early private, decentralised and ad-hoc systems into centralised and State-owned ones. Where the global energy industry was privatised or liberalised from the mid-1980s onwards, the incumbent ex monopoly companies often remained dominant within those electricity systems and retained the primary relationship with customers (4).

Conventional liberalised electricity market and network rules were developed for fossil fuels and nuclear generation: electricity demand follows a reasonably regular pattern over the day; the wholesale price of electricity falls and rises as demand changes. Fossil generators became used to maintaining a certain average price, and profits were made from the times of day when the highest demand led to 'peak' prices. Nuclear power was able to survive economically by acting as a provider of 'baseload' – the minimum demand on the system (5).

Changes within electricity systems

The oil shocks of the 1970s led to a 'new' type of energy policy in California and Denmark, with an impetus away from dependence on non-domestic oil to a more diverse and efficient energy system, encouraging a greater use of renewable energy and combined heat and power plants (6). This kick-started many renewable electricity policies – particularly wind and solar - which have since gradually spread around the world (2).

Changes are now taking place within certain electricity (and to a lesser extent heat and transport) systems that are overturning these conventional characteristics , with implications for system operation, profits, ownership, business models, supply chains, customers and individual and community involvement. They are occurring, in particular, in Germany (see Box 1 for details) and Denmark but also, increasingly, in California, Hawaii, Italy, Ireland, Spain and Portugal – all countries or US States with high proportions of variable renewable electricity (2). Their systems employ a combination of large, centralised, renewable power plants (such as offshore or onshore wind farms) that connect to transmission networks and smaller, decentralised renewable generation that connect to distribution networks.

In parallel, public policy in general takes a more positive attitude than in the past towards the by-products of renewable electricity and energy efficiency (7), as well as a recognition that renewables and associated system operation technologies help provide solutions to energy policy problems other than climate change, for example, fuel povertyair and water pollution, unreliable infrastructure and rising electricity prices. Thus, public policy choices in support of renewables or energy efficiency may not be made only on the basis of energy production or saving.

Changes, while inter-related, can broadly be categorised as being technology-based; economically or financially based; socially and individually driven; and related to public policy and governance. All dimensions are important to the overall stimulation of change.

Technological Change

FIGURE 2

There are two key technology-based changes. The first is falling costs of renewable electricity technologies (8), particularly offshore wind (30% predicted drop over 6 years (9)) and solar photovoltaics (PV; over 50% reduction in the last 5 years in the US (10) and a 70% drop since 2006 in Germany (ref. 11, Figure 2)). These price falls have in part been enabled by increasing volumes of global investment in manufacture and deployment – and market expansion – of those technologies (2, 12). Net global investment in renewable electricity (meaning the amount of investment in new capacity) has surpassed that of fossil fuels from 2011 onwards although gross investment (investment in new capacity plus expenditure on operation and maintenance of existing capacity) still remained higher in fossil fuels (8). Renewables accounted for 58.5% of net global capacity additions in 2014 (2), as shown in Figure 3.

FIGURE 3

Second, better energy system control and integration technologies are enabling new operation of electricity systems via two-way electricity movement; interconnection from the household through to regional markets and networks; domestic and commercial smart grid applications; and more flexibility options such as demand side response (13, 14, 15).

These two technological revolutions have enabled learning-by-doing and led to either more 'ICTised' (that is, 'smart') (16) energy systems, along with their attendant developments of more new entrants, changing business models and ownership structures, and customer involvement (17); or has led to a greater understanding of the benefits of a more flexible energy system, including its economic and technical advantages (18), the creation of new services, and best practice governance. For example, as Figure 4 shows, Germany has increased its already good record of energy system security during a time of rapidly increasing deployment of variable power renewables.
This understanding is, in turn, altering public policy attitudes to renewable electricity and placing flexibility at the core of matching governance changes (see, for example, refs 19, 20), thereby setting the scene for future system development in those countries. The impact of this learning-by-doing will be discussed further below.

FIGURE 4

Economic and financial changes

Crudely, these technological changes have not only altered the costs of individual technologies but have also altered the economics of energy systems in certain countries. Whilst, so far, the economic impacts have been greatest for electricity, energy sectors – whether electricity, heat or transport –

are very interconnected, and an impact on the economics of one sector has an impact on the other two. For example, district heating systems in Denmark are now incentivised at times of high renewable electricity generation, when prices are low, to source their electricity from wind (21).

Zero marginal cost variable renewable electricity displaces both fossil fuel and nuclear power within electricity markets and brings down wholesale peak prices (14, 18, 22, 23). This has led to reduced profits and reduced share prices for, and restructuring of, some large European utilities such as E.ON, RWE, Iberdrola, ENEL and Vattenfall amongst others, all of which operate in several countries, mainly in Europe (24,25,26,27,28,29,30, 31, 32).

Learning by doing has led to an increasing understanding of the flexibility needs of high penetration RE systems but also the system benefits of flexibility, with or without renewables (see refs 14,18). 'Flexibility' is a term which wraps up flexible generation (for example, hydro, open-cycle gas turbines, CHP), demand side response, storage and interconnectors (5, 33). This understanding is, in turn, leading to greater support from national governments, regulators, regional authorities and institutions (15, 20, 34, 35) for these flexible energy resources. This is in part because flexible and integrated system operation is accepted as being more effective and economic than inflexible system operation (8, 22, 36, 37)

In addition, if the cost of storage was to fall as rapidly as that of solar electricity (as some predict it will (38, 39, 40)) then the fundamental characteristic of renewable electricity – that it cannot be stored cheaply – would disappear and flexibility of system operation would further increase. At that point, system operation and the economics of energy - whether electricity, heat or transport sectors - would fundamentally alter.

As a result of renewables displacing fossil fuels and reducing peak prices, wholesale electricity prices are coming down in those countries which have supported a high proportion of electricity from renewables. This benefits society, but in particular the vulnerable or fuel poor. Such positive 'spillovers' are likely to encourage market rules to incentivise flexible operation, which will further aid renewables (15, 41).

Meanwhile, financial analysts – who are in general risk averse - have taken note of these economic changes and predictions and have begun to produce supportive documents in favour of electricity systems based on renewable energy. Some go so far as to predict the end of conventional utilities as we know them (42, 43, 44, 45, 46). Separately from this, analysis of 1400 financial funds saw Green Funds (broadly, mutual funds that limit its holdings to environmentally friendly companies) making 14% higher returns over the last two years than 'black' funds (mutual funds which have holdings in fossil fuels and natural resources) (47).

Social Preference Changes

There are also a growing number of social movements or preferences that support or fit better with decentralised, rather than centralised, energy systems. There are increasing numbers of new small-scale entrants and investors in non-traditional business models (48) as well as prosumers , who both produce and consume renewable energy (2, 5). Social and political preference for local decision-

making and control, social innovation and promotion of social capital is also growing (for example, ref. 49). Decentralised local energy is only one dimension of this broad movement but it complements the social and political preference for local decision-making and control, social innovation and development of social capital. For example, sale of energy from local heat or power plants to local consumers keeps the energy economy benefits in the local area, including local jobs (50).

The global South has very different energy needs to the global North. China (35, 41, 51), India (52), and Brazil (53, 54) have each recently published major energy policy commitments, all of which focus on renewables (for electricity and heat) and energy efficiency. Kofi Annan's Africa Progress Panel has made calls for a decentralised African energy future as the key to poverty reduction (55). There are predictions that the South will 'leapfrog' to renewable energy (not just electricity) technologies in their efforts to enable energy access (56). Indeed, combined investment in renewables in non-North regions is now greater than in the US and Europe (8).

These supportive public policies or statements from China, India, Brazil and Africa Progress are not only for direct energy and environmental goals but also support social interests that are by-products of renewable energy (not just electricity) provision, such as energy access, reduced air pollution and health benefits, or economic development, including jobs. These arguments are being given by faith groups (57, 58, 59), with the Pope being a recent example (58), NGOs endeavouring to reduce global poverty (60, 61, 62), as well as the more traditional Northern consumer groups and trans-global institutions (63).

Furthermore, there is an increasing pressure to end fossil fuel subsidies, for example from the IMF (61) or to reduce coal use, for example Oxfam (64). This links with concerns about the carbon bubble (65, 66) and the rapidly growing disinvestment from fossil fuel campaigns, such as the Guardian Newspaper 'Keep it in the Ground' campaign (67). These campaigns tend to support a flexible, renewable electricity and energy efficient alternative.

Irrespective of social innovation or arguments about the public good, customers in certain regions, such as California or Hawaii are also switching to solar/ storage systems as an economic choice (68, 69, 70). This is not as yet the general situation but does presage change for those countries or regions with a combination of high renewables penetration and high electricity prices or network charges. Andy Stirling has talked of this as a social 'murmuration' (71).

Public Policy and Governance Changes

The combination of technological, economic, financial and social issues discussed above has influenced public policy makers from around the world to make clearer and stronger statements in support of climate change mitigation and / or renewable electricity, energy efficiency and flexible energy systems (eg UNFCCC (72); US Clean Energy Plan (73); EU Market Design Consultation (20); Indian renewables policy (52); China 13th 5 year Plan (35, 51)). This in turn has added to the momentum towards a more flexible, energy system.

Energy governance is taken to mean institutions, policies, regulations, rules and incentives (that is, the rules of the game) and the means by which they were put in place. Governance is therefore

more than direct government involvement. Conventional energy governance tends to suit the characteristics of fossil fuels and nuclear power. Increasingly, public policy statements support development of new, parallel enabling governance which also encourages flexible energy systems and complements renewable electricity and energy efficiency, including market arrangements, for example, market rules that fit renewable energy or demand side response (15, 19, 20); sometimes green priority dispatch (35, 51); and new forms of network regulation to complement increasing renewable electricity connections (19), such as the New York State Reforming the Energy Vision, which is rethinking the governance basis of its energy system (74, 75).

Taken altogether, these policy and governance changes have strengthened the momentum of global public policy discourse towards a flexible, renewable electricity and energy efficient future.

A No-Regrets Policy

As described above, some electricity systems are changing rapidly, whilst other electricity systems or regions around the world look on with interest, or on very rare occasions, with disdain. In some countries, for example because of the more decentralised ownership make-up of Denmark, or the long history of sustainable electricity policies in California, these impacts have been broadly supported.

However, similar changes in the more centralised German (24,76) or Italian (30) energy systems, have had more negative existential impacts on the incumbent fossil fuel actors. Renewable electricity, to an extent, forces more system integration. New ways of operating, with an emphasis on integration (of supply and demand) and flexibility, are challenging the conventional, top-down sales model and undermining its profitability (13). This increases investment uncertainty and risk in non-renewable, non-flexible resources (77).

The social preference and public policy discourse changes exacerbate this but also open up energy system opportunities for those supportive of renewables and energy efficiency – whatever their reasons (78). This has encouraged experimentation in energy sector innovation in Germany and greater levels of interaction, networking, collaborating and cooperation at a local, community or city scale and the burgeoning of new ideas and services (79). The practice changes within the German electricity system span new technologies, economics, business models, ownership and social preference. For some, these changes are welcome.

Knowledge acquired and new ideas tried out in one country (or state / region) can spread beyond its borders. For example, European electricity markets and networks would be more cost-effective if aligned with German system operation issues; hence the EU Consultation on Market Design which will lead to operational changes throughout Europe. But in addition, individuals and businesses may like the idea of a certain social innovation happening in one country and want to try to implement it in their own. Social innovation in the British domestic retail market, for example, has strong parallels to other European examples despite an otherwise conventional energy system with concentrated ownership (48).

The rapidity of falling renewable electricity prices and the impact on utility finances or system operation (24) means it is no longer possible for energy stakeholders to ‘know’ what the future will bring. ‘Waiting and seeing’ similarly adds limited benefits because change is continuous, and

predictions are often such that what has happened appears to be just the beginning of a structural systemic change. As Figure 5 shows, the IEA 2050 High Renewable Scenario projections are for about 4700 GW of solar photovoltaics, while current global deployment is only 200 GW 80). In this situation, following a 'no-regrets' energy policy which would suit any technology pathway makes sense.

Figure 5

Such a 'no-regrets' energy policy could be argued to be one that both increases the energy system flexibility characteristics and that has flexibility at the core of its governance. Greater integration and flexibility capabilities improve the system performance, whatever the technological basis or social preference of a country, whether it be towards greater sustainability or not. The changes within electricity are rippling, and will continue to ripple, around global electricity systems.

Outlook

Rapid existential change is occurring within a few electricity systems, primarily as a result of increasing penetration of renewable electricity, developments in and falling prices of technology, social innovation and the introduction of enabling governance. This has led to falling utility profits and restructuring of some conventional utilities (for example, in Germany, Italy, Sweden, and Spain amongst others), as well as new electricity system operation, ownership and business models in those countries. Countries with high penetration of renewable electricity have had to learn how to operate those systems securely. The key to this is flexibility in the energy system, which has also been shown to be economic. In turn, it has led to an increase of public policy announcements across the world in favour of flexible energy systems, usually in parallel to support for renewable electricity and energy efficiency.

Some countries or states will continue with business-as-usual within electricity and the world is still expected to be reliant on fossil fuels for the next few decades (1); energy systems are long-lived and have long lead times for change. However, these burgeoning electricity changes can be expected to spread across electricity systems around the world. How fast and with what impacts on other energy sectors (such as heat and transport) or fuels (such as oil), is less certain. However, one possibility is that in the future most heat and transport will be fuelled by renewable electricity or from renewable resources.

Even though the discourse has changed in a welcome manner, it is still not sufficient. Governments need to back their policies and speed up the adoption of flexible, renewable and energy efficient technologies; governance needs to change further to enable this; businesses need to alter their business models; and individuals and communities need to be able to take up opportunities for their local areas. Because change is happening so fast in some countries, it is hard for decision-makers to keep up and make policy decisions based on best practice and evidence. Enabling this should also be made a priority.

Overall, the dominant global public policy discourse has shifted towards flexible electricity systems and energy policy appears likely to be characterised over the next few decades as one of increasing momentum towards renewable electricity and energy efficiency across all energy sectors.

Box 1

Germany and the Energiewende

Sitting in the heart of Europe, Germany is a country of 80 million people with a manufacturing-based industry. It is undertaking an 'Energiewende' (a new energy tack), the intention of which is to transform its economy and energy system to one based on renewable electricity, energy efficiency and flexibility, and between 80-95% cuts in CO_2 emissions in 2050 compared to 1990 levels. Broadly speaking, the Energiewende is a sustainable industrial policy, one of whose central planks is learning-by-doing. Its early focus on deploying more renewables (in particular solar and wind, both for heat and electricity) has altered to one of creating an integrated and flexible energy system, as it became clear that this was a necessary, and useful, characteristic of a secure, renewable-based energy system. Because of this, changes are occurring not just within Germany, or between Germany and its neighbours, but also within the European energy policy (11, 19, 20, 22, 81). Figure 2 shows the rapid deployment of photovoltaics in Germany over the last 6 or so years, and their price drops, whilst Figure 4 shows how the security of the German system has increased over this time.

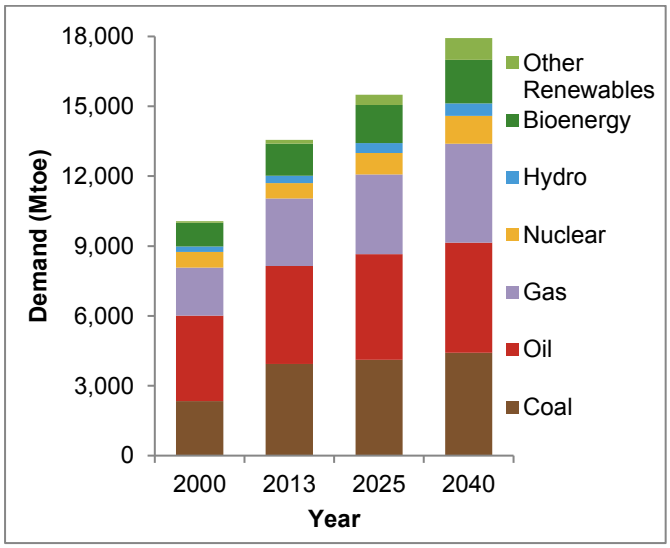

Figure 1. Global Primary Energy Demand by fuel in 2013 and projected for 2040.

The fossil fuel dominated global primary energy demand in 2040 under the New Policies Scenario – the central scenario. This is the scenario which takes account of policies which have been announced as of mid-2015. It shows how demand changes until 2040, and where supply is coming from. Fossil fuels are still the dominant source of energy in 2040. Reproduced from IEA data (1).

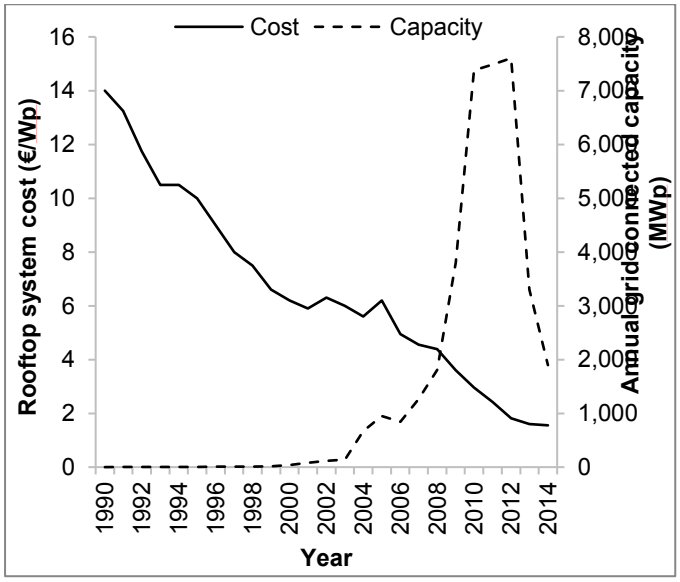

Figure 2. Cost and Deployment of Rooftop PV Systems in Germany 1990-2014

The rapid price falls (line) and take-up (dashed line) of domestic roof top photovoltaic systems in Germany. Reproduced from Fraunhofer ISE data (11).

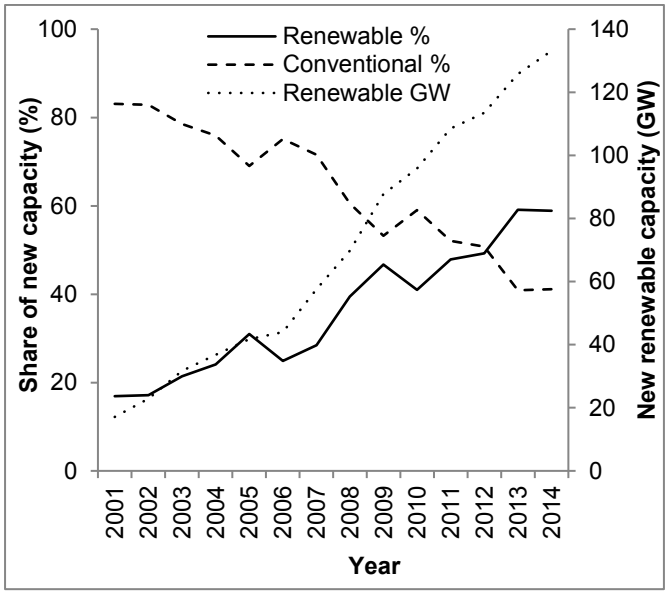

Figure 3. The additional capacity trajectories of renewables versus other power sources (nuclear, gas and coal) 2001-2013

This shows that in 2012 that renewable electricity capacity overtook conventional cpacity for worldwide capacity additions. Reproduced from data from IRENA and the IEA.

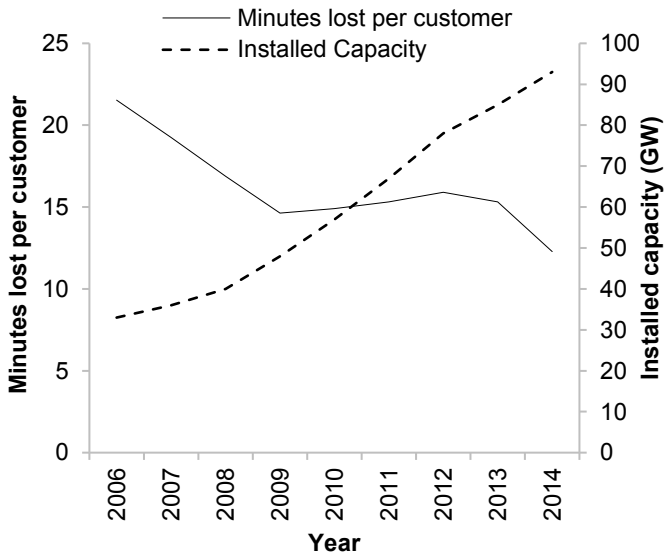

Figure 4. Minutes Lost Per Customer in Germany Relative to Renewables GW Installed Capacity 2006-2014

Whilst Germany rapidly increased its wind and photovoltaic deployment between 2006-2014, its electricity system also improved its customer minutes lost record. This is one of the usual ways of judging how secure an energy system is. Germany, anyway, has a much better record than most other countries in Europe for system security but this figure shows that adding significant quantities of renewable electricity did not harm this measure. Reproduced from BNetz and BMWi data (36 and 37)

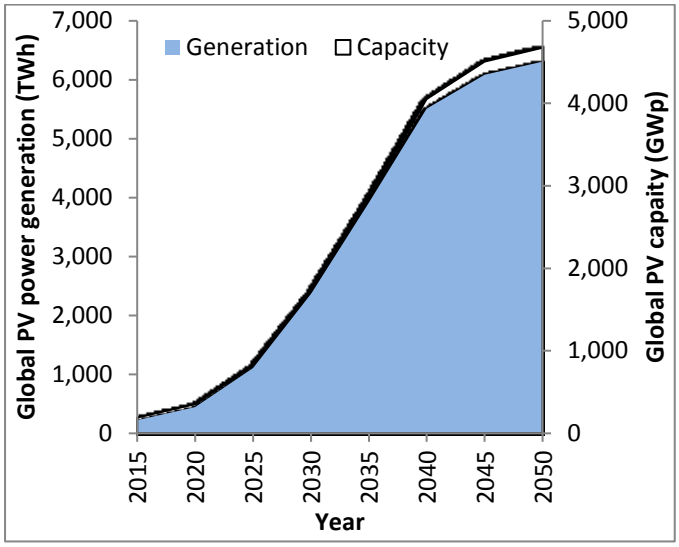

Figure 5. IEA Solar Technology Roadmap High Renewable Scenario Projections for 2050

The IEA projects a high renewable scenario for global photovoltaic deployment by region and as a share of global electricity supply in 2050. It shows the current global 200 GW installed capacity rise to nearly 5000 GW. Although it is a High Renewable Scenario, it is the scenario most in line with recent photovoltaic deployment. One of the German Fraunhofer Institutes also produced a projection for 2050, which projected nearly 6000 GW (12). It underlines how uncertain the future energy mix is for investors and how it is not possible to 'know' what will happen. This makes a 'no regrets' energy policy even more important. Reproduced from IEA data [80]

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