The Impact of Germany's Energy Transition

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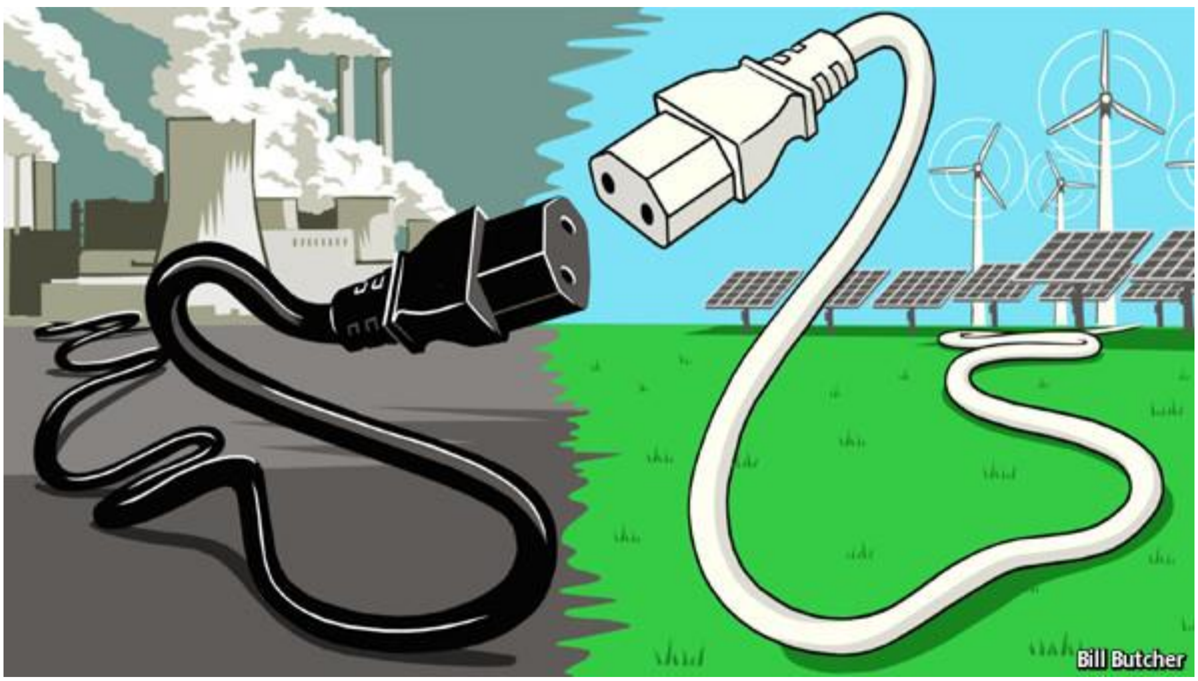

Picture from the Economist/Bill Butcher

Declaration of authorship

I hereby certify that the thesis I am submitting is entirely my own original work except where otherwise indicated. Any use of the works of any other author, in any form, is properly acknowledged at their point of use.

Peter Murphy

1.1 Key concepts, terminology:

Kilowatt (KW) = 1000 watts, the typical consumption of a fan heater or large microwave.

Kilowatt hour (KWh) – the consumption of a fan heater running for one hour. The EU-28 price averaged 20.8 euro cents in 2014 for one KWh. In Germany, the price was 29.7 cents, second only to Denmark at 30.4 cents. (Eurostat)[1] Residential per capita power use in Germany is around 5 KWh a day, costing €1.50.

Megawatt (MW) / megawatt hour (MWh) = 1000 KW / KWh - 1000 fan heaters running for an hour, or one fan heater running for 1000 hours.

Gigawatt (GW) / gigawatt hour (GWh) = 1000 MW / MWh

Terrawatt (TW) / terawatt hour (TWh) = 1000 GW / GWh

Capacity factor – the coefficient used to calculate realistic output from a wind turbine or solar array. E.g. a 1 MW solar array can produce its rated output under midday sunny conditions, but on average, it will yield around 20 percent of this amount over one year. (1 MW x 24 hours x 365 days x 0.2 = 1,752 MWh) Similarly, a wind turbine will produce around 30 percent of its 'nameplate' capacity over the year, accounting for low winds, and shut-downs for maintenance or during storms. Technological advances are raising wind and solar capacity factors.

Transmission

Transportation of power over high voltage cables and over long distances from the source of generation. This infrastructure and its throughput is the responsibility of the grid operator, whose revenue is collected from fees added to electricity bills.

[1] EU domestic electricity costs http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Half-yearly_electricity_and_gas_prices,_second_half_of_year,_2012%E2%80%9314_(EUR_per_kWh)_YB15.png

Distribution

This is the regional or local delivery of power received from the transmission network. The voltage is reduced upon entry into the distribution network. Under EU directives, transmission and distribution responsibilities are supposed to be handled by separate companies.

1.2 Charts

1.2 Methodology

Review of policy papers, academic papers and news reports on Germany’s energy transition.

1.1 Introduction

The shift to renewable power is rapidly gaining momentum as politicians grasp the urgency of acting to slow climate change with the enormous ecological, economic and social costs it entails. The landmark COP21 deal in Paris in November 2015 is the latest manifestation of increasing efforts to limit global carbon emissions and forestall more severe climate change, a phenomenon which is already unfolding and silencing skeptics in its wake.

Even though the debate over the existence of climate change is now largely muted, that question is no longer even a relevant one when it comes to the future of energy. The pursuit of emissions-free energy production has already morphed into a mainstream economic policy as much as an ecological one as solar and wind power become competitive with fossils fuels.

Though this cost parity has been reached decades too late to help avoid some of the consequences of global warming, the deployment of renewable energy will help economies dodge a surge in coal and oil prices that Germany and others believe is inevitable if the world continues to rely on this diminishing resource while demand for energy continues to increase.

Costs for renewable power generation are falling precipitously as the market grows and technology improves, creating a virtuous circle with the positive spill-over effect of making clean power affordable to less developed countries also.

Onshore wind power is already the cheapest form of electricity generation in Germany[2], enabling developing countries whose energy demands are rising, to ‘leapfrog’ fossil fuels and embark on low carbon economic expansion from an early stage.

This thesis focuses on Germany’s energy transition precisely because this industrial giant’s aggressive switch to renewable energy makes it a pioneer in Europe and beyond. Its transition is a valuable case study in terms of regulation and market design for other nations at an earlier stage in their adoption of cleaner energy.

[2] http://about.bnef.com/press-releases/wind-solar-boost-cost-competitiveness-versus-fossil-fuels/

Though the costs are high, Germany is eyeing long-term rewards as its engineering prowess delivers a stream of patented innovations that are positioning the country at the forefront of renewable energy technology which has vast export potential for the coming decades as wind turbines and photovoltaic solar panels rise in efficiency and fall in price. These achievements are also helping to lower the cost for other countries to decarbonise their power generation.

Many technological hurdles have still to be overcome however. Renewable energy is not yet the cheapest form of power generation in all countries, so costs must fall further still and the intermittency of wind and solar power pose a technical dilemma which, though not insurmountable, will complicate the total eradication of fossil fuels.

The shift to renewable fuels contradicts the fundamental logic of economic theory, which dictates that the rational choice for satisfying an economic need is the one which requires the fewest resources. That principle would indicate continued use of still-abundant fossil fuels.

But a broader analysis that incorporates long-term fossil fuel price trends and the heavy externalities in terms of human health and climate change, overwhelmingly points to renewable energy as the most economically efficient way to power the globe, all the more so with the world population forecast to rise by around a quarter by the middle of the century.

Creating the incentive for the markets to invest huge sums of capital now which will take decades to recover requires a degree of market regulation and financial support and which also shares some of the economic cost among society as a whole, which stands to benefit.

"Governments must intervene, because market mechanisms such as prices alone are failing to bring about the drastic and fast changes to the very fabric of our economies required for the protection of our planet." (Hallegatte et al., 2013, via Pegels, 2014)[3].

Expressed in terms of economic theory illustrated in the chart below, Germany's subsidization of renewable energy raises lowers market prices, raising both demand and supply as seen in

[3] Pegels, Luetkenhorst, Pg 2 www.die-gdi.de/uploads/media/Pegels_Luetkenhorst_2014.pdf

the shift from point PQ to P1Q1. The logic is that subsidization raises the scale of production enough that costs fall to the point where the industry turns competitive without aid.

Governments are naturally selective in the use of subsidies, especially within the European Union where members are subject to competition rules, but in the case of German energy, they aim to achieve an objective of far greater importance than the success of a single industry with high export potential – that of making a low-carbon or carbon-free power supply a reality.

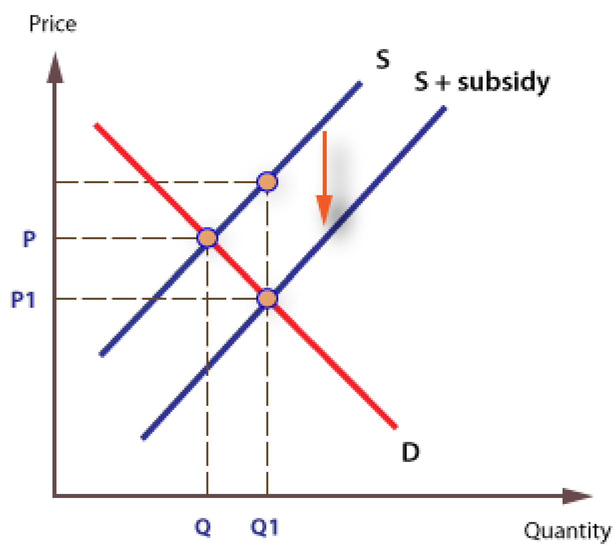

Chart 1. Economics of subsidiation.

Source: http://www.economicsonline.co.uk/Competitive_markets/Subsidies.html

Though this thesis will focus on German policies and discuss European targets only briefly, the existence of EU regulations should not be under-estimated in providing the impetus for a member state to undertake a costly transition like the Energiewende as it is known in German. This is because all 28 countries, not just a few, are investing to improve their ecological footprint to varying degrees, with all of the costs that involves. If this were not a collective effort, the incentive might not be great enough for a smaller number of member states to put themselves at a competitive disadvantage due to initially higher electricity costs.

The Germany-based International Renewable Energy Agency (IRENA) says in its 2016 REmap publication, which sets out a plan for how the world can double renewable energy use by 2030, that the financial benefits in terms of slowing of climate change, agriculture and improved human health could generate savings up to 15 times the amount of investment this would require. The resulting reduction in pollution would also save up to a staggering 4 million lives a year, it estimates, eight times the number killed by malaria.[4]

As Germany's government takes up this challenge, this thesis will examine the impact of the stimulus it is providing in the shift to more ecologically sound electricity provision. This includes the economic impact on energy consumers, the social impact brought about by the 'creative destruction' of an energetic but also economic transition and the impact on the overarching aim of decarbonising the economy of Europe's single largest emitter of greenhouse gases by far.

Though subsidies are paid towards biomass, mostly wood pellets burned like coal to generate power, this thesis will focus on wind and photovoltaic solar as a case study in state subsidisation of a niche technology that will turn into a competitive mainstream one that does away with the negative externalities of fossil fuels.

Though the global case made for renewable energy faces small and rapidly-diminishing opposition, zooming in to examine the problem on a national and local level reveals numerous hurdles that have yet to be overcome as the biggest energy transition since the advent of the industrial revolution creates both winners and losers.

The German case in particular is paradoxical. Despite having deployed more solar photovoltaic power generation capacity than any other country worldwide and ranking third for wind, its reliance on coal and lignite rather than natural gas, for nearly half of its power means its grid is now supplied by a mix of the cleanest and the dirtiest forms of generation.

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[4] Pg 17 Costs/benefits renewables transition
http://www.irena.org/DocumentDownloads/Publications/IRENA_REmap_2016_edition_report.pdf

This is a temporary situation of course and Germany is aiming for an 80 percent reduction in carbon emissions by 2050. But meanwhile the question of how fast Germany can wean itself off solid fossil fuels is of critical importance for climate change since Germany alone accounts for more than one fifth of EU emissions.[5]

This thesis will look at the economic impact of Germany's energy transition and examine the government regulations intended to create incentives and share the heavy upfront economic burden this transition implies.

It will also attempt to explain why Germany's carbon emissions continue to hover at the same level even as renewables claim several percentage points more share in the energy mix each year and look at whether this is likely to jeopardise its reaching of domestic and European CO2 emissions targets for 2020.

The role of carbon markets in this transition, or arguably the lack of one, will also be briefly discussed as will some of the positive and negative impacts of Germany's energy transition beyond its own borders. Though its heavy investment in research and development of renewable energy technologies is lowering the cost of investments for other countries' own eventual energy transitions, Germany's exports of fossil-fuel generated power have given rise to increased 'carbon dumping' in the interim.

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[5] CO2 emissions by EU member state http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Total_greenhouse_gas_emissions_by_countries_(including_international_aviation_and_excluding_LULUCF),_1990_-_2013_(million_tonnes_of_CO2_equivalents)_updated.png

1.3 Background and economic reasoning behind Germany's energy transition

German society's strong environmental conscience, though somewhat tarnished abroad by the recent Volkswagen diesel emissions scandal, is renowned in Europe and is pervasive enough to transcend its entire political spectrum. The resulting consensus is facilitating the implementation of this capital-intensive transition and gives investors confidence that this lengthy process is unlikely to be jeopardised by changes of government. The absence of this risk is positive in that it translates into lower financing costs for capital-hungry projects.

Though the term 'Energiewende' or 'Energy Turn' has been familiar to Germans for several decades, the ethos of the energy transition in its current form, has been formalised through the adoption of the Energy Concept by the Christian Democratic-led governing coalition on September 28, 2010.

Chiefly, it sets out targets to increase of renewables in the power mix by 2020, 2030 and 2050 (to 35, 50 and 80 percent respectively). The first of these targets originates in a set of EU-wide targets for renewable energy for 2020 which cover carbon emissions reductions and improved energy efficiency as well as increased use of renewables. In 2015, 33 percent of electricity was produced from renewables, leaving Germany on target to exceed that target, though its 2020 target for reducing CO2 emissions by 40 percent versus 1990 is now seriously in doubt.

The Energy Concept originally planned to extend the life of Germany's fleet of nuclear power plants until as late as 2036[6] but the Fukushima disaster which happened six months after the Concept was adopted, forced policymakers to abandon this decision. The meltdown of that Japanese reactor galvanised already-hostile public sentiment towards nuclear power, prompting public protests which the government was reluctant to ignore.

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[6] Closure of nuclear power plants
http://www.nytimes.com/2011/05/31/world/europe/31germany.html?_r=0

Eight of the oldest plants were shut down within months of the Fukushima incident, halving what had been 22 gigawatts of nuclear capacity.[7] The last nuclear power plant will now be shut down by the end of 2022 instead of 2036.

The about-turn means that Germany is decarbonising its power supply by first eliminating its only other carbon-free source of electricity except for renewables.

The decision will leave Germany reliant on fossil fuel power for longer than would have been the case if nuclear was retained. At the same time, a popular misconception has arisen that Germany has been ramping up coal-fired generation to compensate.

No new coal generating capacity has been planned as a direct result of the decision to close nuclear plants (Morris, 2015)[8]. Coal-fired power plants opened since the Fukushima disaster were planned well before. They are also more efficient, meaning their environmental impact is reduced, even if still significant and unsustainable. And importantly, the graphic below also shows how power generation from renewable sources has grown at least as fast as nuclear power output has declined since 2011.

Germany has a total power generation capacity well in excess of its power consumption which peaks at around 85 gigawatts, which gives it room to cull some of its most-polluting lignite plants as shall be discussed. This has been happening more slowly than it might however as fossil fuel plants are increasingly generating power for export rather than closing down.

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[7] Germany nuclear capacity http://www.reuters.com/article/us-germany-nuclear-idUSKCN0SQ1G520151101

[8] Energy Transition, The German Energiewende, Heinrich Boll Foundation, revised 2015

Figure 1: Historical and projected structure of power generation and phases of electricity policy in Germany, 1950-2050

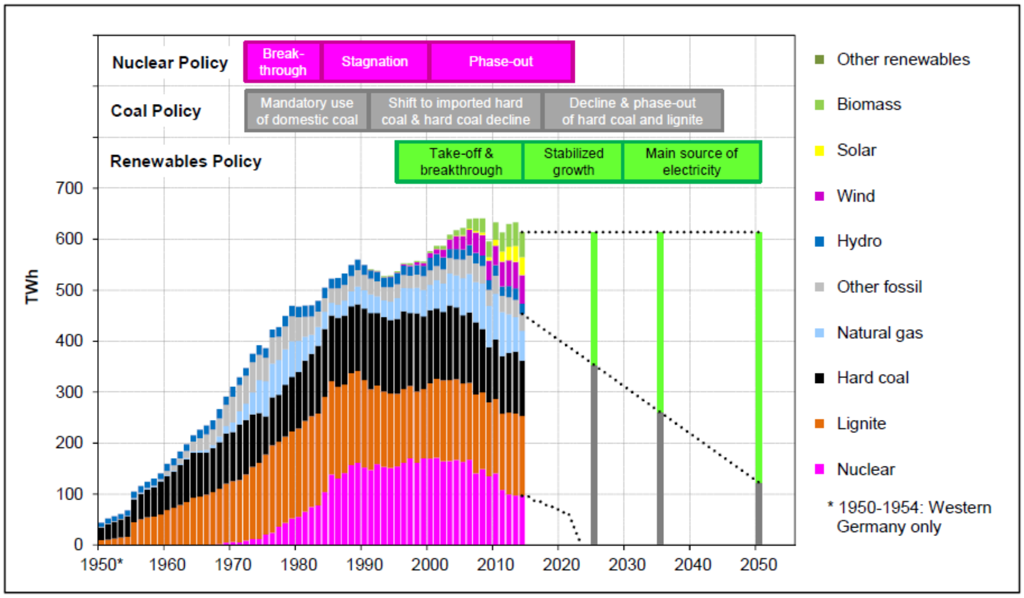

Chart 2. Source: CERRE, Centre on Regulation in Europe, Oct. 2015 citing Statistical Office of German coal industries, Oko-Institut

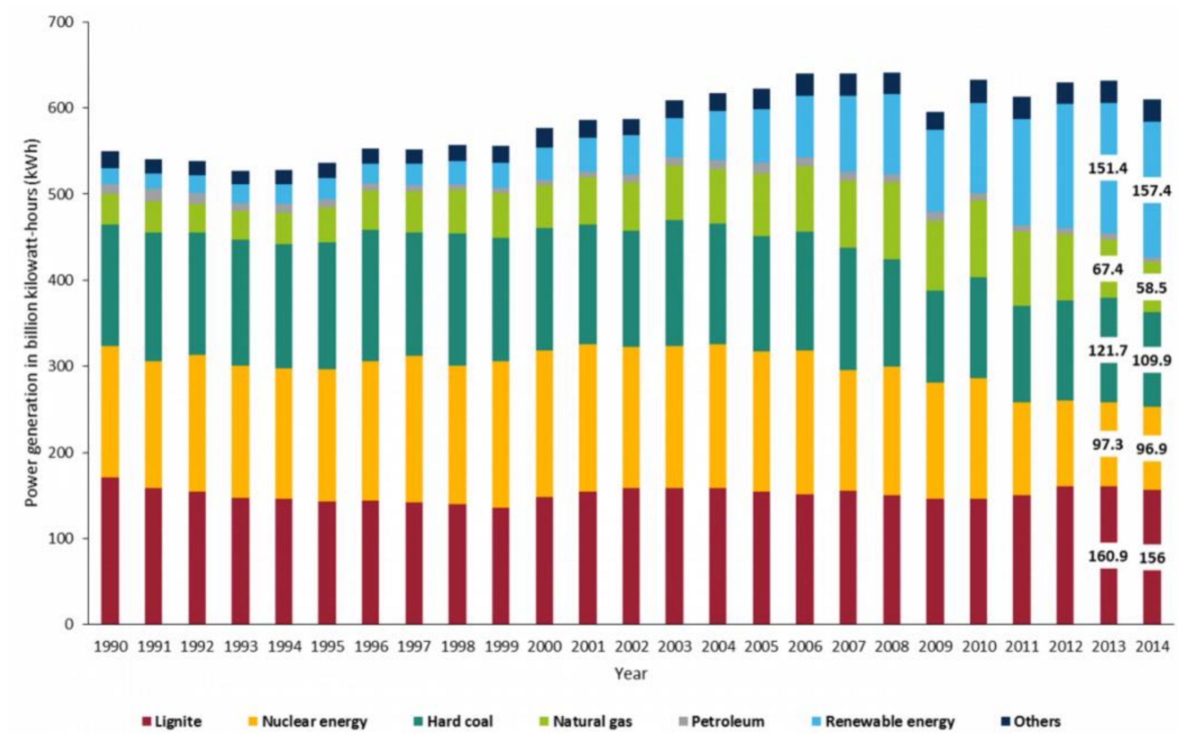

Chart 3. Germany's power generation by source[9].

[9] Chart. Germany's power mix
https://www.cleanenergywire.org/sites/default/files/styles/lightbox_image/public/images/factsheet/ageb-power-generation-source-1990-2014-neu.png?itok=WzEO7c_d

Interestingly, the United Kingdom has taken an opposite approach, aiming to phase out what remains of its coal generation within a decade while building a new nuclear power plant.[10]

Given that Germany is the world's sixth biggest carbon emitter[11], the loss of nuclear generation capacity before fossil fuels makes will unavoidably have the result of significantly slowing the cull in its greenhouse gas production. That makes the question of how fast Germany will roll-out renewables to eliminate coal and even dirtier brown coal or lignite, all the more pressing.

"There is no widespread call for shifting the overall objective of energy-climate policy. Even those critical of the *Energiewende* do not seek to overhaul the long term goals of the energy transition**.** Rather, there is debate over how best to achieve them," says the 2014 report[12] "Transforming the Electricity Portfolio Lessons from Germany" by Charles Ebinger, John P. Banks and Alisa Schackmann of the privately-funded Brookings Institute.

The more quickly German power can decarbonise, the smaller the bite it will take out of the world's remaining carbon 'budget' or the amount of carbon that can be added to the atmosphere without hitting a 2 Celsius warming. Above this level scientists believe the impact of climate change will intensify exponentially.

The benefits of the German energy transition are not confined to within its own borders. As a leader in innovation, Germany has been at the forefront of developments in wind turbine and solar technology that have led to dramatic cost reductions that put greener power within reach of more and more countries. Though less intense climate change is a non-excludable good from which all will benefit, Germany is already reaping economic benefits through a burgeoning export market for these technologies which it is steadily improving.

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[10] UK to phase out coal http://www.dw.com/en/britain-turns-its-back-on-coal-power/a-18857593

[11] Global carbon emissions by country http://data.worldbank.org/indicator/EN.ATM.CO2E.KT/countries

[12] Pg 39 http://www.brookings.edu/~/media/Research/Files/Reports/2014/09/transforming-electricity-portfolio-renewable-energy/Transforming-Electricity-Portfolio-web.pdf?la=en

Solar and wind power are expected to eventually become the cheapest forms of producing power outright, regardless of location or subsidies.

Conversely, the complex energy shift Germany has undertaken also has some negative spill-over for other countries as this thesis shall discuss. Its efforts have led it to be accused of holding down already-low prices on the European Emissions Trading Scheme for example, which complicates the task of bringing financial pressure to bear on industry in other European countries to reduce emissions.

A point-form answer to the question regarding of what are the observable impacts of the German energy transition points to the following key aspects, each of which will be discussed in this thesis.

- Germany now has one of lowest costs for renewables capacity in world
- Rapid increase in share of renewables yet no significant fall yet in overall GHG emissions
- Households, not industrials, foot most of the bill for the energy transition
- Transmission bottlenecks arise as generation and consumption points grow more distant
- Fossil fuel generators being slowly relegated to back-up power supplier role, face economic precarity
- Germany blamed for depressing European carbon price, slowing EU-wide transition

2 The Energiewende as a market driver

The regulations introduced in 2010 through the Energy Concept are the legislative foundation of Germany's energy transition, aspects of which have since been emulated by other countries.

The use of regulation is necessary to bring about this transition since market forces alone are not sufficient to divert privately-owned financial resources towards technologies which are not yet the most efficient in economic terms, even if their ecological merits are undisputed.

The transition also implies the premature curtailment of existing fossil-fuel infrastructure, investments for which were based on the expectation of consistent returns over several decades.

Since none of this serves the interests of private enterprise, the Energy Concept aims to tweak costs and benefits to align its ecological and economic goals with the corporate objective of profit.

The creation of the European Emissions Trading Scheme (ETS), the world's single largest carbon market, is supposed to bring about this realignment of the market towards carbon intensity reduction by internalizing the cost of pollution. But as this thesis will discuss, flaws in its design have so far left this mechanism without significant influence.

In the absence of a meaningful market signal from the ETS, Germany's Energy Concept is seeking to achieve the same objectives at the core of the carbon market, but through different means.

2.1 The anatomy of the legal framework of Germany's energy transition

The Energy Concept finalized by the government on Sept. 28, 2010 and adopted by parliament shortly after has the stated objective of providing guidelines for achieving "an environmentally sound, reliable and affordable energy supply".

Its specific market-influencing mechanisms are enshrined in individual legislations, some of which existed already at the time of the Energy Concept's publication, and others which followed months after. But the key feature of this document was the fixing of targets for reductions in greenhouse gas emissions, for the incorporation of renewables into the energy mix, and for reductions in energy consumption through improved efficiency.

The table on the next page sets out the emissions reductions targets for the European Union, and Germany's sometimes differentiated targets within those, as set out in the 2010 Energy Concept document.

Germany's energy targets

	2020	**2030**	**2040**	**2050**
GHG cut (vs 1990)	-40 % (vs 1990) (EU-wide target is 20 pct)	-55 % (vs EU-wide goal 40 %)	-70%	EU goal: -80-95 %
Renewables in gross final energy consumption	18 % (vs 20 pct EU target)	30% (vs 27 % EU-wide goal)	45%	60%
Renewables in electricity (consumption)	35%	50%	65%	80%
Primary energy consumption **(vs 2008)**	-20%			-50%
Electricity consumption **(vs 2008)**	-10%			-25%
Energy consumption in transport **(vs 2005)**	-10%			-40%

Chart 4. German and EU targets for carbon emissions, energy consumption and efficiency

The Energy Concept retains the central pillar of guaranteed feed-in tariffs for new renewable power installations which were first introduced in 1990. Feed-in tariffs are bonuses paid on top of the market price for electricity supplied to the national grid to enable renewables to compete until they grow more competitive. New renewables projects are guaranteed a fixed rate for 20 years.

The feed-in tariff is paid by consumers on their electricity bills as an item referred to as a surcharge. It added around 6.1 euro cents per kilowatt hour to domestic power bills in 2015[13] but power-hungry industry contributes only a fraction of this amount. Analysts say is basically an exemption and many see this as the single biggest flaw in the regulatory design of Germany's energy transition.

Annual degression lowers the feed-in tariff by around one tenth each year as the cost of renewables as the market grows. These provisions are enshrined in the Renewable Energy Act, known by its Germany acronym EEG. The feed-in tariff varies according to the scale of the facility generating renewable power and also varies by type i.e. wind, solar etc.

Another regulatory feature of the transition is the 'merit order' which requires that grid operators feed available renewable power into the transmission network before conventionals, meaning it is conventional generation which must be curtailed first in periods of surplus generation.

Since total renewable capacity remains well below Germany's peak consumption, this means all renewable power produced in Germany is normally consumed. As shall be explained later, this rule is leaving conventional fossil fuel power producers increasingly vulnerable financially as their plants are increasingly relegated to the role of back-up supplier.

The requirement that the power grid be expanded is also included, to ensure growing power production in the blustery north reaches the industrial hubs of the south and west. The Energy Concept also highlights the need to increase the density of interconnections with grids of neighbouring states – important to smooth out the supply volatility inherent in renewable

[13] http://energytransition.de/2012/10/renewable-energy-act-with-feed-in-tariffs/

generation. The Renewable Energy Act specifically makes it law for grid operators to provide the connections necessary to hook up now utility-scale wind and solar plants to the grid, boosting investor security.

The document estimates that investments required to bring about the energy transition would amount to around 20 billion euros a year through 2050 but notes that savings made through reduced purchases of fossil fuel would offset some of the cost.

The broad goals laid out in the Energy Concept were codified through the adoption of six laws in mid-2011 which are collectively referred to as the Energy Package.

The Renewable Energy Act has subsequently been revised in 2014 and is due to undergo further modifications in 2016. The changes will be discussed in the next section.

2.2 A critical look at the Energy Transition regulatory framework

The legislative framework of the energy transition has been very successful in achieving the objective of increased deployment of renewable energy, so much so that Germany is now the world's third-biggest producer of power from wind after China then the United States, with 45 gigawatts of capacity installed by the end of 2015[14].

Until 2015, it also ranked first worldwide for solar with 39.6 gigawatts[15] of capacity installed by the end that year during which it was overtaken by China. Its high ranking, first worldwide on a per capita basis, is testimony to the cost cuts and rising efficiency of solar panels that the energy transition has helped bring about through its feed-in tariff support.

The cost of new solar and wind generation capacity in Germany is now one of the lowest in the world. Residential installation of solar photovoltaic panels costs only around one third of what it does in California[16], one of the U.S. states with the most enthusiastic uptake of renewables.

Indeed Germany's feed-in tariff model is being emulated by a number of other countries and it has earned praise for the simplicity of its legal aspects.

As the energytransition.de web site dedicated to the topic of the German energy transition puts it: "The standard contract for feed-in tariffs that you sign with your utility is two pages long in Germany. In contrast, the United States has Power Purchase Agreements (PPAs), which can easily be 70 pages long and are individually negotiated between the seller and the buyer (say, a utility company)."[17]

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[14] Global Wind Energy Council 2015 market update http://www.gwec.net/wp-content/uploads/vip/GWEC-Global-Wind-2015-Report_April-2016_19_04.pdf

[15] http://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Capacity_Statistics_2016.pdf

[16] Cost of solar, Germany vs California http://www.irena.org/DocumentDownloads/Publications/IRENA_Power_to_Change_2016.pdf

[17] Simplicity of feed-in tariff contract http://energytransition.de/2012/10/renewable-energy-act-with-feed-in-tariffs/

The framework has also been endorsed by the European Commission after its review of support measures for renewable energy among member states:

“Based on a comparative assessment of renewable energy support policies in its member states, the European Commission concludes that “well-adapted feed-in tariff regimes are generally the most efficient and effective support schemes for promoting renewable electricity” (EC, 2008, p.3).

But as the energy transition picks up pace, it has encountered some difficulties that have necessitated revisions to its regulations. These revisions, which shall now be discussed, are taking place with increasing frequency to enable policymakers as concern mounts over the growing cost of the surcharge consumers pay towards renewables.

Analysts and industry say some of these adjustments in the opinion of some analysts now threaten to put a brake on the energy transition or at least halt its acceleration.

2.3 The cost of the feed-in tariff

One of the key criticisms is that the renewables surcharge is paid almost exclusively by households whose bills have been rising rapidly as a result. Industry contributes only a tiny fraction to the total cost.

In a country where protestors have taken to the streets to demand the end of both coal and nuclear generation, the surcharge has nonetheless been well-tolerated so far despite contributing to making German retail electricity the most expensive in Europe after Denmark.

It is necessary to understand the mechanism of the surcharge to understand why the cost of renewables has been increasing electricity bills for household consumers even if the wholesale price of power in Germany is actually beginning to fall.

Consumers pay the surcharge (6.35 euro cents per kilowatt hour in 2016)[18] only on the portion of the country's domestically-consumed electricity that is generated by renewables. In 2010, when renewables represented only 17 percent of all electricity generated, this was not such a significant addition. But renewables now provide around 33 percent of electricity. That translates into a higher charge for consumers. However, the surcharge is not increasing in a linear fashion since the feed-in tariff is being steadily reduced for new projects to compensate for falling investment costs.

The chart below shows that the forecast fall in the cost of electricity should more than compensate for the increase in the surcharge in 2016.

[18] Renewables surcharge rate 2016, Pg. 1 https://www.bmwi.de/English/Redaktion/Pdf/renewable-energy-surcharge-in-2016-facts-and-background,property=pdf,bereich=bmwi2012,sprache=en,rwb=true.pdf

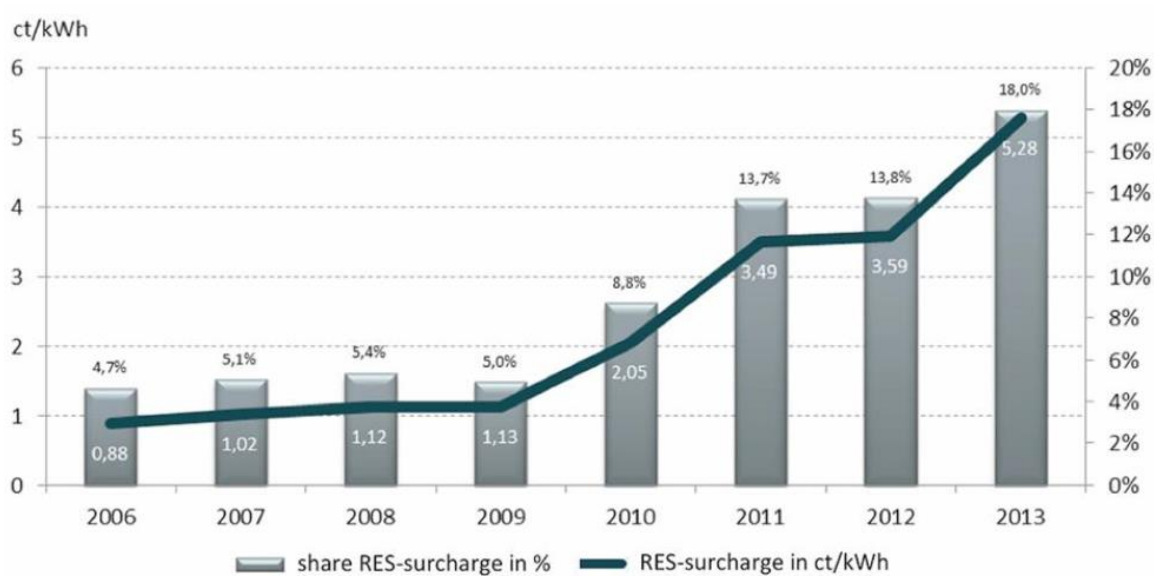

Chart 5. Renewable surcharge in final power costs. Source: Nordensvard/Urban, 2015 – The Stuttering Energy Transition in Germany. Energy Policy, Vol. 82: 156-165

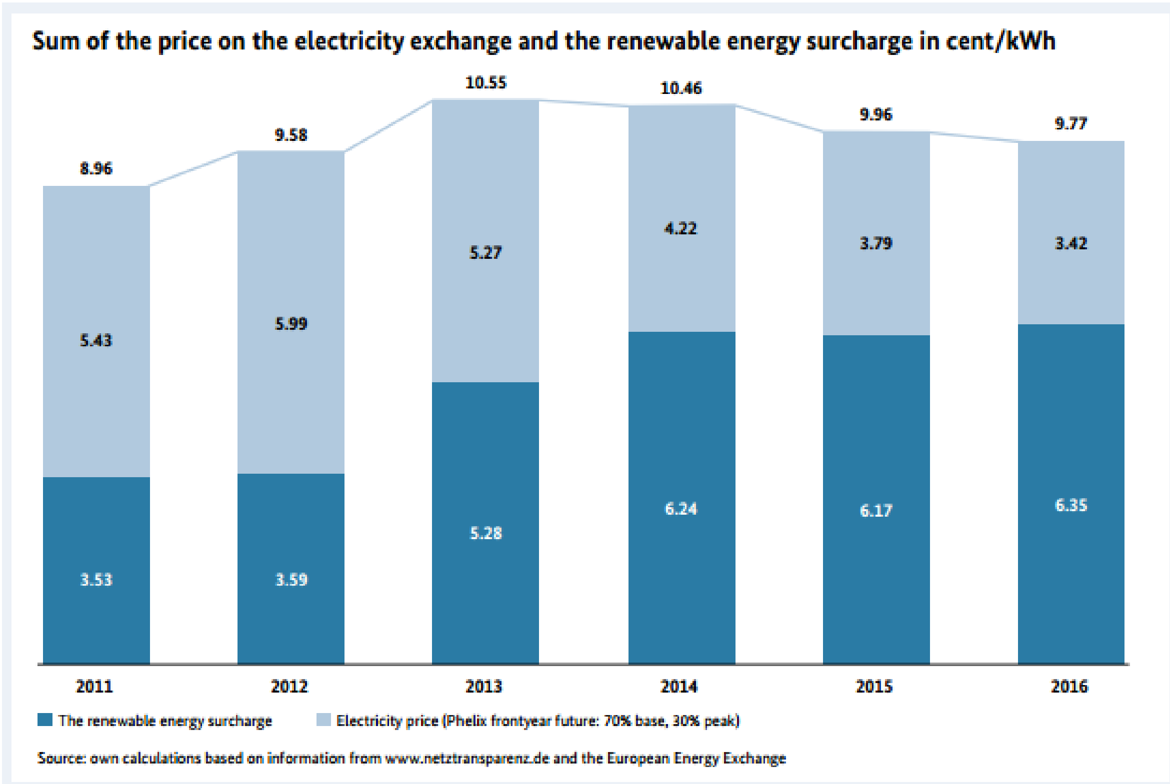

Chart 6 – German Ministry of Economy and Energy[19]

Total surcharges contributed by consumers for the feed-in tariff amounted to around 23 billion euros in 2015.[20] In 2014, when surcharges totalled a lower 20 billion euros, Economics Professor Gert Brunekreeft put the average cost to households at around 218 euros for the year[21]. It is not clear which charges and taxes his report takes into account since Chart 6 would suggest surcharges are falling slightly.

[19] Chart X https://www.bmwi.de/English/Redaktion/Pdf/renewable-energy-surcharge-in-2016-facts-and-background,property=pdf,bereich=bmwi2012,sprache=en,rwb=true.pdf

[20] 2015 Feed-in tariff total https://www.bundesregierung.de/Content/DE/Artikel/2014/10/2014-10-15-eeg-umlage-2015.html

[21] Surcharge cost per household http://theconversation.com/germanys-green-power-surge-has-come-at-a-massive-cost-33202

The kilowatt-hour rate of the feed-in tariff paid to wind energy producers as defined in the 2014 update of the Renewable Energy Act is 4.95 euro cents but with a higher 8.9 cents in the first five years to enable developers to recover capital invested more quickly. Solar feed-in rates ranged between 9.23 cents and 13.15 cents depending on the size of the project.[22]

Loading more of the financial burden onto industrial consumers would likely prove politically challenging, with lobbies likely to fight hard against bigger contributions based on the fact that industry pays the third-highest rates for power in Europe after Italy and the UK at 14.9 euro cents per kilowatt hour. The EU average is 11.9 cents. Around 2,305 companies in total[23] are virtually exempt from contributing, purportedly to prevent higher power costs putting them at a disadvantage internationally.

As a recent article on the Renewables International portal commented, wholesale power prices have fallen between one and two percent since 2011, making industry objections to losing their exemption more difficult to justify. It also notes that 116 companies are close to the threshold below which they would no longer consume enough power to qualify for the exemption. Should they slip beneath it, their power bills would surge as a result. That therefore kills any incentive they might otherwise have to invest in energy efficiency. This kind of problem could be avoided with a sliding-scale of fees under which exemptions would alter gradually according to consumption.

In an article[24] by Nordensvard, J. and Urban, F., 2015 'The stuttering energy transition in Germany' published in *Energy Policy*, Vol. 82: 156-165, it notes that consumers are not yet benefitting from the falling price in electricity which their subsidies have helped to bring about.

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[22] Pg 31 Feed-in tariff rates http://www.bmwi.de/English/Redaktion/Pdf/renewable-energy-sources-act-eeg-2014,property=pdf,bereich=bmwi2012,sprache=en,rwb=true.pdf

[23] Industry feed-in tariff exemptions total (in German, refer to "Frage 9") http://www.bmwi.de/BMWi/Redaktion/PDF/P-R/Parlamentarische-Anfragen/2016/18-7961,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf

[24] Nordensvard and Urban, The Stuttering Energy Transition in Germany, 2015. Pg 10. http://eprints.soas.ac.uk/19701/1/Energy%20transition%20Germany%20manuscript%20Nordensvard%20Urban.pdf

The article says utilities companies are buying electricity on the power market place at lower and lower rates as renewables, whose fuel is free and marginal cost close to zero, undercut conventional generators. However they are not yet passing on these reductions to distribution companies with whom they have fixed contracts.

“Energy providers and utilities buy the cheap electricity on wholesale markets and sell it at expensive consumer prices; despite a reduction of the wholesale electricity prices,” the Nordensvard study notes.

The same authors also question whether the subsidies paid may be too generous and impede entrepreneurial innovation by failing to expose producers to greater economic pressures that would spur efforts to decrease costs further.

It is curious that renewables are unable to undercut conventional power producers since they still have a similar levelised cost or production cost spread over their projects’ lifetime, even if they have a negligible marginal cost to produce power. This research has not been able to identify the explaining factors for that or obtain one from a renewables research institute with with which contact was made.

Since feed-in tariffs expire after 20 years, those projects which were guaranteed higher payments will be the first to be removed from the list of recipients as shown in Chart 7 below, meaning savings should quickly mount up when this period is reached, though projects were fewer in number in the earlier stages of renewables’ expansion.

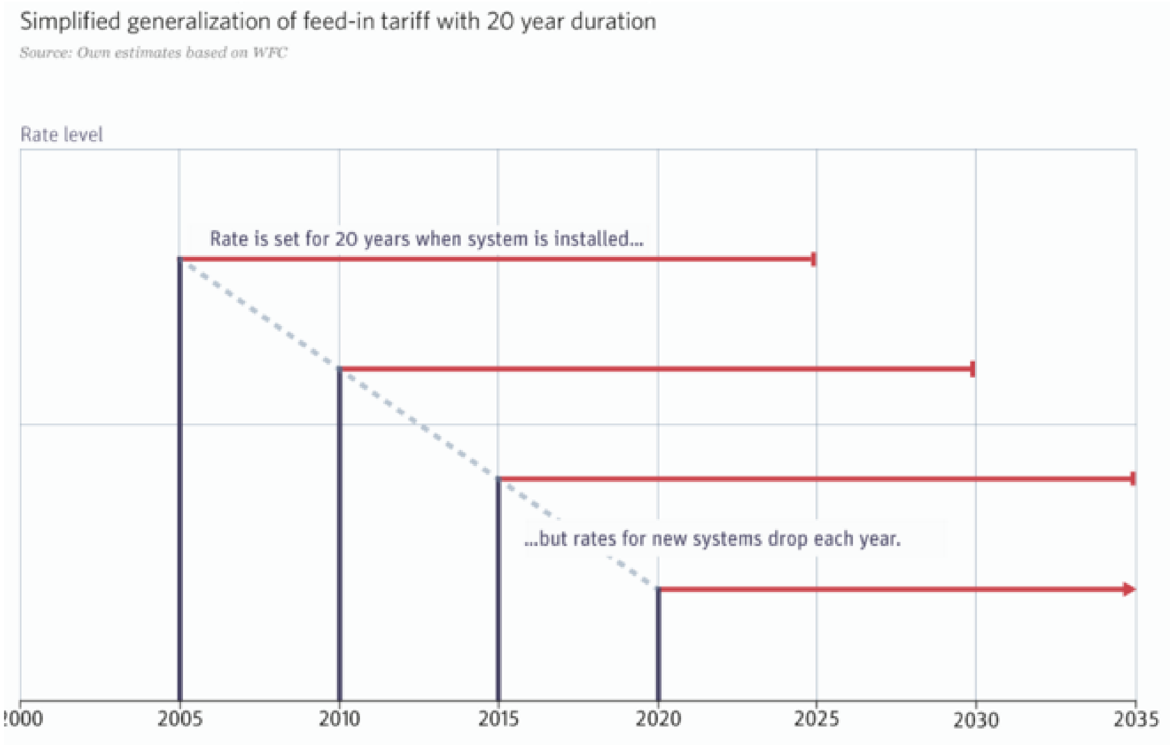

Chart 7. Source: www.energytransition.de [25]

The energy think tank Agora Energiewende has calculated that this will result in a gradual decline in the energy surcharge from 2023 onwards and that the amount consumers pay towards it will drop by 30 to 60 percent, adjusted for inflation, from then until 2035. It calculates that despite a levelling off of the surcharge since 2014, it will continue to increase from 2017 to 2023 by one to two cents per kilowatt hour.

Its briefing[26] argues that this marks a short period of "moderate burden" for Germans who stand to gain from cheaper, cleaner electricity in the post transition phase.

[25] Feed-in tariff chart http://energytransition.de/2012/10/renewable-energy-act-with-feed-in-tariffs/

[26] Quote from head of Agoria Energiewende think tank https://www.agora-energiewende.de/en/press/agoranews/news-detail/news/energiewende-kostenscheitel-in-sicht/

“The big power price rises caused by the expansion of renewable energies are a thing of the past, and the time to reap the fruits of these initial investments is nearing,” wrote Dr. Patrick Graichen, the think tank’s director.

The gradual curtailment of the first, higher subsidies granted which can then be allocated to new projects is immensely positive since the same some can now subsidise a much larger addition of capacity, due to lower rates paid, in turn reflecting lower costs.

Though there is much debate about the cost of subsidies towards renewables to households, Pegels and Lutkenhorst of the German Development Institute argue in a 2014 article that the public pays roughly the same in subsidies towards fossil fuels and nuclear but that this is rarely realised.

“The subsidies provided by the FiT are not higher than the subsidies paid per unit of electricity generated from coal and nuclear power. In essence, a visibility bias is at work here. While the subsidies for renewables appear explicity as electricity surcharge on the power bill of end consumers, subsidies for conventional energy sources are embedded in state budgets.”

The positive take-away from this statement is that while subsidies have been an integral part of the economic model of conventional fuels, they are intended to be temporary in the case of renewables and to be phased out once their cost falls to a sufficient degree. That means in the long-term the transition to renewables will eventually end this economic burden on public coffers. The article cites tax cuts and management of nuclear waste disposal as two such subsidies.

Though there is no question that German power prices are comparatively high in Europe, there is debate over the extent to which the cost of the energy transition is burdening consumers, particularly the lowest income families for whom electricity represents a larger share of their income.

While some have gone as far as branding the renewables surcharge as spiralling “out of control”[27] others analysts say in an economy of Germany’s size, the 20 or so billion euros annual spending on subsidising renewables, paid from householders’ pockets, is not a major cause for concern and a price worth paying for the social and ecological benefits it brings and the financial ones, even if they will only come later for consumers.

[27] Surcharge cost “out of control” http://www.ft.com/intl/cms/s/0/4b5ec792-252e-11e3-b349-00144feab7de.html#axzz4BC9ilmNO

2.4 Reforms to the Renewable Energy Act

In a bid to slow the rise in the surcharge, in 2014 the government introduced revisions to the renewable energy act governing feed-in tariffs, as described in a factsheet by economic consultancy Oxera[28].

The most important change is the abandonment of a feed-in tariff set by decree in favour of one set by auction. Developers who bid to receive the lowest feed-in will win the right to build projects offered to them.

The government plans to hold three to four such auctions each year and it will now designate the areas in which renewables are to be constructed rather than leaving this up to entrepreneurs. Importantly, under the auction system the government will now control the renewables capacity that can be built each year by using target bands or 'breathable caps' for the deployment of renewables. These will begin at 2.5 gigawatts per year for solar and 2.8 gigawatts for onshore wind.

The 'breathable caps' or target bands have a mechanism that boosts financial incentives should new renewables capacity fall below the lower end of the new bands due to lack of interest by developers.

A 2.8 gigawatt target for annual new onshore wind capacity would mark a significant reduction after growth of between 3 and 4.7 gigawatts per year from 2013 to 2015. For solar on the other hand, the government may actually have to increase the level of subsidisation it currently offers through fixed feed-in tariffs to increase new photovoltaic capacity, since this has plummeted to half its target level at around 1.3 gigawatts now.

Solar installations have nose-dived after the government make draconian cuts to feed-in rates after sharp drops in the cost of solar panels of around 60 percent between 2008 and 2014[29]. It

[28] 2014 reforms to EEG Renewable Energy Act http://www.oxera.com/getmedia/87c47c7d-d209-4936-9344-d054fe0aad4f/Almost-a-reform.pdf.aspx?ext=.pdf

[29] Drop in solar costs. Pegels, Lutkenhorst, Pg 4. www.die-gdi.de/uploads/media/Pegels_Luetkenhorst_2014.pdf

was prompted to do this because investors were pocketing a large profit when they received the feed-in tariff towards the end of that period because the government had not been able to lower the subsidy rate enough, having, like analysts and industry, failed to predict such a rapid decline in costs. The resulting financial attractiveness of solar had led to a staggering 7.5 gigawatts of installed capacity in 2011 alone[30].

The first auctions for rights to build renewables were held in 2015 as a pilot and only solar projects were on offer. The winners at the auction actually made bids that were slightly *higher* than the current feed-in tariff[31], when it was believed auctions would under-cut the current level of state support.

The Energy Ministry says in a written summary of the auction plan[32] that the change aims to ensure financial support is at a level just high enough to stimulate private investment but no more, to ensure value for money for consumers. The measures will take effect if they are approved by the German parliament, the Bundestag, and its counterpart, the Bundesrat which is akin to an upper house or senate.

Overall for solar, the energy transition is already nearing an end in terms of subsidies in any case. No further feed-in tariffs will be offered for new solar once total installed capacity reaches 52 gigawatts. That leaves around a dozen gigawatts more to be installed, a level likely to be reached around 2020 in accordance with the target bands for renewables, giving the technology time to become even more competitive and ensure it can compete with other power sources without subsidisation.

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[30] Solar subsidy cuts http://www.reuters.com/article/us-germany-solar-incentives-idUSTRE81M1EG20120223

[31] Wind power auction rate higher than feed-in tariff http://www.renewablesinternational.net/german-pv-auctions-told-you-so/150/452/87253/

[32] Energy Ministry guide to auctions system http://www.bmwi.de/English/Redaktion/Pdf/eckpunktepapier-eeg-2016,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf

As the chart below shows, solar claims the largest share of feed-in tariffs at present.

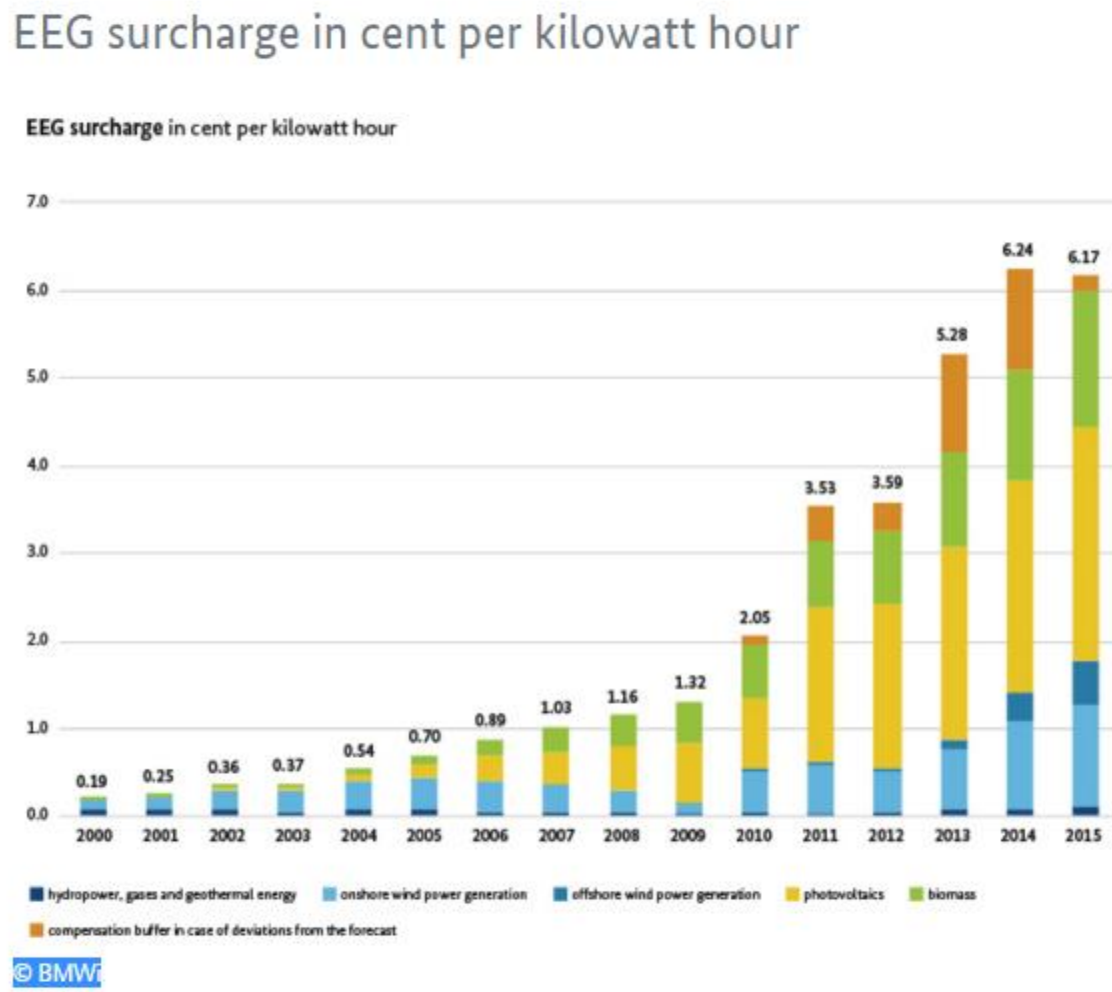

Chart. 8 EEG surcharge in cents per kilowatt hour

Source: bmwi.de Web site of Federal Ministry of Economic Affairs and Energy

A report by the Federal Network Agency which manages the grid, shows that a total of 85.3 gigawatts of renewable power capacity was eligible for the feed-in tariff by 2014, double what it was five years earlier.

Another regulatory change is that producers of renewable energy for self-consumption with installations larger than 10 megawatts, will have to pay the renewable energy surcharge that pays for feed-in tariffs, on the energy they are producing themselves, albeit at a discounted rate. This is to prevent the base of contributors who pay towards the cost of the energy transition from shrinking excessively as self-production and storage expands. That would risk leaving national grid operators unable to cover costs, especially at a time when huge investments in expansion are necessary.

In an attempt to integrate renewables into the regular electricity market, new projects will have to sell their power via the spot electricity exchange market from 2017. They will continue to receive the feed in tariff by receiving the average of the monthly differential between the spot market price and the guaranteed feed-in tariff rate. Articles on this mechanism do not explain clearly exactly what this means.

In reaction by industry and NGOs compiled by the Clean Energy Wire portal, environmental campaigner Greenpeace has said the changes could push smaller players out of the market and that this could jeopardise the achievement of Germany's climate targets. The German wind energy association in turn has said the target bands will constrain its industry and prevent it from deploying capacity fast enough to compensate for the upcoming loss of the remainder of Germany's nuclear plants. It says the cap on wind power should be at least 30 percent higher.

2.5 Neglected transmission grid

Another key criticism levelled at Germany's energy transition, is that it has too narrow a focus on stimulating renewables' capacity growth, creating a lop-sided energy transition that has not been accompanied by investment in transmission to deliver this new, cleaner power. It is not exclusively a flaw in the energy transition's design however, as the 2011 Energy Package of legislations do contain provisions for an expanded transmission network. It is in part due to disputes between states or 'lander' as they are known in German and the federal government in Berlin which have apparently now been resolved since a deal between partners in the government coalition in July 2015 ended this friction[33].

Slow grid expansion did not pose major problems while renewables remained a niche source of power. But now with increasing quantities of wind power being generated in the windier north, far from industrial consumers in the south and west, lack of transmission is rapidly turning into a major bottleneck. In fact it threatens to put a brake on the rapid growth in renewables witnessed in the last five years, given that existing transmission capacity is now often saturated and because of the long lead times needed to expand the network.

Economy and Energy Minister Sigmund Gabriel commented on this in a speech in May 2016, as reported by the Deutsche Welle news agency[34].

"We've got into an absurd situation," Gabriel said. "We produce cheap electricity in the North [of Germany] and cannot bring it to the South [because of insufficient transmission capacity], then we buy the electricity a second time from other [fossil-fuelled] power generators as a result, and then offload the redispatch costs onto end-consumers."

As the Deutsche Welle article notes, he was referring to the fact that wind power producers are paid for the power they are unable to transmit due to infrastructure bottlenecks, inflating the

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[33] Federal gov't, lander deal on transmission lines http://www.reuters.com/article/germany-energy-coal-idUSL8N0ZH50V20150702

[34] Gabriel on transition slow-down http://www.dw.com/en/germanys-shift-to-clean-power-fast-or-slow/a-19296798

final cost of electricity provision. Though investments in new transmission capacity will require enormous amounts of capital, they will at least be offset to some degree by avoidance of these double payments.

The bottleneck problem has become serious enough for the government to consider excluding certain northern regions from future onshore wind power auctions if local grids are already struggling to keep up with large volumes of renewable energy supplies,"[35] which they are not able to offload to other regions via the transmission network.

Wind producers are also occasionally forced to curtail wind generation when gusts are stronger due to insufficient transmission capacity. The amount of energy unused for this reason tripled to 1,581 GWh in 2014 over the prior year.[36]

This also raises questions over how Germany can possibly develop its offshore wind technology, another segment with huge export potential, if north-south connections are already saturated.

The Nordensvard article says an inadequate grid has become the No. 1 concern within the Germany's power industry.

"The large majority of interviewees suggested that the main bottleneck for the Energiewende is the out-dated and under-funded grid, not the size or state of current wind energy technology in Germany," comments the Nordensvard study, based on 18 qualitative interviews with experts from energy firms, business associations, research organisations and the government.

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[35] Germany may exclude some regions from wind power auctions
http://www.bloomberg.com/news/articles/2016-05-16/germany-just-got-almost-all-of-its-power-from-renewable-energy

[36] Federal Network Agency report on grid
http://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/BNetzA/PressSection/ReportsPublications/2015/Monitoring_Report_2015_Korr.pdf?__blob=publicationFile&v=4

It concludes: “The key policy recommendation we suggest is that mechanisms for fostering wind energy innovation and technology in Germany should go beyond focusing on feed-in tariffs only for up-scaling of turbines and core technologies and should aim to promote and finance deployment technologies and systems integration technologies, most importantly with regards to improving the aging grid system and enhancing grid integration.”

The cost of the construction and operation of the grid is paid for by electricity consumers through network charges added onto their bills and construction is carried out by transmission system operators (TSOs), private companies running the grid on a concession basis, according to the Federal Network Agency. Germany’s four TSOs are 50Hertz owned by Belgian grid operator Elia, Amprion owned by a German consortium, Holland’s TenneT TSO and TransnetBW owned by German utility EnBW.

2.6 Renewables' weather-dependent volatility

The biggest weakness of wind and solar power is their intermittency - solar for obvious reasons can only generate energy for up to half of the day. Wind in turn can vary in intensity during the course of the day and in longer-lasting seasonal patterns.

With Germany's power still predominantly provided by fossil-fuels, this has not yet become a problem for Germany. But with a goal of meeting 80 percent of all energy needs including transport and heating as well as power, from renewables by 2050, Germany is likely to need an almost carbon-free power mix by then, given that eliminating fossil fuels is likely to be more difficult for those other two uses.

The government has yet to define a strategy for how it will maintain grid stability as renewables grow and with them, inevitable daily peaks and troughs of power generation, but expanding cross-border grid connections and investing in storage capacity are the main options.

The Agora Energiewende think-tank argues in a 2013 paper, "12 Insights on Germany's Energiewende" that grid expansion is the most economically-efficient means to stabilise power availability compared to "prohibitively expensive" grid storage options and it would provide greater means to export power surpluses which the article forecasts will increase to as much as 41 gigawatts at any one time by 2030, or about half of Germany's current peak power usage. Earnings from those sales will help offset some of the heavy cost of expanding transmission capacity.

Indeed, the European Union has set a 2020 target of achieving interconnections capable of exchanging 10 percent of the bloc's total power production, between member states, in part to boost competition and lower prices in some states.

An EU-funded study by a consortium of experts and stakeholders has concluded that grid expansion across the bloc at a level that will be adequate to make a very low-carbon economy possible by 2050, will require investments of between 100 and 400 billion euros[37].

However, a grid with denser cross-border connections will save consumers between 12 and 40 billion euros a year by 2030[38], it estimates. The savings will derive in part from the avoidance of using peak capacity generation, basically the more costly forms of generation which power networks use to cover daily periods of peak demand, by importing surpluses generated at lower cost.

In terms of storage, the one technology that has existed for decades is 'pumped hydro', which involves using off-peak surplus power to pump water up a gradient to a second reservoir at a higher altitude, then to release this water back down again through hydroelectric turbines during peak hours. (See photo below). Operators pocket the difference between the off-peak purchase price and peak-hours sales price. The systems consume more power than they produce but only consume it when there is a surplus and can displace fossil fuels for peak power generation.

[37] EU grid investments http://www.e-highway2050.eu/fileadmin/documents/e_highway2050_booklet.pdf

[38] EU grid interconnections 2020 target http://eur-lex.europa.eu/resource.html?uri=cellar:a5bfdc21-bdd7-11e4-bbe1-01aa75ed71a1.0003.01/DOC_1&format=PDF

(Photo: Vattenfall)

But just as Germany begins to study options for storage, it is already beginning to lose some of its pumped storage capacity, not because the technology in itself has no future role, but rather because it is unable to find one in the interim while fossil fuels and renewables exist side-by-side.

As an example, utility Vattenfall was preparing to close one of its pumped hydro facilities in 2013 due to the fact that prices for power during peak demand times, one of which is around midday, have collapsed due to the surge in solar power now being harvested around that time.

In a report by Der Spiegel newspaper that year, it quoted Vattenfall's CEO as saying that the plant operated for only 277 hours in 2012, down from 2,784 hours in 2009 since price peaks that made it profitable to operate, were by then only occurring for a few hours a day. It did not see economic sense in making the 150 million euro refurbishment the facility required.

At the same time, some experts see pumped hydro as playing an invaluable role once renewables are the dominant source of generation.

"Pumped storage power plants should be given first priority, because they are the only existing industrial-scale power storage systems and, beyond that, also make many valuable contributions to the power grid. We have to adapt the framework conditions in such a way, that this added value is also adequately remunerated," Stephan Kohler, Chairman of the Board of the German Energy Agency was quoted as saying in 2014 in an industry publication[39].

Recent comments reported by the Greentech Media website suggest a government-funded study now under way into energy storage is likely to recommend a strategy for energy storage with a significant role for converting surplus power into heat which can be used to supply hot water to houses. Demand-side management which aligns industrial consumption to fluctuations in power availability, is also likely to have a prominent role in grid stabilisation, the site reported, based on comments from the study's coordinator, Christoph Pellinger[40].

Nonetheless, Germany has so-far rejected demand-side management at household level through the use of smart meters in homes that enable consumers to monitor power use on a digital display and defer consumption, for example use of washing machines, when it shows that peak power rates apply. This practise on a national scale, is known as load-shifting. A government-commissioned study[41] carried out by the multinational Ernst & Young study did not convince policymakers that the cost of rolling-out the meters was justified by potential savings.

Developing capacity to store power will become increasingly important, though it may not be clear for some time how much is needed, since this will depend on densification of the grid nationally and internationally.

As renewables expand, their higher priority on the merit order means it will become increasingly difficult to regulate generation since coal-fired plants are difficult to turn up and down over the course of a day. These plants are designed to provide a constant supply for the

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[39] Support for pumped hydro storage http://www.waterpowermagazine.com/features/featurepumped-storage-the-future-in-germany-4291865/

[40] Grid storage http://www.greentechmedia.com/articles/read/batteries-will-not-be-the-future-of-grid-balancing-in-germany

[41] Smart meter study http://www.bmwi.de/English/Redaktion/Pdf/cost-benefit-analysis-for-the-comprehensive-use-of-smart-metering-systems,property=pdf,bereich=bmwi2012,sprache=en,rwb=true.pdf

grid, known as base load, while other more flexible natural gas has traditionally been useful as a means to meet the daily spikes in demand around midday and early evening.

Reassigning fossil fuels to the role of providing additional, variable power rather than round-the-clock 'base load' will pose a technical challenge that will need to be carefully managed as it is gradually phased out in the coming decades.

The European Commission and International Energy Agency had predicted that network balance would be in jeopardy once intermittent renewables exceeded 5 percent of the power mix but this level has been surpassed many times over and Germany still has one of the world's most reliable power supplies with outages totalling just 12.3 minutes in 2014[42] according to Germany's Federal Network Agency, the Bundes Netz Agentur.

The phasing out of fossil fuels is also likely to need to careful management on a financial level also. An article[43] by the Economist magazine in late 2013 when Germany's renewables capacity was significantly less, said utilities had become one of the worst-performing sectors on European stock markets, with their value falling by half since 2008, due in part to deteriorating profitability with the expansion of renewables. It noted that utilities tended to make most of their profit through sales of more expensive peak-hours power, but increased availability of midday solar had diminished the premium for this electricity over base load prices, by three quarters.

These difficulties will be discussed further in the section covering the state of coal-fired generation.

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[42] Total power outages
http://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/BNetzA/PressSection/Reports
Publications/2015/Monitoring_Report_2015_Korr.pdf?__blob=publicationFile&v=4

[43] Utilities drop in value http://www.economist.com/news/briefing/21587782-europes-electricity-providers-face-existential-threat-how-lose-half-trillion-euros

2.7 People power – feed-in spurs community-level investment

One novelty of the German energy transition lies in the fact that it has thrust a new actor into the limelight in an energy sector until recently the preserve of large utility and transmission companies – that of communities and households.

Around half[44] of the solar capacity of Germany, the world's second largest despite its northern European climate, is fixed to the rooftops of homes and businesses and owned by the occupants. This is positive as a demonstration of strong public desire to reduce the environmental impact of individuals, not that this has ever been in question in the case of Germany, though the energy transition's design has until recently also offered very appealing incentives in the case of solar in particular.

This is a positive trend in that rooftop installations makes efficient use of space, avoiding or reducing competition for land with agriculture which is a risk with utility-scale projects.

On the other hand, the sheer volumes of solar power produced by households throws up a problem which governments the world over will face as renewables displace fossil fuels. Power produced and consumed on-site reduces the amount that is required from the grid.

Since consumers pay towards the upkeep of the grid based on the amount of power they consume, this reduces the contribution from those who produce their own. Unless there is a policy change, that will eventually likely lead to an increase in the kilowatt-hour rate paid towards transmission and distribution, which will impact low income households who are more likely to be wholly reliant on grid power.

The upcoming move towards an auction-based model for determining feed-in tariffs will not apply to households whose rates will continue to be determined by decree.

[44] Citizen share in solar ownership http://energytransition.de/2013/10/citizens-own-half-of-german-renewables/

2.8 The European Emissions Trading Scheme's role … or the lack of one?

The European Emissions Trading Scheme or ETS is a pioneering project which no other region of the world has so far been able to emulate on a similar scale, but its effectiveness has so far been disappointing due to miscalculations during its inception over predicted market performance. This has led to carbon prices so low that they now provide little stimulus for stakeholders to make serious efforts to decarbonize their business activities.

The role the cap-and-trade-based ETS should be playing in Germany's energy transition is to tweak costs and benefits such that reducing the carbon intensity of industrial activity, is made more financially attractive.

With ceilings for companies' carbon emissions set by sector, the carbon market obliges enterprises to either invest in reducing their own emissions, or buy carbon credits if that is a cheaper. This economic pressure is supposed to be maintained at a constant level by annual reductions to the amount of carbon that can be emitted without cost.

Companies whose emissions exceed their sectoral limit must buy credits from other companies who have not used their full allowance, either due to slower activity or through their investments to reduce emissions. This internalises some of the cost of pollution by penalising heavier carbon emitters while financially rewarding those who make cuts.

Reducing emissions on a European level means all member states' industries are subject to a similar financial burden, enabling them to decarbonise while maintaining a level playing field for businesses inside the bloc. Two thirds of EU members' foreign trade is with other countries in the bloc.

The ETS has failed to apply the pressure its creators had foreseen nonetheless due to the fact that its limits have been made to comply with due to an over-allocation of carbon credits.

New rules that tighten the supply of carbon allowances or in other words force polluters to start paying for emissions above a lower threshold will be introduced – but not until 2021. In Germany at least, it already looks like an effective ETS may arrive too late to the game to be the main driver of the switch to renewables.

The cost dynamics of the renewable energy technology market, which has witnessed dramatic price falls in solar and onshore (not yet offshore) wind means both are expected to become the lowest cost source of power generation outright in every country.

A report[45] by the World Wildlife Fund (WWF) in 2014 calculated that dealing with low, ineffective carbon prices by imposing minimum rate would have the effect of shifting some of the cost of the German energy transition from households to industry since the latter would have the incentive to invest in renewable power as conventional power would cost comparatively more.

The European Commission says the surplus supply of credits on the carbon market was partly caused by the 2009 financial and economic crisis which caused recessions or slowdowns across Europe and due to high levels of 'imported' credits through offsets financed by companies within the EU but implemented abroad.[46]

As a short-term measure, the Commission postponed the auctioning for the 2014-2016 period of 900 million carbon credits, each of which represents one tonne of carbon to tighten the supply of credits and improve the market's functioning. This is a significant amount, even if this amount is spread over three years. Coincidentially it is roughly equivalent to Germany's annual total carbon emissions of around 912 million tonnes. **See Chart 10 on page 55.**

On top of this, the Commission plans to create a reserve fund which can inject or withdraw carbon credits to avoid excessive market volatility during unexpected spikes in demand or if supply of unused credits is unexpected inflated by higher-than-expected reductions in emissions.

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[45] WWF report on ETS carbon market http://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF-Studie_Den_europaeischen_Emissionshandel_flankieren.pdf

[46] European Commission ETS rule changes http://ec.europa.eu/clima/policies/ets/reform/index_en.htm

France is proposing to introduce a floor in the carbon price for French companies participating in the ETS, of 30 euros a tonne[47] versus a market price of around 6 euros a tonne in May 2016.

The lack of significant impetus from the carbon market to catalyse the shift towards renewable energies shouldn't necessarily be looked upon as a set-back for Germany's energy transition, since this transition was designed around this. It can even be argued that the ineffectiveness of the carbon markets made necessary the state's intervention to decarbonise power faster.

Pegels and Lutkenhorst suggest that the lead Germany has taken may have helped hasten recent piecemeal changes to the ETS as its decarbonising efforts weaken demand for carbon credits, and that the country's unilateral progress may translate more ambition on a European level.

"[T]he lower price of certificates opens political space for tighter ETS caps without threatening the competitiveness of companies. Without such tighter caps, however, the parallel operation of (Germany's) FiT (feed-in tariff) and ETS will crowd out the former's emission reduction benefits – at least for those emissions traded under the ETS," the authors conclude.

[47] http://www.theguardian.com/environment/2016/may/17/france-sets-carbon-price-floor

2.9 Slow-down in sight?

In mid-May 2016, a breath-taking headline appeared in news media that Germany had just come within a hair of supplying all its power needs from renewable energy for several hours.[48] The achievement was on a sunny Sunday afternoon when solar generation was high and demand low, but nonetheless, it was a major landmark in a country with a population of almost 90 million, even if on a day when much of its industry was idled.

It was rightly heralded as testimony to the success of the country's pioneering energy transition. But at the same time, Germany is showing increasing signs that it is planning to slow or curb the pace of the energy transition, for the reasons discussed above – its high cost and difficulties maintaining grid stability particularly until transmission infrastructure is improved.

The new target bands for wind capacity are set around the average level of installations of on-shore wind in the last few years yet in the case of wind, its effect may be to apply the brakes on the sector as it begins to accelerate. Installation figures for 2014 and 2015 from the German Wind Energy Association show that Germany added a higher 4.8 and 3.7[49] gigawatts of capacity respectively in those years so a cap of 2.5 gigawatts looks draconian. Analysts point out that the installations in 2013 and 2014 were boosted however by the inclusion of previously constructed projects that were awaiting grid connections, rather than capacity which underwent construction in those years.

The German Wind Energy Association also says there has been a rush to develop projects before the introduction of aforementioned auctions which will replace the feed-in tariff on utility scale projects.

"In 2017, radical changes resulting from the announced auctioning model pose a threat. We are extremely sceptical about these given the complexity of German construction and planning law

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[48] http://www.independent.co.uk/environment/germany-just-got-almost-all-of-its-power-from-renewable-energy-a7037851.html

[49] New installed wind capacity https://www.wind-energie.de/en/infocenter/statistiken/deutschland/installed-wind-power-capacity-germany

and the length of approval procedures," wrote Hermann Alberts, President of the German Wind Energy Association in the foreword of its 2015 Yearbook[50].

In the case of solar, feed-in payments will no longer be offered for new capacity once it expands by around another quarter to reach 52 gigawatts. The key question is whether solar deployment will continue unabated in the absence of subsidies, especially in light of the fact that it has already slowed due to a sharp reduction of subsidies. In fact, solar installations in 2015 plunged below even the government's 2.5 gigawatt target band to just 1.3 gigawatts according to the Fraunhofer research institute[51].

Though these moves look set to lead to a slowdown in new wind turbine deployment, in reality the impact may not be so important in the short term since lack of transmission capacity in the north of the country, the prime location for wind power, is saturated, meaning additional wind power generated there would struggle to be transmitted.

A Deutsche Welle press article and blog posts by energy economists note that the fossil fuel power industry has been lobbying the government for a slow-down in the energy transition because renewable power frequently undercuts their prices since wind and solar have almost no marginal cost except for maintenance, to produce electricity, only fixed costs.

RWE already announced in 2013[52] that it was closing fossil fuel power plants with a combined capacity of 3.1 gigawatts because wholesale power prices had fallen to the extent that they could no longer be operated profitably.

If RWE's power plants or at least some of them are no longer profitable, that raises the question of why the rest of Germany's coal fleet isn't also closing down, or at least devising a

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[50] German Wind Energy Association Yearbook https://www.wind-energie.de/sites/default/files/download/publication/yearbook-wind-energy-2015/wem_2015.pdf

[51] Germany solar capacity additions for 2015 https://www.ise.fraunhofer.de/en/publications/veroeffentlichungen-pdf-dateien-en/studien-und-konzeptpapiere/recent-facts-about-photovoltaics-in-germany.pdf

[52] RWE 2013 closure of fossil fuel plants. http://www.germanenergyblog.de/?p=13924

new economic model in collaboration with the government that ensures they can remain operational, as per their contractual obligations.

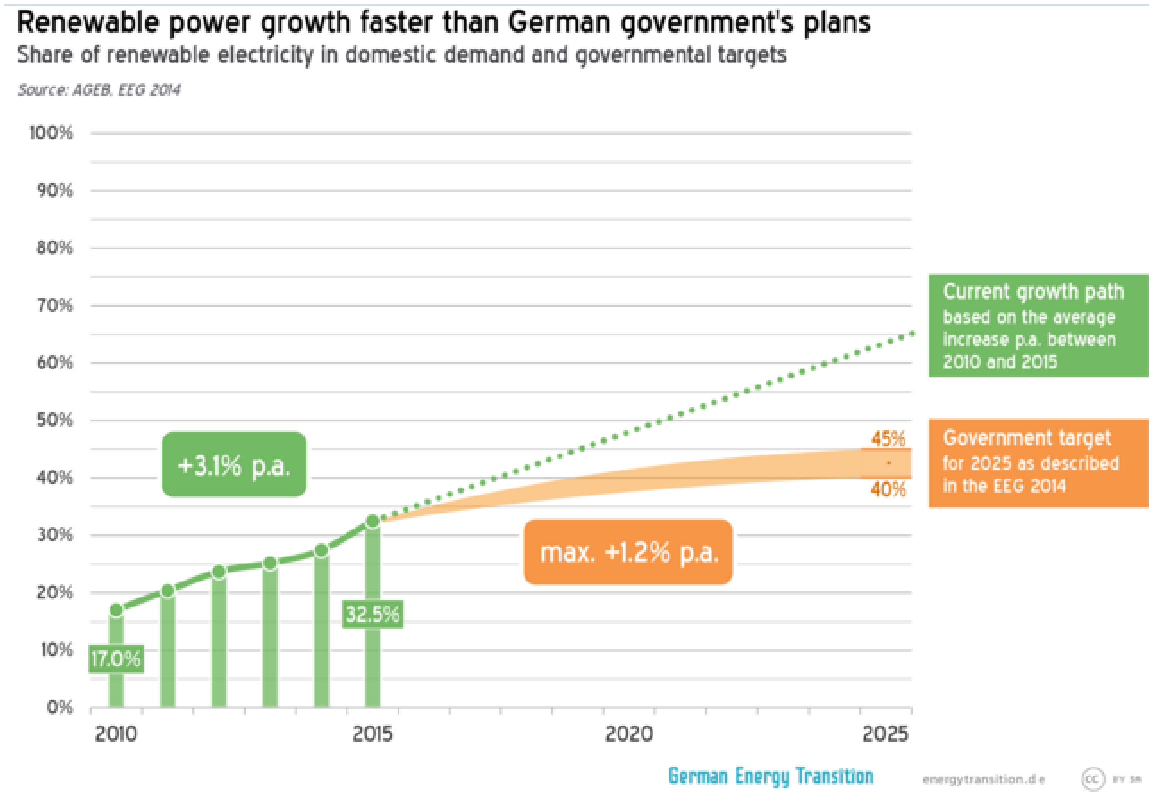


Chart 9. Source: http://energytransition.de/2016/01/germany-is-20-years-away-from-100-percent-renewable-power-not/)

3 The clean-dirty transition

After discussing the legal framework within which the transition is taking place, we will now take a closer look at the composition of Germany's power generation as it stands in 2016 and the paradox of stubbornly stable carbon emissions despite greener electricity. This section will look at difficulties in eradicating coal and lignite more quickly and why policymakers have not sought to promote natural gas to take on the role of a bridge fuel after the policy u-turn on nuclear.

The potential of the nascent offshore sector which is still a niche player in the transition will also be discussed along with a brief mention of the synergies a renewable power supply will generate as electrification of transport begins.

3.1 More renewables, yet emissions flat?

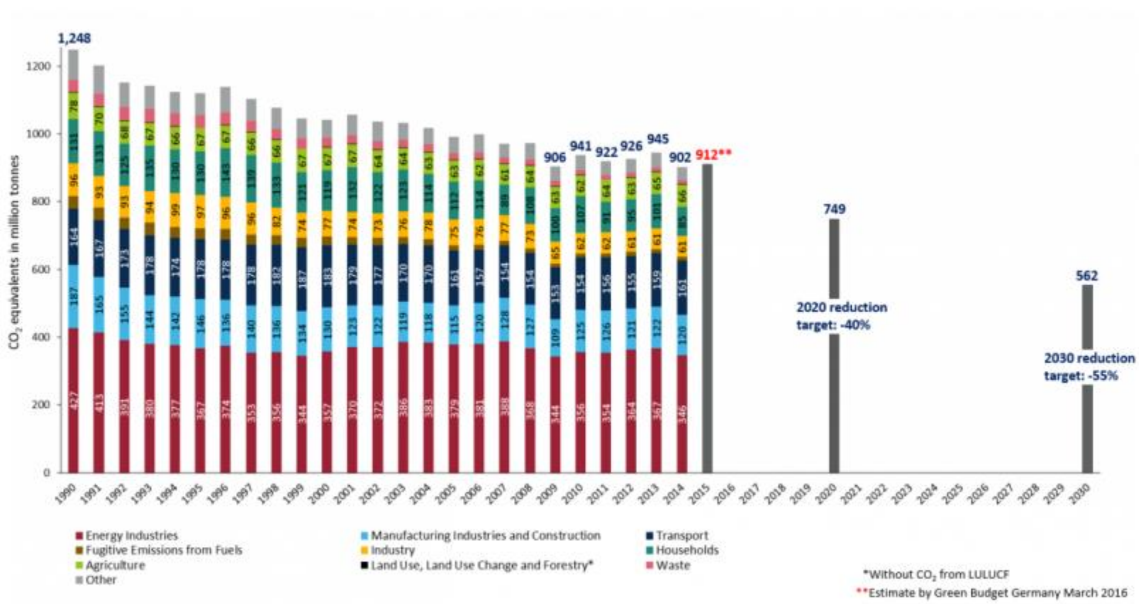
The paradox of Germany's energy transition is that the increase in the share of renewables in its power mix, despite having risen from 17 percent in 2010, to 33 percent in 2015, has not resulted in a significant drop in CO_2 emissions.

Some press reported that Germany was significantly ramping up coal-powered generation and that CO_2 emissions were on an upward trend as a result, but in reality coal power output has plateaued but will now take longer to displace from the power mix due to the lost nuclear capacity it is compensating for. As the chart shows, Germany's carbon emissions had been declining but this curve flattened out in 2011. A dip in 2009 was linked to slower economic activity in the midst of the unfolding global financial crisis.

More recently in 2015, there was another small increase in emissions following a significant 4.6 percent drop in 2014. Carbon emissions from power generation actually decreased in 2015 however and the rise was related to an increase in consumption of gas for heating and fuel for freight transport. Emissions from power might have fallen further were it not for the shut-down in 2015 of Germany's largest nuclear power plant, Grafenrheinfeld, with a capacity of 1.3 gigawatts. It was the first to close since the wave of nuclear closures in 2011.

The Federal Environment Agency said[53] record exports, which hit 50 terrawatt hours in 2015, preventing a greater reduction in fossil fuel power generation greater than was achieved. The Fraunhofer Institute says coal and lignite generation fell in 2015 by around 5 terrawatt hours. Since the 'merit order'rule ensures renewable power is consumed on the grid first, that means any surplus production for export is generated by fossil fuels whose output would automatically be lowered if there were not buyers for it abroad.

[53] Federal Environment Agency on 2015 C02 increase https://www.umweltbundesamt.de/en/press/pressinformation/uba-emissions-data-for-2015-indicate-urgent-need



Graph by Clean Energy Wire, data from German Environment Agency (UBA) and Green Budget Germany

2 The red segment shows emissions from energy industries

Chart 10 – German carbon emissions by source

The continued deployment of renewable energy since the decision to permanently close eight nuclear reactors shortly after the Fukushima disaster has added more generating capacity to the grid than was lost with their closure. However, additional renewable capacity is not yet enough to also start also displacing coal and lignite. With another eight nuclear plants to close by 2022, this will further delay the displacement of fossil fuels with renewables.

3.2 Easing off the gas?

Natural gas emits only half the CO_2 of coal to produce equivalent power (approx. 227 kg per MWh versus 414 kg for coal)[54], so why isn't Germany giving it preference as a 'bridge fuel' while renewables capacity climbs, after nuclear's fate was sealed in 2011?

Natural gas has a lot of advantages over hard coal and lignite. Besides its lower carbon emissions, it has greater flexibility as a back-up source of power for the grid with the ability to be 'ramped up' or increase output, faster than coal plants when there is a surge in demand.

The main problem is that natural gas is comparatively expensive compared to coal and gas prices rose sharply in the last decade. Its price has nonetheless been falling rapidly since early 2015 as the chart below shows so market behaviour could still change. European countries' domestic natural gas reserves have fallen however and Russian imports are rising again after a dip, accounting for 39 percent of the EU's gas imports in 2013.[55]

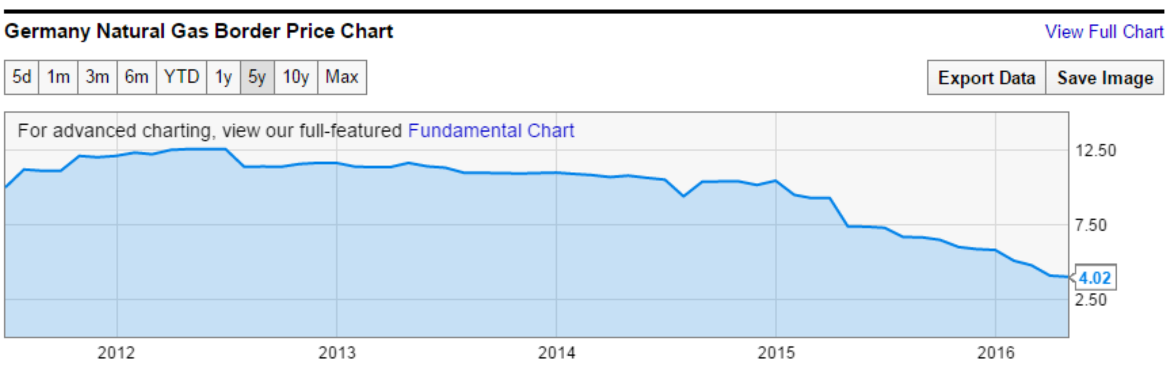


Chart 11. Source: ycharts.com [56]

[54] Gas and Coal – emissions http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,163182&_dad=portal&_schema=PORTAL

[55] EU Russian gas imports http://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_production_and_imports#Imports

[56] Germany gas prices https://ycharts.com/indicators/germany_natural_gas_border_price

Increased reliance on what would probably be mainly Russian gas would be a difficult policy to sell domestically given the high-profile examples of Russia using its gas supplies, and the abrupt interruption of them, as a political weapon. Russia is also under European Union sanctions though exports of oil and gas to the European Union are not subject to these. A major increase in gas imports from Russia would conflict to some extent with the economic pressure the EU is trying to exact on Russia through the sanctions.

The arrival of the first imports of shale gas from the United States in the European Union in April 2016, could increase competition in the market if the U.S. gains a foothold in the European market, potentially driving prices down, as could the ending of trade sanctions against Iran that could result in it eventually exporting gas to the European Union.

Germany's own gas industry, which by 2014 met only around 12 percent of domestic needs versus around 20 percent a decade earlier[57], says investment to recover shale gas resources in Germany is necessary to staunch the industry's decline, but it acknowledges this risky method of extraction faces overwhelming opposition.

According to a 2014 article[58] from the Oxford Institute for Energy Studies entitled 'The New German Energy Policy: What role for Gas in a De-carbonisation policy?', natural-gas fired plants, like coal, are compatible with carbon capture and storage technology, which is added to power plants to recover carbon emissions for storage, usually in liquid form in underground cavities such as disused oil wells. That means gas has the potential to have an even smaller carbon footprint than it does today. Questions remain over the fact that plants fitted with this technology are less fuel-efficient as a result, the main reason why the technology has generated little enthusiasm in the coal sector.

[57] German shale gas http://www.reuters.com/article/germany-fracking-idUSL5N0L41TO20140206

[58] Oxford Institute for Energy report on gas **http://www.igu.org/sites/default/files/node-page-field_file/the-new-german-energy-policy-decarbonisation-march-2014.pdf**

Gas –fired plants also have the benefit of being already-able to run on methane recovered from farms or landfill sites as well as renewable gases produced as a means of storing surplus renewable power, which the study says, makes investments in it ‘future-proof’ versus coal.

Nonetheless, about four times as much German power is generated from coal and lignite as it is from gas, chiefly because of its high price versus coal. The study suggests a European carbon price of 50 euros a tonne, instead of around 6 euros today, would be necessary to create an incentive for a switch away from coal and towards gas. The ETS carbon price has never risen beyond around 33 euros in its 11-year history.

The Oxford study acknowledges that raising the carbon price through whatever mechanism to that level is unfeasible as it would put European industry at an unacceptable disadvantage with rivals on other continents. It raises the idea therefore of raising only the price of emissions derived from coal but does not elaborate on how this might be implemented.

The idea has obvious merit from an ecological point of view but implementing a shift towards gas, some of which would come through the conversion of coal-fired power plants, might be difficult given the capital the private sector would need to invest at a time when power prices are falling and regulations for renewable power is shifting.

On top of this, forecasting the economics of a fossil fuel plant that will operate alongside an (eventually) majority renewables mix, is complicated further by difficulties predicting a typical average capacity factor for the plant (the intensity of use as a percentage of its maximum potential) since renewables have priority access to the grid.

The study suggests designing a system to compensate gas-fired power plants for the potential capacity they can offer to the grid at short notice, even if this is not actually called upon regularly, since grid stability is an asset of financial value in itself. That would give utilities operating gas-fired plants the assurance that they would at least cover their fixed costs.

Though gas is a much more costly option, the Oxford study argues that Germany’s elimination of coal would make it harder for developing economies like China and India to quibble over the urgency of doing away with coal, since at present they highlight its continued use in more economically developed countries.

A study by Germany's Öko-Institut showed that the deployment of renewables across Europe was pushing out natural gas generation, rather than coal, due to high gas prices which are deterring consumption.

"CO_2 emissions in the European power sector … could be lower by some 100 million tonnes if the decline in fossil power production since 2010 had been coal instead of gas."

That represents about 2 percent of total EU greenhouse gas emissions expressed in CO2 equivalent in 2013 (Eurostat)[59], a significant amount as the bloc seeks to achieve a 20 percent cut in greenhouse gas emissions by 2020.

The Öko-Institut study says coal-fired power generation accounts for three quarters of the European Union's carbon emissions, a startling figure but one which contains a nugget of hope in the fact that most coal-reliant European nations, with the possible exception of Poland and some smaller eastern states, have shown the political will to eliminate it completely. That will lead to dramatic carbon emission reductions when coal-fired plants begin to be shut down in greater numbers.

[59] EU total GHG emissions in 2013 http://ec.europa.eu/eurostat/statistics-explained/index.php/Greenhouse_gas_emission_statistics

3.3 The hard coal reality

Though gas supplies in Europe have tightened, oversupply and low prices have existed for around four years in the seaborne or international coal market. That market trades coal from Russia, Colombia, and South Africa among others[60], but it has been depressed by a surge in volumes of coal from the United States, where a switch to shale gas caused domestic demand for coal to plummet. Volatility or surges in now-depressed seaborne coal prices are less likely in as a result[61], which is positive for Germany given that it now imports most of the hard coal it consumes, even if lignite is domestically sourced.[62]

Germany's clean-dirty transition underscores the economic complexity of moving power supplies towards a technology which is still evolving, improving and falling in price and which demands massive up-front capital investments to be able to reap the benefit of free fuel (wind and sunshine).

The embracing of coal and lignite, while a highly questionable policy, providing 42 percent of total power in 2015[63], at least has the merit of leaving more economic resources available to invest in development and deployment of renewable energy than might be available if more money was channelled to gas-fired power generation. Though the transition may be a dirtier one with coal, the transition itself may be shorter with political pressure only likely to grow for the elimination of coal generation as soon as possible. A recent spate of protests blocking railways serving coal mines and invading to shut down mines themselves are evidence of this.

Germany's country-specific EU 2020 target is to reduce greenhouse gas emissions by 40 percent by 2020 (versus 1990 levels), giving it an external impetus to do away with coal. The

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[60] EU coal imports by origin http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

[61] Seaborne coal market analysis http://www.reuters.com/article/us-column-russell-coal-asia-idUSKCN0R412H20150904

[62] Germany coal imports http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

[63] 2015 power mix https://www.cleanenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts

German government sealed a plan in July 2015 to idle some of its largest lignite-burning power stations with a combined capacity of 2.7 gigawatts, but leave them available in case extra generation capacity is needed at some point. The utilities, Germany's publicly-listed RWE, Vattenfall owned by the Swedish government, and Mibrag operated by Czech private holding EPH, will receive a total of 1.8 billion euros to compensate them for profits they will forfeit over the seven years they will keep the plants on stand-by. After that they will be permanently closed.

The government also ended state-subsidised financing for the construction or modernising of coal-fired power plants at the end of 2014[64].

The rapid progress of renewables has caught business leaders and policymakers off-guard however. A Handesblatt article points out that utilities were making huge investments in fossil fuel power plants from around 2005, which CEOs now deem unprofitable as power prices plunge[65].

One example is the newly-constructed 1 billion euro Westfalen-D coal power plant owned by RWE, which is now unlikely to ever be switched on, while EON has applied to close two recently-opened gas-fire plants which it says are unprofitable.[66]

In all, 25 gigawatts of new coal capacity proposals were cancelled between 2010 and 2015 while only 1.1 gigawatts were under construction, according to the Sierra Club environmental foundation[67].

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[64] Fossil fuel subsidies https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/9954.pdf

[65] Investment in fossil fuel plants https://global.handelsblatt.com/edition/395/ressort/companies-markets/article/electricity-prices-in-a-free-fall

[66] http://www.bloomberg.com/news/articles/2015-12-23/brand-new-rwe-plant-is-latest-victim-of-merkel-s-energy-shift

[67] Coal project cancellations 2010-2015 http://sierraclub.org/sites/www.sierraclub.org/files/uploads-wysiwig/final%20boom%20and%20bust%202017%20(3-27-16).pdf

The merit order rule prioritising consumption of renewable power means that as wind and solar continue to expand, fossil fuel plants will be increasingly side-lined during times of lower demand, increasing their already financially precarious situation.

That sets in motion a self-reinforcing erosion of the competitiveness of fossil fuels: as their overall output diminishes when their capacity factor (total annual usage) falls, each kilowatt hour of power they produce becomes more expensive, since fixed costs are divided by a shrinking quantity of power produced. That higher marginal cost will further increase the competitiveness of renewables which should accelerate their deployment.

This trend, which Bloomberg New Energy Finance has referred to as a “virtuous circle” could be impeded from intensifying the roll-out of renewables however by the new target bands which limit the addition of new renewables capacity, as previously discussed.

Underscoring that Germany may be moving away from coal faster than the recent construction of a small number of new, more efficient coal-fired plants would suggest (by incorporating lower capacity factors into the calculation), is the government’s decision to end subsidised hard coal mining in 2018[68] which suggests an upcoming drop in consumption. Germany plans to rely solely on imports thereafter. One driver behind this is the higher cost of digging deeper to retrieve remaining coal reserves which are less accessible.[69] The closure of this very old industry however will imply costs to lessen its social impact. In 2012, around 17,000 people were employed in coal mining[70], the majority in the western Ruhr region.

While social pressure on a regional level over the forthcoming job cuts in mining areas may prove a challenge for the government, it is also coming under pressure from the opposite direction from those who are clamouring for an end to the burning of coal and lignite, as recent protests at mines and coal railways have shown.

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[68] http://www.bmwi.de/English/Redaktion/Pdf/germanys-new-energy-policy

[69] German coal getting more expensive to mine http://www.worldwatch.org/node/5834

[70] Oxfam German coal analysis
https://www.e3g.org/docs/Germany_G7_coal_analysis_September_2015.pdf

In fact, the government has faced protests in every direction it has sought to turn – over initial plans extend the life of nuclear power, over attempts to close coal mines down and then for failing to close down lignite mines. It is fair to say in the lengthy process of ending a deeply-entrenched fossil fuel path dependency, the government is limited in its range of options of 'bridge' fuels with the loss of nuclear capacity first.

Analysts concur that utilities companies are now paying a very heavy price for under-estimating the momentum behind renewables when they were still planning a panoply of new fossil fuel projects over the last decade.

Publicly-listed utility EON for example posted a record 12-month loss in early 2016 citing the collapse in German power prices caused by expanding renewables. This has prompted it to bundle the fossil-fuel generation side of its business into a separate unit called Uniper while it increasingly turns to investment in renewables and transmission[71].

[71] EON reports record loss http://www.ft.com/cms/s/0/b5fffac6-e5c5-11e5-ac45-5c039e797d1c.html#axzz4BfQnmVoN

3.4 Offshore wind

Though offshore wind relies on the same technology as onshore, it is otherwise quite different in economic, technical and even social aspects. Wind power is roughly twice as expensive as onshore wind power[72] though the differential has begun to decline. Additional costs arise from the difficulty of installing the turbines on the high seas and fixing their foundations in sometimes deep waters on the continental shelf.

Though the economics of offshore wind are unfavourable at present and the fact that there are mixed feelings in the wind sector about the merits of pursuing this power source given advances in onshore wind, the government has nonetheless fixed a target of reaching 6.5 gigawatts capacity by 2020 and 15 gigawatts by 2030. Offshore is at an earlier stage on its learning curve than onshore and solar and the industry believes that costs can be lowered significantly.

Though achieving these reductions and scaling up research and development will be costly, the idea has merit at a time when Germany is still at a fairly early stage in its energy transition and most of the world's developed countries lagging even further behind. This could translate into huge demand in years to come for German companies who can position themselves at the forefront of the market by innovating to lower costs.

Offshore sites will also be of increasing value as the number of prime onshore sites with the best wind characteristics begins to decline, as observed by the International Renewable Energy Agency (IRENA)[73].

Offshore wind can capture larger volumes of power by making use of bigger blades and winds over the sea tend to blow more consistently, providing power more reliably than onshore wind and potentially helping reduce the amount of storage capacity that will be required to

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[72] Onshore vs offshore costs http://www.windpowermonthly.com/article/1380738/global-costs-analysis-year-offshore-wind-costs-fell

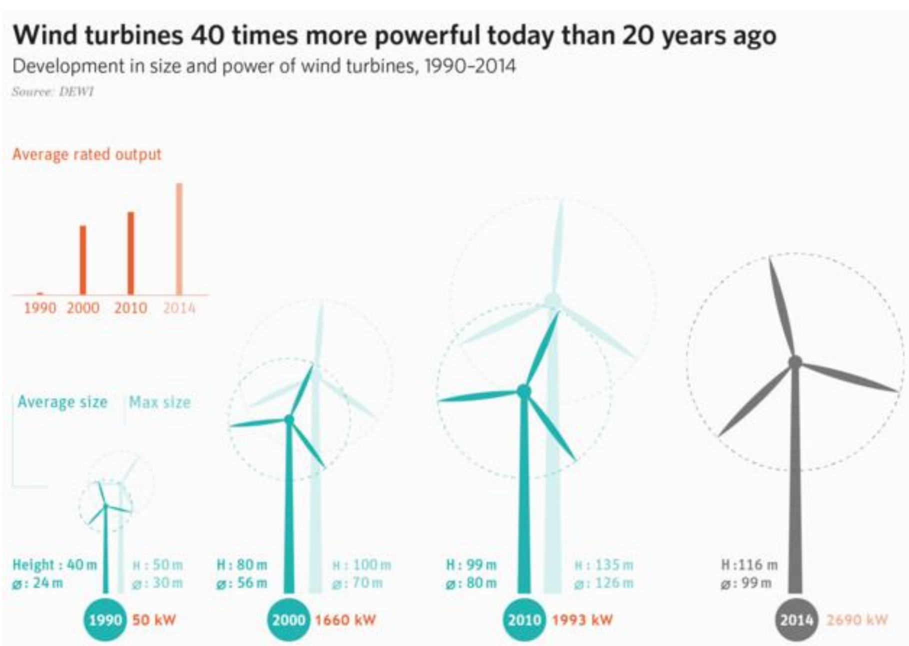
[73] Decline in prime onshore wind sites http://www.irena.org/DocumentDownloads/Publications/IRENA_Power_to_Change_2016.pdf

compensate for dips in renewables' output. One study[74] of Denmark's wind generation said the capacity factor of offshore wind was close to double that of onshore wind. That means the same wind turbine would produce nearly twice as much when located at sea.

A number of manufacturers are preparing to commercialise 10 megawatt wind turbines, whose maximum output would be dozens of times higher than onshore wind turbines of the early 1990s as the chart below shows.

One of the key hurdles facing the German offshore wind sector at present is the lack of north-south transmission capacity, a problem discussed earlier. However, given the long lead times involved in constructing offshore wind capacity, this problem should be closer to being resolved by the time they are nearing completion.

As of end 2014, according to Morris/Pehnt, Germany had one gigawatt of installed capacity with close to the same capacity under construction.



[74] Capacity factors offshore/onshore Pg 5, fig 6 http://cf01.erneuerbareenergien.schluetersche.de/files/smfiledata/3/1/7/2/7/1/V2BC37NhCFWindDK.pdf

Chart 12. Source: Energy Transition website http://energytransition.de/2012/09/renewables/

3.5 'Repowering'

Another interesting development in wind, onshore specifically, is that some turbine installations from the early 1990s are already nearing the end of their projected lifespan and are being replaced with more modern turbines occupying the same spot but yielding many times more power – a process known in the industry as 'repowering'. The above chart shows the advances in turbine technology and output. The German Wind Energy Association says that on average new turbines installed in the place of 20 year-old models are yielding four times more power due to a combination of improved efficiency and larger average rotor sizes, which is a major step forward given this is achieved without an increase in the use of land.

Capacity factor of Germany's onshore wind turbine fleet has risen in Germany by around 40 percent, according to IRENA[75].

[75] German onshore capacity factor growth Pg 57
http://www.irena.org/DocumentDownloads/Publications/IRENA_Power_to_Change_2016.pdf

Synergies – electrification of transport

There are many unknowns in the transition as it stands today, in particular regarding the possibility that new technological breakthroughs will improve the competitiveness of renewables and intensify the transition further still. Policymakers, analysts and industry alike mostly failed to predict the huge fall in the cost of solar power in the last decade and research continues to improve the efficiency of solar cells, the minute components in panels that generate power.

The development of a low carbon grid is also paving the way for a dramatic reduction in emissions in another sector – transport – as electric cars gradually turn into a mainstream mobility solution as battery prices plunge, driving ranges increase and rapid charging networks are rolled out. Germany aims to have 1 million electric cars on its roads by 2020, by when nearly half of its power supply could be carbon free, if not more.

The substitution of gasoline-powered cars with electric ones leads to an instantaneous cut in emissions, especially when charged with renewable power, given these cars' energy efficiency is about three times higher than that of internal combustion engines.

Because of their high efficiency, electric cars are not forecast to load a lot of extra demand onto the grid, (8 percent globally according to Bloomberg New Energy Finance)[76]. Moreover, a recent trend of falling power consumption in Germany and elsewhere means the capacity to charge a nationwide fleet of cars will be more easily met without creating a need for much more infrastructure. Plus, electric cars tend to be charged at home overnight, making use of power at the time when surpluses occur and power is sold at off-peak rates.

Electrification of transport which will be powered by an increasingly carbon-free grid will therefore instantly diminish carbon emissions from transport with each electric car and bus that replaces a petrol of diesel one. Transport accounts for nearly one fifth of Germany's total carbon emissions.

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[76] Electric cars' global power demand http://www.bloomberg.com/news/articles/2016-06-13/we-ve-almost-reached-peak-fossil-fuels-for-electricity

Electrified transport, much as with the learning curve for renewables power, still requires technological advances that will lower the cost and extend the power density of batteries, the vehicle's single most expensive component.

Germany looks unlikely to reach its 2020 target of one million electric cars on its roads (with only around 25,000 at present)[77] but it announced in April 2016[78] 1 billion euros in subsidies, or 4,000 euros towards the purchase price of each car, a measure that should speed progress towards that target. The subsidy emulates what Germany has been doing through the energy transition – using public money to stimulate demand for cutting edge technologies which have not yet matured to become economically competitive and for which there currently exists a cheaper rival, albeit one whose externalities are not paid for by the manufacturer or user.

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[77] Electric car registrations http://www.bloomberg.com/news/articles/2016-06-13/germany-needs-emissions-free-car-fleet-by-2030-official-says

[78] Electric car subsidies https://www.theguardian.com/world/2016/apr/28/germany-subsidy-boost-electric-car-sales

Conclusion and perspectives

Germany's energy transition has generated great excitement both within and beyond its borders and had considerable success. It is showing the world that a populous industrialised nation can move rapidly away from fossil fuels which harm the environment as well as human health, to a technology that has existed for centuries in windmills and another which most people first came to know as a mysterious purple strip that enabled their calculator to run without a battery.

The transition has also generated a fair share of anxiety and negative press as policymakers tread unchartered waters to manage the deployment of technologies which will up-end long standing business models in the power sector.

Though Germany has made some astounding achievements in terms of renewables deployment, putting more solar panels under its (often grey) skies than any other country bar China, looking at the broad picture, there is still a long way to go and reasons for concern as it continues to generate almost half of its power with coal and even dirtier lignite.

In fact, despite the speed of its energy transition, Germany still looks set to fall short of its EU carbon emissions reduction target for 2020, according to an expert commission monitoring the energy transition, unless additional measures are taken on top of current plans. The commission says in a 2014 report[79] that "no compensatory measures", which appears to mean allowances, were made for the fact that Germany shuttered half its nuclear fleet after committing to the target.

In a country which generates as much power as 19 of the smaller members of the European Union combined[80] and as the world's sixth biggest emitter of CO2, the speed of Germany's grid

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[79] Danger of missing 2020 EU CO2 target
https://www.bmwi.de/English/Redaktion/Pdf/monitoringbericht-energie-der-zukunft-kommentare-zusammenfassung-2013,property=pdf,bereich=bmwi2012,sprache=en,rwb=true.pdf

[80] http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Net_electricity_generation,_1990%E2%80%932013_(thousand_GWh)_YB15.png

decarbonisation is of critical importance as the world sets itself the aim of slashing emissions in the coming decades to avoid more severe impacts from climate change that will otherwise likely occur.

Nonetheless, energy is now a rapidly-evolving sector continually confounding economic models and forecasts, with price decreases for renewables notably beating expectations and showing no sign of abating. One record has been following another for efficiency of solar cell conversion of sunlight into power and turbines are capturing ever more energy from the wind. Germany's energy transition policies can take a lot of credit for this by catapulting into the mainstream a technology which would have remained side-lined in the market for much longer without subsidies until it turned competitive. This is especially true given the continued low prices on the European carbon market which are likely to persist until reforms take effect early in the next decade.

Reforms to the regulations governing the energy transition have arisen from panic over the rising cost of these subsidies, but the proposed changes which will require firms to compete at auction on the basis of the lowest feed-in tariff they will accept, have come under fire from the industry and NGOs alike. Though both of these have an interest in the acceleration of the energy transition, their doubts over these changes seem founded.

Because wind and solar technology have now fallen significantly in price and with that, the amount of subsidies paid, each extra cent consumers pay on their electricity bills towards the cost of the feed-in tariff subsidises a lot more renewable power than even just a few years ago. The German energy transition is in a phase of increasing rather than diminishing returns. Falling power prices are a further testament to this.

IRENA's June 2016 "Power to Change"[81] report shows that cost reductions are far from coming to an end. It forecasts a 44 percent reduction in the cost of German solar, already one of the

[81] Forecast drop in German solar prices, Pg 43
http://www.irena.org/DocumentDownloads/Publications/IRENA_Power_to_Change_2016.pdf

world's cheapest locations, by 2025, but says cost reductions here and in other countries depend on a conducive public policy framework.

Forthcoming reforms, which still need parliamentary approval, look set to deliver mixed outcomes. While the wind sector says a switch to setting feed-in tariffs by auction and new target bands with which the government will control the development of renewables, will result in a slow-down for their growing industry, it is likely to help turn-around a steep slowdown in solar installations which have fallen below government targets.

It would be interesting to dig deeper into what has driven the government's decision to implement target bands at a time when renewables have capacity to grow both at home and abroad, especially given that Germany stands a good chance of missing its EU-mandated 2020 carbon emission reduction target.

While it is true that German households pay close to the highest price in all of Europe for their power, acceptance of the energy transition remains high and the only recent protests the country has seen recently relating to energy have not been over the cost of renewables but rather to demand that coal and lignite are shut down sooner.

The planned termination of coal mining, but not lignite, in Germany from 2018 is likely to increase hostility to fossil fuel generation and accelerate its demise should public opposition reach the dimensions seen with nuclear. The only merit it still has at a time when cleaner, competitive options exist, is a social one through the 17,000 jobs that remain in mining but this one redeeming feature of coal in Germany will soon vanish.

At this stage of the energy transition, when carbon-free power generated now exceeds the grid's ability to transport it, there is little doubt that priority should be given to investments in transmission. That will help lower power costs further by eliminating the problem referred to as 'redispatch' or paying wind farms for power they produce but which they are unable to feed into the grid for lack of capacity. Without it, the likelihood Germany can turn still-fledgling offshore wind into a competitive technology ripe for international export is diminished, if it cannot develop it efficiently and on a big enough scale at home.

Depending on the press coverage one reads, Germany's energy transition is either an enlightened embrace of technology and social mobilisation to deal with the world's most pressing ecological problem or sheer lunacy on the part of politicians won over by ecologists whose zeal for environmental protection has blinded them to hard economic realities.

But so far Germany is so far proving the latter naysayers wrong. The grid remains one of the world's most reliable even with a one-third renewables generation achieved in 2015 and technological advances are increasing the options for the storage of renewable power. The cost to consumers for each new megawatt of renewables capacity has also fallen significantly since the start of the energy transition.

The transition has been blamed for some extent for the financial dire straits of fossil fuel-based utilities companies who are posting significant losses as renewables slash the cost of power on the grid. Some of these woes were self-inflicted due to decisions to invest heavily in power plants in the last decade that would lock fossil fuels into the power mix for decades, even as renewables were taking off. Had these companies not backtracked on most of these projects, their red-inked balance sheets would look worse still.

The energy transition is also responsible for a good deal of these companies' struggles now, but this should hardly come as a surprise, since the killing of coal and gas to replace them with alternatives which are more viable in almost every respect is the ultimate aim of the entire project.

It is an latest example of what the late Austrian-American economist Joseph Schumpeter (1883-1950) termed 'creative destruction' or the elimination of an economic sector that technology has surpassed. The benefits are so overwhelming however that the damage done to one industry while a new one with greater merit flourishes, should not be a major consideration. However, financial assistance for the firms paying the biggest economic toll as society benefits, especially given their importance to the German economy and expertise in the power sector as grid operators, looks justified, to ensure their short-term solvency.

It now remains to be seen what impact forthcoming changes to Germany's incentives to renewables will have especially at a time when renewables prices are falling. The question now is whether stimulus is being slowed too early along this sector's growth trajectory, or whether momentum from steady cost reductions will give solar and wind technology the resilience they need to fly with their own wings.

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