Energy Transition after the Paris Agreement: Policy and Corporate Challenges

Background paper for the
34th Round Table on Sustainable Development
28-29 September 2016

WindEurope Summit,
Hamburg

Richard Baron, OECD*

* This paper was prepared under the authority of the Chair of the Round Table on Sustainable Development at the Organisation for Economic Co-operation and Development (OECD). The reasoning and opinions expressed herein do not necessarily reflect the official views of the OECD Secretariat or the governments of Member countries.

ACKNOWLEDGEMENTS

This paper was authored by Richard Baron, with research support from Maria-Eugénia Le Gourriérec and editing by Amelia Smith (OECD).

The author is grateful to Andrew Prag (OECD), Kristian Ruby (Wind Europe) and Connie Hedegaard (Chair, OECD Round Table on Sustainable Development) for their comments and suggestions.

The Round Table on Sustainable Development event "Energy Transition after the Paris Agreement: Policy and Corporate Challenges" is organised in partnership with Wind Europe.

TABLE OF CONTENTS

SUMMARY – QUESTIONS FOR DISCUSSION

Decarbonisation of the electricity sector is at the heart of the response to the climate change threat. A rapid transition is necessary to avoid locking in more CO_2 emissions from fossil fuel-based power generation, and to accommodate the penetration of low-carbon technologies. The Paris Agreement reinforces the urgency of action in this area.

Europe has lowered the carbon content of its electricity sector significantly more than any other continent since 1990, through a range of sometimes disruptive energy and climate policies. Yet much more is needed to arrive at the almost full decarbonisation that energy and climate scenarios indicate is required by the middle of this century. The policy challenges to achieving this unprecedented evolution, and the implications for corporate strategies and business models, are considerable.

The power sector finds itself in an intricate, not-fully-stabilised web of policy signals (renewable and other low-carbon support measures, nuclear energy policy, EU emissions trading and domestic CO_2 prices), electricity market arrangements and technological changes. Conventional power generators face reduced revenues from wholesale markets due to factors including lower electricity demand (driven by the economic crisis and energy efficiency gains) and growing 'out-of-market' renewable energy supply (driven by measures such as feed-in tariffs), reducing their ability to finance further balance-sheet investments, whether low-carbon or otherwise. Several jurisdictions are coming to the rescue with various payment mechanisms to keep thermal plants online and ensure electricity security. The demand-side is also increasingly mobilised. At corporate level, there is a trend of divestment of coal plants, which are at risk as further CO_2 reductions are required. Business models are being shaken as new generation (small-scale and decentralised) comes in.

Even under ideal conditions, some power generation assets will be stranded, as the required pace of decarbonisation is faster than the natural rate of capital stock turnover. The central question is whether the transition can be managed in an orderly fashion, limiting asset value destruction and costs. A fair distribution of costs across economic agents is another critical element in the success of the transition.

Questions for discussion

- Many factors are at play in the evolution of the electricity system and its incumbent companies. What major uncertainties and disruptions are on the horizon?

- Are current market arrangements sustainable to drive an efficient low-carbon transformation of the electricity system? How do different country solutions look from this perspective?

- What would be the desirable policy mix to drive an orderly transition of the power sector and ensure the necessary long-term signals to investors to prioritise low-carbon solutions?

- The transition to decarbonised electricity systems will have varying cost impacts (carbon cost, infrastructure investment, stranded assets) depending on the stakeholder (generators, system operators, end-users). How are countries dealing with the distribution of costs?

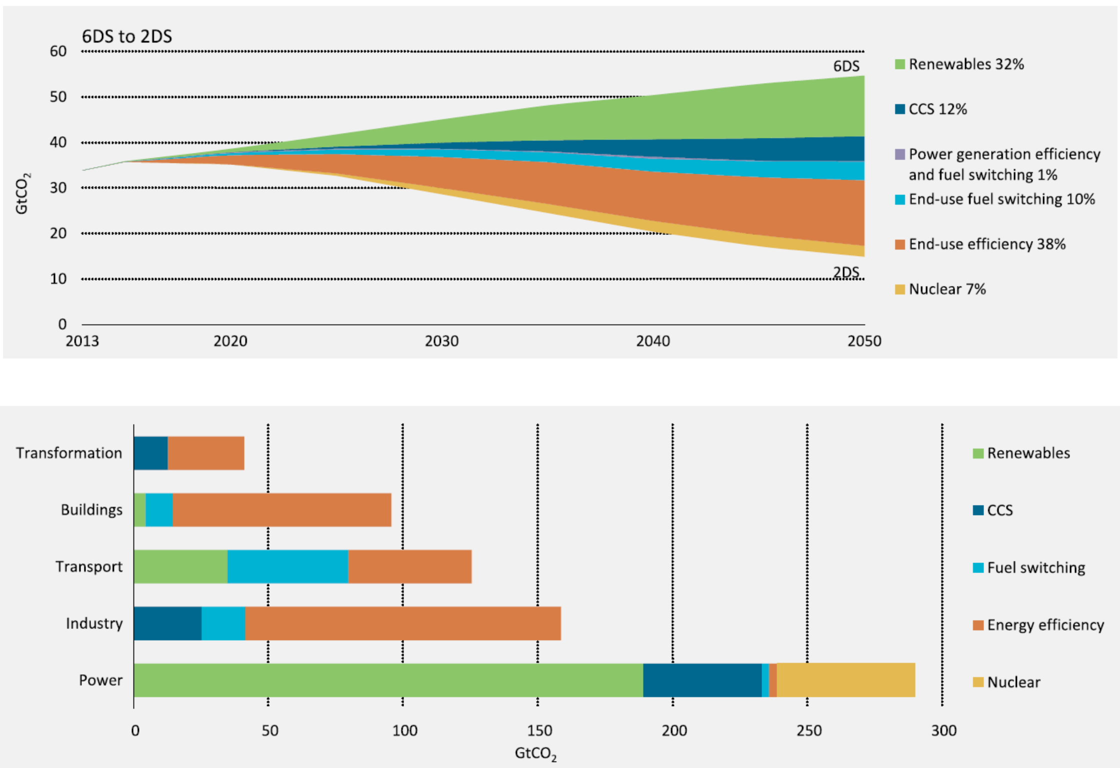
I. INTRODUCTION: THE ELECTRICITY AND CLIMATE CHALLENGE

1. The Paris Agreement established the international climate policy objectives to "hold the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels" and "achieve a balance between anthropogenic emission by sources and removals by sinks of greenhouse gases in the second half of this century" (Articles 2 and 4, UNFCCC, 2015).

2. There is a broad and growing consensus that the electricity sector has an essential role in achieving decarbonisation of the economy. Electricity generation needs to shift to low-carbon technologies, relying on a diverse range of technological solutions (both centralised and decentralised) and a transition needs to be made from direct fossil-fuel uses towards more electricity efficient ones. The details of this 'low-carbon electrification' will differ from country to country depending on geography, resources, level of revenues and existing infrastructure.

3. The IEA's 2-degree compatible scenario (2DS) projects a 79% increase in electricity demand between now and 2050; the share of electricity in the final energy mix would grow from 18% to 28% over that period. Electricity demand from transport would also grow very significantly in this scenario, amounting to close to 7% of total electricity demand by 2050.

Figure 1. Contribution of technology area and sector to global cumulative CO_2 reductions between IEA's 6-Degree and 2-Degree scenarios (2013-2050)



Source: IEA (2016a), Energy Technology Perspectives 2016.

4. In its report to the Clean Energy Ministerial, "Tracking Clean Energy Progress 2016", the IEA indicated that despite rapid penetration of wind and solar photovoltaic (PV), low-carbon technologies are not globally on track to meet the 2°C milestone by 2025 (IEA, 2016b). Issues to be resolved range from electricity market designs necessary to reflect the costs and benefits of various resources (especially variable renewables and gas), to the lack of an adequate carbon price to encourage switching away from coal-based generation, to limited investment in carbon capture and storage (CCS).

5. The carbon intensity of power generation, measured in tons of CO_2 emitted per MWh of electricity, has evolved in markedly different ways across regions since 1990:

- An 18% reduction in North America (with a recent shift from coal to gas).
- A 33% reduction in Europe, resulting from a growing share of zero-carbon generation (especially renewables in the last decade), and general improvement of the fossil fuel mix (shifting from coal to gas, despite high gas prices early in the decade).
- A 22% increase in Asia-Oceania, due to the shutdown of nuclear capacity in Japan after the Fukushima accident and despite rapid growth in generation from new renewables.

6. These figures confirm the European lead on the path to decarbonisation thus far. The transition has been challenged by the financial and economic crises (a drop in demand), as well as by disruptive, sometimes unexpected evolutions (e.g. cost reductions of renewable energy solutions). At a time when the Paris Agreement stresses the urgency of climate action, and countries around the world start acting to limit CO_2 from power generation, it is useful to reflect on the European experience from both a policy and corporate perspective.

II. STATE OF PLAY

7. The electricity sector is in a maelstrom. The PwC Power and Utilities Disruption Index[1] reflects senior executives' concerns in the 2020 time horizon over regulatory uncertainty, market dislocation, difficulties in attracting investment and growing emissions. Europe appears to be the most affected of all surveyed regions, due to several factors:

- Stagnating demand since the financial and economic crises. Electricity consumption in EU-28 declined by 4.8% between 2010 and 2014 across the three major end-uses: industry, services and residential. The successful implementation of various energy-saving directives in household electric appliances is likely to further reduce demand as efficiency improves. Lower demand for electricity in industry is largely the result of the drop in industrial activity during the crisis (industrial electricity demand peaked in 2007). However, efficiency efforts are also at play in industry, e.g. in electricity motor drives, albeit with less impact on performance than observed in household appliances (Bertoldi, López-Lorente, Labanca, 2016).

[1] The disruption index is part of a PricewaterhouseCoopers annual survey of 73 senior executives in 70 companies operating in 52 countries on all continents. It covers five areas: policy and regulation, customer behaviour, competition, the production service model, and distribution channels. http://www.pwc.com/gx/en/industries/energy-utilities-mining/power-utilities/global-power-and-utilities-survey/disruption-index.html.

- Over-investment in gas-based capacity, leading to present overcapacity in fossil-fuelled generation.

- Rapid growth of variable renewable electricity supply, including decentralised generation, prompted by national objectives (EU 2020 renewable targets, Germany's nuclear phase-out) and accompanying financial support schemes.

- Declining wholesale market prices, concurrent with…

- …mothballing or stranding of old and new fossil-based generation capacity. For instance, Enel had 23 plants totalling 13 Gigawatts of capacity that produced no or little electricity in 2015; GDF-Suez (now Engie) mothballed or closed 2.4 GW in 2013.[2]

- Confusion arising from conflicting policy signals:

    - Initial generous financial support to renewables, later reformed, sometimes retro-actively, to reflect budgetary constraints and rapidly declining technology costs.

    - Low (and fluctuating) CO_2 allowance prices in the EU Emissions Trading System, and an allowance surplus that allows the continuation of coal-based generation. While this does not as such contradict the objective of the EU ETS (the cap on emissions is being respected), it challenges its role as a guide for future investment in decarbonisation.

- Regulatory uncertainty as policy-makers start reconsidering the organisation of markets and the policy mix to achieve climate and security of supply objectives, as illustrated by the emergence of various types of capacity mechanisms (e.g. payments to plants that would otherwise close to remain available and provide security of supply).

- Challenges to the operation of electricity markets faced with the massive inflow of variable renewables – i.e. technologies for which they were not originally designed. This occasionally leads to the curtailment of renewable supply and negative prices.[3]

8. Utilities, which remain critical actors in the energy picture, are under pressure. The largest listed European utilities reportedly lost EUR 500 billion in capital value between 2008 and 2013, and not all have recovered.[4] Corporate strategies have emerged to respond to this new environment and to the decarbonisation agenda, with a common trend towards the divestment of coal assets:

- In the context of Germany's ambitious *Energiewende* (40-45% of renewable energy by 2025),which combines the phase-out of nuclear capacity and the rapid penetration of renewable electricity supply, major utilities E.On and RWE have both decided to separate their activities into conventional and new power generation (Barclays, 2016).

---

2 Source: http://www.italy24.ilsole24ore.com/art/business-and-economy/2015-04-29/a-new-life-for-enel-s-power-plants-213753.php?uuid=AB3kjAYD.

3 IEA (2016) notes, however, that the curtailment of distributed generation "has the potential to considerably increase the connection capacity and therefore accelerate the deployment of wind and solar power […] curtailment can lower the overall cost and accelerate the deployment of wind and solar PV."

4 The Economist, 2013. This figure refers to the top 20 energy utilities.

- In France, both Engie and EDF are looking to sell coal-based generation assets in Poland (Reuters, 2016).

- Vattenfall recently decided to sell its coal-based power generation capacity to the Czech company EPH. Its divestment decision was accompanied by the Swedish government's purchase and cancellation of EUR 736 million worth of EU CO_2 allowances between 2018 and 2040.

9. Divesting coal-based generation is legitimate from a corporation's point of view: in addition to one-off revenues from the sale, a company minimises the growing risk of stranded assets if and when carbon prices rise, and legitimises its position as a responsible actor in the transition to a low-carbon world. Beyond the motivation of individual corporations is the question of the impact of divestment on the near-term carbon profile of the sector, as buyers of divested coal plants may be more intent on maximising their operations. This decision would be facilitated by current and projected low carbon prices, but may lead to a less aggressive decarbonisation agenda, as the risk of stranded assets is passed to new investors.

10. The pace of electricity decarbonisation coherent with the Paris Agreement is well beyond the natural rate of capital stock turnover in generation (IEA, 2016c), and the stranding of high-carbon assets is likely to continue. In light of this and low wholesale prices, utilities and power generators are now less well-equipped financially to make the transition. It is critical to re-think incentives and regulatory settings to minimise the cost and ensure the sustainability of the shift to low-carbon.

III. RETHINKING FRAMEWORKS AND INCENTIVES

> ***Debates on market design for a low-carbon power system generally present two contrasting policy options: reliance on either wholesale electricity markets with a strong carbon price, or technology-specific policies and regulations […] It is increasingly clear that a binary opposition is no longer sufficient to define the market framework.***
>
> IEA, 2016c

Re-aligning power markets with new technologies and policy agendas

11. There is an apparent contradiction in today's functioning wholesale electricity markets: prices are going down whereas what were once more expensive supply sources are being mobilised (wind and solar PV). There are logical factors behind this picture (overcapacity on the supply side, successful penetration of new renewables through out-of-market support, low emissions leading to a low CO_2 price), but the reality is that the wholesale market no longer reflects the fundamentals of generation. Further, if the imperative is to continue investing in low-carbon generation, the market fails to send a signal in this direction.

12. A recent analysis of the coherence of policy and regulatory frameworks with the low-carbon transition found that "current designs of wholesale electricity markets in many OECD countries are not strategically aligned with the low-carbon transition. They do not deliver the long-term price signal that investment in high capital cost, low-carbon technologies such as hydro-electricity, nuclear power, wind turbines, solar technologies and geothermal installations or fossil fuelled-plants fitted with carbon capture and storage (CCS) would require." (OECD-IEA-ITF-NEA, 2015).

13. The essence of the problem is that wholesale electricity markets were built to fit previous technologies (e.g. the combined-cycle gas turbine as marginal supplier setting the price for all other generators in the market), based on marginal cost pricing alone. These arrangements cannot guarantee an adequate return on investment in technologies whose marginal generation cost is zero (wind and PV). These depend on the occurrence of very high prices in times of scarcity – often politically untenable – to recoup their investment. In addition, as the market share of variable renewables increases, their low marginal cost of supply will drive wholesale prices down further, increasing the risk of insufficient revenues.

14. This especially applies to low-carbon, high-capital cost technologies. In fact, the observed decline in wind and PV technology costs makes financing conditions and the ability to mobilise low capital costs more important in the competitiveness of capital-intensive renewable energy technologies (IEA, 2015). Looking at support measures for renewables in the context of the *Energiewende*, Nelson et al. (2016) find that shortening revenue support from 20 to 15 years could increase energy costs by 15 to 18% depending on the technology. In the same vein, the European-funded DiaCore project found that the weighted average cost of capital for onshore wind projects varied between 3.5% in Germany and 12% in Greece in 2014. Equity cost varies in a similar range across European countries (6 to 15%). This largely reflects the stability and credibility of the renewable energy policy and accompanying support measures (Noothout et al. 2016).

15. The above should not imply that variable renewable energy – or innovative low-carbon technologies in general – should be shielded from the market. On the contrary, their exposure to market prices is important to encourage the design of facilities that can generate when prices are higher. This is the logic behind shifting from an ‘unconditional’ feed-in-tariff payment to a feed-in-premium such as the United Kingdom’s Contract for Difference: a generator receives payment covering the difference between the observed market price and an agreed strike price.

16. A better optimisation of power supply also means that system costs, which vary depending on technology (e.g. flexible or variable), should be reflected in the bidding process to arrive at a more cost-reflective pricing regime.[5]

17. The integration of electricity storage in electricity markets also warrants attention. Electricity storage has an important role to play in a decarbonised electricity system – a projected 310 GW of grid-connected capacity by 2050 in the United States, Europe, India and China according to IEA (2014a). Storage can play multiple roles in the electricity system (frequency regulation, load following or off-grid applications). The cost-effective deployment of storage capacity will require changes in market and regulatory frameworks. In the United States, transmission assets were forbidden to participate in wholesale electricity markets to avoid market manipulation; regulations had to be adjusted to allow storage to receive compensation for supplied services. Time-of-use pricing is also key to encourage storage: cheaper electricity can be stored and resold when prices peak (IEA,2014a).

18. Countries are bringing various, not-yet-complete solutions to accommodate a growing share of variable resources, while limiting their potentially disruptive effect in an over-supplied, low-demand electricity market.

5 Policy alignment issues also go beyond those specific to the electricity sector; policies relating to trade and investment restrictiveness, sovereign credit rating, rule of law and levels of state-ownership may also be important. Ongoing OECD empirical analysis is assessing which elements of the broader business environment have been significant in affecting investment levels in renewables.

A high CO_2 price combined with other measures

> ***Cost effectiveness of renewable power to further improve, but policies remain key.***
>
> IEA, 2015

19. The discussion on emissions trading running up to the Kyoto Protocol had a marked impact on domestic climate policy choices, including in Europe, where emissions trading soon appeared as *the* economically efficient solution to greenhouse gas mitigation. The notion of emissions trading as a universal solution has been somewhat challenged since. Climate mitigation requires a longer-term approach in which technology dynamics play an important role, justifying targeted RD&D support to low-carbon technologies; specific measures are also needed to overcome market barriers that make carbon pricing less effective. One can of course debate the mix of instruments and the stringency of policy objectives (GHG vs energy efficiency vs. renewable energy targets), but economic efficiency arguments no longer back the single-instrument approach.[6]

20. In the EU context, the Emissions Trading System is 'simply' meant to put a cap on large stationary sources and to allow them to achieve it at least cost. Emissions are now well below the original cap, resulting in a low price of CO_2 allowances. This is not a problem in principle (the ETS is about a least-cost way to meet the target), but there are negative side-effects:

- Low CO_2 prices mean lower electricity prices when fossil plants operate at the margin, and lower revenues for 'infra-marginal' power generators exposed to wholesale prices (hydro, nuclear, but also gas or coal plants, depending on relative fuel prices). This explains why several power companies argue for a higher CO_2 price and the end of subsidies to cost-competitive renewables.

- The CO_2 price is not strong enough to drive investment in low-carbon technologies, despite the improving cost-competitiveness of wind and PV. If the carbon price were higher, its volatility would still add a degree of risk to investors in low-carbon technologies – the recently introduced market stability reserve aims at avoiding large supply-demand imbalances and should somewhat smooth price variability.

- CO_2 emitters in heavy industry are not encouraged to innovate and are satisfied with a low carbon cost, given that their foreign competitors have been subject to less stringent CO_2 mitigation policies.

21. Further, the existing surplus of EU allowances risks undermining the ETS's long-term objective. Several proposals are now on the table to amend the ETS, including cancellation of surplus allowances, tightening of the caps, and introduction of a price floor or price corridor. The UK has already introduced a 'carbon price support rate' paid by power generators, which contributed to halving the quantity of electricity produced from coal, to the benefit of gas (a lower gas price also helped). The future of the carbon price hinges on the still-uncertain choice among these options.[7]

---

6 Theoretical and applied work shows that GHG emissions pricing, the removal of market barriers (e.g. to support energy efficiency improvements in the household sector) and RD&D are complementary and can work to minimise the cost of GHG reductions better than pricing alone would (Acemoglu et al., 2012; Hood, 2011; Fischer and Newell, 2008).

7 See Canfin, Grandjean, Mestrallet, 2016.

22. The decarbonisation of electricity cannot be left to the carbon and wholesale electricity markets as they stand. A financial perspective makes this clear: low-risk and stable revenues imply low capital costs and lower generation costs from low-carbon technologies. The mid-term policy question is how to create a competitive environment suited to the cost profile of low-carbon technologies (high-capital, low-operation costs) in which the cost of carbon and the security of supply and variability features of different technologies are fully incorporated. Whether or not the price of carbon reflects the near-term (coal vs. gas) or a long-term (towards zero carbon) constraint on emissions will influence the need for additional support to innovative low-carbon technologies.

How can policy-makers and companies adjust in the meantime?

23. Countries have introduced measures to help the power sector cope with near-term transition problems. The following is a broad-brush description of measures enforced in key countries (IEA 2015, 2016c).

- **France** adopted a feed-in premium[8], launched tenders for offshore wind and solar PV, and will introduce a carbon price floor for the power generation sector in 2017. This ‘tax’, intended to start at EUR 30/tCO_2, may only apply to coal plants, contrary to the initial design in which all fossil-based generators were covered. A capacity mechanism is due to start in 2017 (based on certified capacity and demand-side aggregators; suppliers are obliged to hold capacity certificates). Smart grids are under experimentation.

- In 2012, **Italy** adopted a renewable energy plan with auctions for a range of technologies as well as a market-wide capacity mechanism (“a tool for procuring sufficient *reliability options* to ensure resource adequacy”, IEA, 2016c).

- **Germany** is temporarily in a high-carbon phase as coal plants substitute phased-out nuclear capacity. Its renewable capacity continues to grow, based on auctions which set maximum volumes to limit the increase in electricity tariffs. A strategic capacity reserve was introduced which contracts old capacity otherwise likely to leave the market, for use in scarcity situations.

- The **United Kingdom** introduced private Contracts for Difference to support the deployment of renewables and nuclear, and a capacity mechanism. It is auction-based and may not run every year depending on capacity margins; the first auction ran for 2018/19, with 2.8 GW of new capacity and a total of 49.3 GW. The UK recorded rapid growth in RE supply in 2015, with record PV deployment. Its carbon price floor (GBP 18/tCO_2) and Large-combustion Plant Directive are pushing coal out of the market.

24. Some commonalities emerge, such as the introduction of auctions, feed-in premiums or contracts for difference, following state aid decisions favouring market-based instruments and countries’ interest in rationalising their support measures. The introduction of different capacity mechanisms is also striking, as these new revenue streams alter the economics of power generation, especially fossil-fuel plants, and may artificially prolong the lifetime of carbon-intensive capacity, hence delaying the penetration of low-carbon technologies.[9] Further, their diversity across countries can act as a barrier to divestment (OECD, 2016).

---

8 http://www.developpement-durable.gouv.fr/Application-de-la-loi-transition,47733.html.

9 In systems like the United States’ PJM, capacity payments can be a substantial part of a plant’s revenues.

IV. ISSUES AHEAD

Toward enhanced co-operation in support of decarbonisation?

25. An important part of the decarbonisation agenda is the ability to rely on a broad geographic basis to bring low-carbon generation to consumption centres, and on a wide range of generation resources to accommodate variable supply with limited disruptions. This requires both physical infrastructure (interconnectors) and regulatory infrastructure. The European Network of Transmission Systems Operators for Electricity (ENTSO-E) recently agreed on network codes for power generation that set “conditions of competition in the internal electricity market, to ensure system security and the integration of renewable electricity sources, and to facilitate Union-wide trade in electricity” (European Commission, 2016).

26. The Energy Union describes the general ambition for this evolution, with climate mitigation as its premise and an interest in maintaining energy security and competitiveness (European Commission, 2015). International transmission is lagging behind a 2002 European Council target of achieving an interconnection capacity of 10% of installed generation capacity.[10] The European Commission subsequently needs to expand interconnection capacity to 15% by 2030. A single number cannot reflect the economically efficient level of interconnection between specific countries, but there is a general understanding that an increase in interconnections from current levels would benefit consumers and allow a better balancing of intermittent resources (European Parliament, 2016). Problems with grid security and congestion caused by German wind power surges in its eastern neighbours also underline the importance of better transmission. Meanwhile, Scandinavian and central and eastern European countries currently have interconnections above 15%.

Can stranded assets be managed?

27. In the IEA’s 450 Scenario (representing a 50% probability of meeting a 2-degree stabilisation objective), fossil fuel and power generators would see some of their assets stranded. The required pace of decarbonisation implies that fossil-based facilities will have to cut operations before their investment costs are recouped. By 2035, stranded assets in power generation would amount to USD 120 billion on a global basis (IEA, 2014b). This estimate reflects a rather orderly transition, when one considers the EUR 500 billion plunge of European utilities’ capital market value between 2008 and 2013 (The Economist, 2013). These indicators are not strictly comparable (economic value of assets vs. company market valuation), and the half-trillion euro loss had multiple factors behind it, but the numbers illustrate the vulnerability of the utility model in the face of a disruptive transition and may ultimately question companies’ ability to finance it. The newly introduced capacity mechanisms may help from a financial and energy security perspective, but can only be temporary as decarbonisation proceeds. The solution requires a regulatory and policy overhaul – the later this comes, the larger the generation capacity that risks stranding.

28. Can other forms of compensation be envisioned in cases of stranded assets? During the development of Australia’s emissions trading system, the government initiated a process to buy back the highest-emitting coal plants through auction. While compensating shareholders for the early closure of the plants, this would have avoided higher emissions and a higher carbon price – at tax payers’ expense, however, which may be hardly feasible at the moment. The corporate solution – divesting coal capacity – may be rational from a shareholder perspective, but seems to push the problem further into the future as new owners may seek to maximise production.

[10] “In 2014, eight [Member States] were still below their target of 10% and would benefit of market integration by an increased interconnection capacity” (European Parliament, 2016).

Who carries the cost of decarbonisation?

29. A related issue is the distribution of the decarbonisation costs across stakeholders. Householders are at the heart of this question, as they usually see the highest electricity rates, including taxes for the support of renewable energy deployment. An economic analysis measuring the direct effect of energy taxes in 21 countries found that taxes on energy are generally regressive, i.e. represent a higher share of income in the poorer segments of society (Flues and Thomas, 2015). The increase in distributed generation may raise further problems from this perspective, as users most able to afford PV and storage systems – becoming independent from the grid – may leave it to the remaining, poorer consumers to support grid costs. Smart meters are another 'investment' that householders must face, even if it is meant to lower future electricity bills. This point also illustrates the importance of providing energy efficiency solutions to rate-payers that could face a rising price per kWh and may eventually be exposed to real-time pricing.

30. Industrial electricity users are in different situations depending on their jurisdictions. In Germany, the largest electricity users enjoy exemption from the renewable support tax and benefit from low wholesale electricity prices driven in part by the penetration of renewables. On another issue, some countries have opted for the compensation of large electricity users for the price increment triggered by the price of CO_2 feed through the electricity price. For industrial consumers in other countries, this indirect cost, albeit low at today's CO_2 price level, is an important element of the discussion of the ETS reform.

Further disruptions, opportunities and risks on the horizon?

31. A number of policy, technical and organisational changes may bring additional uncertainties, with disruptive impacts on technology choices, market shares, and business models:

- **Storage**: how soon to affordable personal storage combined with roof-top PV? Could a significant share of the market go 'off-grid'?

- Alternatively, more decentralised and variable generation reinforces the central role of the **transmission and distribution grid**.[11] Is the model for electricity companies to shift from energy producers to access and reliability providers? How would this affect the economic model of various actors in the electricity value chain?

- **Curtailment of variable renewable** resources is on the rise. Is there a quick fix to this problem, or could it become a serious impediment for the deployment of variable resources?

- The role of **smart-metering** and big data in managing load. Are information technology and telecommunications companies possible new entrants in the supply market?

- Could smart metering uncover large, still untapped, **energy efficiency potentials**?

- Could the penetration of **electric vehicles** catch the electricity system by surprise?

- Solar and wind get much attention from policy-makers. Will **geothermal** ever pick up?

- How soon can **markets** be revamped to reflect the new characteristics of a low-carbon electricity system (e.g. variability, flexibility) in wholesale market competition?

---

[11] "The advent of micro-grids and self-generation means the need for a cost-effective provider of reliability at the centre grows." (Jim Hughes, CEO First Solar, in McCrone (2015).

- Are there other **mega-trends** at play (Europe's 'secular stagnation') that could override the above?

32. The above list is an indication of the complex and uncertain environment in which the electricity sector finds itself as it embarks on the low-carbon transition. It points to the need to stabilise the policy frameworks for the low-carbon transition, but also to leave the future open for various stakeholders that will have to adapt to likely disruptions.

REFERENCES

Acemoglu, D. et al. (2012), "The environment and directed technical change", *American Eaaconomic Review*, American Economic Association, Vol. 102, No. 1, February, http://dx.doi.org/10.1257/aer.102.1.131.

Barclays (2016), *German Utilities – 2 degrees (2°C) of separation*. Equity Research, 7 March 2016.

Bertoldi P., J. López-Lorente, N. Labanca (2016), Energy Consumption and Energy Efficiency Trends in the EU-28, EUR 27972 EN; doi 10.2788/581574.

Canfin P., A. Grandjean, G. Mestrallet (2016), *Propositions pour des prix du carbone alignés avec l'Accord de Paris*. Rapport de la Mission remis à Ségolène Royal, Présidente de la COP 21. DICOM-CAB/COU/16199 – Juillet 2016.

Department of Energy and Climate Change (2016), *UK Energy Statistics, Q1 2016*, London.

ENTSO-E (2016), "Preparing the age of renewables: new rules for connecting to the grid to apply in all EU by mid-May". 27 April 2016. https://www.entsoe.eu/news-events/announcements/announcements-archive/Pages/News/2016-04-27-rfg-published.aspx.

European Commission (2016), *Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators* (Text with EEA relevance) C/2016/2001, OJ L 112, 27.4.2016, p. 1–68. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:JOL_2016_112_R_0001.

European Commission (2015), *A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy*, COM/2015/080 Final, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2015%3A80%3AFIN.

European Parliament (2016), *Energy Union: Key Decisions for the Realisation of a Fully Integrated Energy Market*. Study for the ITRE Committee. IP/A/ITRE/2015-01, PE 578-968. April 2016.

Fischer, C. and R. Newell (2008), "Environmental and technological policies for climate mitigation", *Resources for the Future Discussion Paper*, RFF DP 04-05, April, revised February 2007, Resources for the Future, Washington, DC, available at: www.rff.org/rff/Documents/RFF-DP-04-05-REV.pdf.

Flues, F. and A. Thomas (2015), "The distributional effects of energy taxes", OECD Taxation Working Papers, No. 23, OECD Publishing, Paris. http://dx.doi.org/10.1787/5js1qwkqqrbv-en.

Hood, C. (2011), "Summing up the parts: Combining policy instruments for least-cost climate mitigation strategies", International Energy Agency Information Paper, OECD/IEA, Paris, available at: www.iea.org/publications/freepublications/publication/Summing_Up.pdf.

IEA (2016a), *Energy Technologies Perspectives 2016 – Towards Sustainable Urban Energy Systems.* OECD/IEA Publishing, Paris.

IEA (2016b), *Tracking Clean Energy Progress 2016 – Energy Technology Perspectives 2016 Excerpt, IEA Input to the Clean Energy Ministerial*. OECD/IEA Publishing, Paris.

IEA (2016c), *Repowering Markets – Market design and regulation during the transition to low-carbon power systems*. OECD/IEA Publishing, Paris.

IEA (2015), *Renewable Energy – Medium-Term Market Report 2015*. OECD/IEA, Paris.

IEA (2014a), *Technology Roadmap – Energy Storage*. OECD/IEA, Paris. www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergystorage.pdf.

IEA (2014b), *World Energy Investment Outlook*, OECD/IEA Publishing, Paris.

Liebreich, M. (2014), "The Energy System in 2014 – Did the Ice Really Crack?" Bloomberg New Energy Finance, 16 December 2014.

McCrone, A (2015), "Upbeat Summit hears of age of plenty". Bloomberg new Energy Finance, 27 April 2015.

Nelson D., M. Huxham, S. Muench and B. O'Connell (2015), *Policy and Investment in German Renewable Energy*. A Climate Policy Initiative Report. April 2016.

Noothout P. et al. (2016), *The impact of risk in renewable energy investments and the role of smart policies* – DiaCore, Final Report. Contract N°: IEE/12/833/SI2.645735, February.

OECD (2016), *OECD Business and Finance Outlook 2016*, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789264257573-en.

OECD-IEA-ITF-NEA (2015), *Aligning Policies for a Low-carbon Economy*, OECD Publishing, Paris. http://oe.cd/lowcarbon.

Reuters (2016), "Update 1- France's Engie looks to sell Polish coal-fired power plants", 19 April 2016, http://www.reuters.com/article/engie-poland-idUSL5N17M31I.

The Economist (2013), "How to use half a trillion euros – Europe's electricity providers face an existential threat", http://www.economist.com/news/briefing/21587782-europes-electricity-providers-face-existential-threat-how-lose-half-trillion-euros.