SUSTAINABLE FINANCE PROGRAMME

SMITH SCHOOL OF ENTERPRISE AND THE ENVIRONMENT

UNIVERSITY OF OXFORD

Closing Coal in China:

International experiences to inform power sector reform

Working Paper

February 2017

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Acknowledgements

We would like to acknowledge the support provided by Malcolm Keay, Daniel Tulloch, Ben Caldecott, Alex Pfeiffer, Jiahai Yuan, and Juan Ma at various stages of this paper's production. The contents of this paper are the authors' sole responsibility. They do not necessarily represent the views of the organisations with which the authors are associated or any of their members.

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Executive Summary

This study addresses two issues related to coal-fired generation. The first is how selected countries in the European Union and North America are making the transition away from unabated[1] coal-fired power. The second is to identify reforms that could ease a similar transition in China. It concentrates on coal-fired generation, not on the mining of coal, its industrial use or the political economy frictions related to closure of facilities that use coal.

International consensus

There is a growing consensus in the scientific community and among policymakers that achieving the central aim of the Paris Agreement requires an early capping and then a rapid decline in global unabated coal-fired generation. This implies prematurely shutting down many existing coal-fired stations and substantially reducing CO_2 emissions in those that continue to operate. It also implies building no new unabated coal-fired stations. This consensus has been driving policy and financial decisions in a number of developed OECD countries, notably in the EU and North America, which are the focus of this report.

In spite of the growing consensus, coal-fired generation has continued to grow, especially in the large emerging nations. This is because coal-fired power continues to be economically attractive in many countries, as long as the environmental costs are not included in the analysis. However, with growing concern over local and global environmental impacts of coal-based emissions, more governments are introducing policies and regulations that threaten the economic viability of unabated coal-fired generation. This raises questions about how to facilitate an efficient transition away from coal. International experience offers some guidance that could be useful in countries that are making this transition or would like to do so.

China is very different from the OECD countries that are the focus of this study. In spite of the differences, and in some cases because of them, there are many challenges and opportunities where international experience may be relevant for China. In particular, this report answers three broad questions related to phasing out coal-fired generation. First, how have governments, regulators and electricity companies managed the process of closing plants prematurely? Second, how have governments and markets discouraged investment in unabated coal-fired generation assets? Third, what are the opportunities related to the transition away from coal and how have they been exploited?

The remainder of the Executive Summary refers to best practice from international experience and its potential relevance for China.

Credible long-term signals

Best international practice involves governments sending clear policy signals with respect to long-term (2050) intentions for coal and more generally to deal with climate change. If the intention is to reduce coal use significantly, and the related CO_2 emissions, there needs to be an overall policy for phasing out coal and the related emissions in all sectors, not just in the power sector. Otherwise, there is a risk that placing the policy burden on

[1] By 'unabated', we mean that the plants do not have carbon capture and storage (CCS) or other technology to abate CO2 emissions. 'Coal-fired generation' refers to plants that have no abatement technology.

the power sector will give incentives for industry to use coal, rather than electrify or to use less carbon intensive fuels. Furthermore, the government needs to send clear signals with respect to the future of coal-based generation.

China has already made a commitment to peaking greenhouse gas emissions by around 2030, increasing non-fossil sources to 20% by 2030 and reducing carbon intensity 60-65% below 2005 levels by 2030.[2] In addition, it has introduced cap-and-trade programmes covering a number of industries,[3] increased substantially the role of renewable energy and taken steps to reduce coal consumption, including bans on approving new coal power plants (except combined heat and power plant) in three industrial regions: Beijing-Tianjin-Hebei, Yangtze River Delta and the Pearl River Delta.[4] China has also included some ambitious CO_2 emission performance targets in the Thirteenth Five Year Plan on Controlling Greenhouse Gas Emissions. However, we are aware of no official government policy on the role of coal-fired power in the longer term, or on reducing emissions from coal-fired stations through closure of assets or retrofitting them with CCS or other abatement equipment.

Long-term policy signals in the countries we have studied are usually sent through one or more of the following: (a) the introduction of climate change or other legislation that phases out coal altogether or that defines steep emission reduction targets that are incompatible with continued unabated coal-fired station operations; (b) emission performance standards that effectively require CCS or similar abatement equipment for new and/or existing power stations; (c) the requirement for new plants to be 'carbon capture ready'; (d) a credible, long-term CO_2 emission price floor which rises over time; (e) refusal to provide public finance for unabated coal-fired power; and (e) disclosing to financial markets information on the risk of stranded assets. In many countries with a tradition of competitive markets, governments now provide this sort of long-term signal. The report assumes that, in spite of the difficulties of doing so, China plans to move in the same direction as the countries analysed in this review, albeit at a different pace. If so, it should provide clear long-term policy signals.

If China plans to maintain coal-fired generation while reducing CO_2 emissions significantly, it is important to be clear about policies related to curbing emissions from existing plants. Retrofitting of carbon capture and storage (CCS) has had little support in the US and the EU in large part because most plants are old and often inefficient. However, because China's plants are on average very new and efficient, there is greater potential economic benefit from CCS retrofitting and from seeking new commercial ways to utilise the captured CO_2.

Accelerating power market reform

Most of the international experience referred to in this report occurs in systems that are liberalised and make use of competitive market mechanisms, for instance to support least cost dispatch, retail competition, regional trading, integration of renewables, resource adequacy and flexibility. China began its electricity reform at the beginning of this century, but the system is still very rigid in ways that effectively protect coal-fired generators and discourage competition from renewable energy, demand response and other sources of cleaner energy. This rigidity promotes the use of coal and is inconsistent with the objective of efficient decarbonisation.

Fortunately, additional reform is now being discussed in China, especially taking on board the ideas in Document 9, which was released by the State Council in May 2015. For example, the recently announced Thirteenth Five Year Plan on Electricity System Development indicates that China will start trial spot market power trading by 2018 and that spot market trading with be fully operative in 2020, after reforming transmission and distribution tariffs.

[2] J. Tollefson, 'China pledges to curb emissions', *Nature news*, 2015.
[3] R. Mao et al., *China Carbon Market Research Report*, edited, Beijing, Environomist, 2016.
[4] State Council, *Air Pollution Prevention and Control Action Plan*, edited by State Council, Beijing [in Chinese], 2013.

These developments seem to be broadly consistent with the use of the market mechanisms in other countries, although it is important to see the details. Key ideas in Document 9 are to set separate tariffs for transmission and distribution based on the principle of earning 'cost plus reasonable profit', and to separate retail from network activities. This is important because it allows for greater competition both in the retail market and in the wholesale generation market, supporting least cost dispatch and pricing that reflects short-term marginal costs. With or without that structural change, it is important to introduce least cost dispatch. This would permit the introduction of short-term price signals to support spot trading and encourage demand response and other sources of flexibility, which in turn would facilitate the integration of renewables and regional trade. The reform could also help to significantly reduce, or even eliminate, guaranteed annual 'non-market' coal quotas.

In short, an important message from international experience is that competitive electricity market mechanisms improve efficiency and can help to reduce the cost of phasing out coal, for instance to ensure resource adequacy and provide flexibility when coal is replaced. More generally, the challenges of climate change and local pollution offer a good opportunity to accelerate the process of power sector reform in China. We welcome evidence that China is indeed accelerating market reform and look forward to seeing the details of that reform.

Carbon emission allowance prices and trading

There is a growing international consensus in favour of pricing carbon (CO_2) emissions. China is introducing a national cap-and-trade system for carbon in 2017, building on over ten years of experience with the Clean Development Mechanism and its seven pilot carbon markets. No doubt, China has learned from the successes and the failures of other carbon markets. Nevertheless, we would highlight three messages from international experience.

First, credible, long-term carbon price signals are important to encourage investment and innovation in low carbon technologies. This encouragement could be achieved through the introduction of a long-term forward-looking, rising, carbon price floor for emission allowances. An alternative is a central banking system that adjusts the supply of allowances to ensure that prices remain within upper and lower limits. The key is credibility, which the Chinese government is well placed to provide.

Second, China may want to consider determining the lower price limit for emission allowances by reference to the concentration of greenhouse gases in the atmosphere, so as to provide a sharper price signal if needed. Since this is an idea that makes sense at a global level and has consequences for competitiveness of specific industries, China might consider making this a proposal for all countries to adopt in future UNFCCC negotiations.

Third, the funds raised through auctioning of allowances or through environmental taxation could be recycled within the economy, either to reduce the impact of higher energy costs on vulnerable consumer groups or to support investment in decarbonisation projects. At least half the funds from the EU ETS must be dedicated to climate change or energy related purposes. The idea of fiscal revenue neutrality – where additional auction or tax revenues are fully recycled in the economy – also has considerable merit, not least because it reduces opposition to pricing or taxing carbon emissions.

Ownership structure and governance

Most of the international experience studied in this report refers to privately owned companies operating in markets where networks are separately owned from generation and retail activities, and where generation and retail are subject to competition. Governments define the laws and regulations, but companies for the most part make investment decisions based on the economic merits of the investment, and are free to change their business model and company structure.

In China, on the other hand, the ownership structure and the monopoly over networks and retailing may blunt important economic signals and distort decisions. For instance, public ownership of coal-fired plants may make it even more difficult (than for private companies) to shut those plants due to the consequences for local communities. It may also encourage the building of new plants when they are not needed since the consequences of stranded assets are farther down the road and may be ignored. In this respect, we support the structural reform ideas identified in Document 9 and other measures to lower the barriers to entry (by private investors) and encourage competition in all stages of the electricity value chain.

Regulation of local air pollution has strong public support

Although climate change is a powerful reason to phase out coal-fired generation, one message from international experience is that local air pollution and related health concerns have triggered regulations and public support for the displacement of coal by lower carbon alternatives. This is of course also true in China.

Compensation for owners of existing coal-fired plants?

International practice in liberalised electricity markets normally involves giving the owners of existing plants many years notice of any regulatory changes that will require additional investment to meet new emission standards. Owners are given the option either to make the investments, or to opt out. If the owner chooses to opt out, the plant is typically given a transition period and a controlled operating regime before it shuts down. Furthermore, the normal practice is not to subsidise the required investment to meet the new standards. This approach has good incentive properties and is especially suitable for systems with relatively old and inefficient plant. It does not require the payment of compensation.

However, governments sometimes agree to compensate owners for 'lost profits' related to the early closure of coal plants, or to help finance the investment needed to meet new environmental standards. The case for compensation is greatest when plants are relatively new and when owners have been given explicit guarantees of cost recovery. In the interest of encouraging early closure of coal-fired generation, or retrofitting of CCS on relatively new and efficient plants, China may want to consider some form of financial compensation.

Discouraging investment in new unabated coal-fired plants

Closure of existing plants, especially when they are relatively new as in China, is much more difficult than discouraging investment in new unabated coal-fired plants. Closing plants prematurely means that investors do not recover sunk investment costs. This is likely to lead to strong opposition from investors, employees and the local community. The case for closing older, inefficient plants is much easier to make and China has been expert in replacing old with new plants. Likewise, it is easier to make the case for closure of plants that are causing local pollution, as China has also done very recently.

Investment in new plants involves putting at risk potential returns, not the loss of sunk costs. The decision not to proceed with the investment usually implies very limited losses related to expenses incurred before the investment in undertaken. In cases where investment in new plant is being considered, investors should make their assessment taking account of the risks that could devalue the asset once it has been built. Government can help by providing clear long-term signals for investors.

Exploiting opportunities of the transition away from coal

Governments and companies in Europe and North American are finding ways to exploit the opportunities afforded by the transition away from unabated coal. That transition corresponds to a fundamental transformation of the energy sector, involving decarbonisation and decentralisation of the electricity sector, as well as electrification of key end markets, such as transport and buildings. This transformation is broadly beneficial for society, and also offers an opportunity to promote the development of new lower-carbon technologies and business models that are sustainable and have global markets.

What does this mean for China? Reforms of the kind identified in Document 9 – especially those that support efficient merit order dispatch and prices based on short-run marginal costs – could open the door to the creation of competitive wholesale markets for energy, capacity, flexibility and other services. These reforms and markets would encourage more efficient use of existing resources, regional coordination of investment and operations, the integration of renewable power and generally lower system costs and prices. Furthermore, they would encourage investment in digital technologies (including blockchains) and new business models that would allow consumers to participate as 'energy citizens' in the electricity markets through self-generation, demand response and storage. And they would support the process of electrification of final energy markets, lowering China's reliance on imported fossil fuels.

We have seen how this transformation is changing business models in other countries. It explains the restructuring of incumbent electricity utilities, such as E.ON and RWE, in order to separate stranded or potentially stranded assets (like coal and nuclear generation) from those activities with the greatest potential (networks, renewables and consumer services). It explains entry into the electricity sector by new players, like Tesla, Google and Apple, not to mention the companies that specialise in renewable power. As it did in the renewables business, China has the potential to exploit the opportunities afforded by embracing the transformation of the energy sector.

As other countries are doing, China should encourage a public narrative focused on how best to exploit the opportunities of building a low carbon economy. As low carbon technologies move into the market, the nature of the climate policy debate is changing. The challenge now is how to make the economy work better – smarter, cheaper and cleaner – and pick up all the climate benefits on the way.

1. Introduction

This study addresses two issues related to coal-fired generation. The first is how selected countries in the European Union and North America are making the transition away from unabated[5] coal-fired power. The second is to identify ideas for reforms that could ease a similar transition in China.

It is important to begin by defining the scope of this study. The paper concentrates on coal-fired generation, not on the mining of coal, its industrial use or the political economy frictions related to closure of facilities that use coal. It also focuses on countries where coal-fired generation assets are stranded in the sense that they have experienced or are likely to experience 'unanticipated or premature write-downs, devaluations, or conversion to liabilities'.[6] In most of these countries, public policies and financial markets reflect that current trends in unabated coal-based generation are inconsistent with achieving global climate change targets. In the US, closure of coal plants also reflects that gas-fired generation is economically more attractive. Investor expectations of more stringent environment regulations and deteriorating financial prospects accelerate closure of many coal-fired plants and discourage investment in upgrades or new plants. The study draws on experience of the transition away from unabated coal-fired generation in selected countries and on the reforms that have smoothed that transition.

This international experience will be especially relevant for China if the intention is to cap and then reduce unabated coal-fired generation. China has already made a commitment to peaking greenhouse gas emissions by around 2030, increasing non-fossil sources to 20% by 2030 and reducing carbon intensity 60-65% below 2005 levels by 2030.[7] In addition, it has introduced cap-and-trade programmes covering a number of industries,[8] increased substantially the role of renewable energy and taken steps to reduce coal consumption, including bans on approving new coal power plants (except combined heat and power plant) in three industrial regions: Beijing-Tianjin-Hebei, Yangtze River Delta and the Pearl River Delta.[9] China has also included an ambitious CO_2 emission performance targets in the Thirteenth Five Year Plan on Controlling Greenhouse Gas Emissions.[10] Nevertheless, we are aware of no official government policy on the role of coal-fired power in the longer term, or on reducing emissions from coal-fired stations through closure of assets or retrofitting them with CCS or other abatement equipment.

China is very different from many of the other countries that are making the transition away from coal. Its very heavy reliance on coal, high economic growth and concern for economic development make an early end to coal-fired generation very challenging, even if the aim is to reduce this reliance. This contrasts with the experience of wealthier countries with lower growth rates and less dependence on coal. Furthermore, the reliance on domestic coal is considered to be a matter of national security in China, which is not the case for countries that rely mainly

[5] By 'unabated' we mean that the plants do not have carbon capture and storage (CCS) or other technology to abate CO_2 emissions. 'Coal-fired generation' refers to plants that have no abatement technology.

[6] Ben Caldecott et al., *Stranded Assets and Thermal Coal - An Analysis of Environment-Related Risk Exposure*, edited, Oxford, UK, University of Oxford, 2016. Page 9

[7] Tollefson; ibid.

[8] Mao et al.; ibid

[9] State Council; ibid.

[10] China's Five Year Plans are a series of social and economic development initiatives. The most well-known five-year plan is the Five Year Plan on Social and Economic Development, which provides general guidance for economic development, sets growth targets, and proposes reforms at the beginning of each five-year period, with the thirteenth and last period being between 2016 and 2020. Specific plans on different industries and regions are usually issued by different national/regional government departments, following the general guidance from the Five Year Plan on Social and Economic Development. For example, in this report, we refer to the Thirteenth Five Year Plan on Electricity System Development and Thirteenth Five Year Plan on Controlling Greenhouse Gas Emissions. These specific plans usually define more detailed tasks and targets to address topics like electricity and greenhouse gases.

on coal imports or that have alternative, competitive domestic energy resources. Another important difference is the need to keep the closure of generation assets in sync with the closure of domestic coal production. In fact, China has been closing small mines recently, leading to higher coal prices.[11] This points to a wider problem, compared to most other countries, with the possible exception of the US: what happens in China will affect the world coal market and the prospects for meeting global climate change objectives. There is also the important difference that in China, unlike elsewhere, a large proportion of coal demand is from industry, so policy should be about reducing unabated coal used in all sectors. Otherwise there is a risk that placing the policy burden on power will give incentives for industry either to use coal rather than electrify, or to generate their own power using coal. China's coal-fired generation fleet is also relatively young by comparison to the fleets in OECD countries, notably the US; this makes early closure in China potentially more difficult than in many countries.[12] Another difference is ownership: most of the international experience applies to privately owned generation assets, whereas in China the national and local governments are important shareholders. China also has more experience than other countries with organised closure of smaller and more inefficient plants; this experience will no doubt inform China's efforts to address current problems of excess capacity. Finally, China's political system differs from the other countries undergoing the transition, in particular because of its heavy reliance on government planning and the relatively limited reliance on market mechanisms. In short, China is very different from the other countries studied in this paper and any potential guidance for reform must be qualified by this fact.

In spite of the differences, and in some cases because of them, there are many challenges and opportunities where international experience may be relevant for China. In particular, this report answers three broad questions related to phasing out coal-fired generation. First, how have governments, regulators and electricity companies managed the process of closing plants prematurely? Second, how have governments and markets discouraged investment in unabated coal-fired generation assets? Third, what are the opportunities related to the transition away from coal and how have they been exploited?

There is a general message from international experience, namely that market and regulatory reforms can assist with the transition. This does not mean that liberalisation *per se* favours decarbonisation or closure of coal-fired generation, but rather that market mechanisms can help to lower the costs of the transition away from coal, and to provide incentives for innovation and the development of new low carbon energy resources. Of course, public policy decisions are required to design markets and regulate them effectively, and above all to send clear signals to guide investment decisions in very long-lived assets.

The paper has six sections, in addition to this introduction. Section 2 summarises briefly the global trends in coal-based generation and identifies the countries where the transition away from coal has begun or is now over. It also reviews briefly the scientific literature on coal and climate change, emphasising the need to cap and quickly reduce emissions from coal in order to stay within the global carbon budget that is consistent with keeping temperature rises below 2ºC. Section 3 addresses questions about China's policy with respect to the closure of existing generation assets and investment in new or existing assets. It emphasises the potential for stranded assets and the cost of retrofitting CCS if existing assets are not shut. The remainder of the report (Sections 4-6) considers

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[11] Bloomberg News, *China Grappling With Runaway Market It Started*, http://www.bloomberg.com/news/articles/2016-11-04/coal-surge-leaves-china-grappling-with-runaway-market-it-started, 2016, (accessed 11 November).
[12] The average coal fleet age in the United States was 45 years in 2013 (See Taylor Dimsdale, Julian Schwartzkopff, and Chris Littlecott, *G7 Coal Phase Out: United States* in A Review for Oxfam, edited, London, E3G, 2015.). The average coal fleet age in United Kingdom was 45 years in 2015 (See DECC, *Electricity: Chapter 5, Digest of United Kingdom Energy Statistics (DUKES)*, edited, London, Department for Business, Energy & Industrial Strategy, 2016.). We do not have relevant data for other OECD countries. However, we are aware of some relatively new coal power plant in European countries, including Germany and Poland. In China, most of the existing coal power generation capacity was built after 2002.

issues where international experience may offer potential insights for China to consider. Section 4 analyses experience with closing existing plant; Section 5 summarises experience with investment in coal-fired plants; and Section 6 identifies some of the opportunities afforded by the transition away from coal. Section 7 draws together the main ideas for electricity sector reform in China to smooth the transition away from unabated coal-fired generation. While recognising the challenges of this transition, our goal is to reinforce and accelerate the reforms that are already underway.

2. Global trends with respect to coal-fired generation

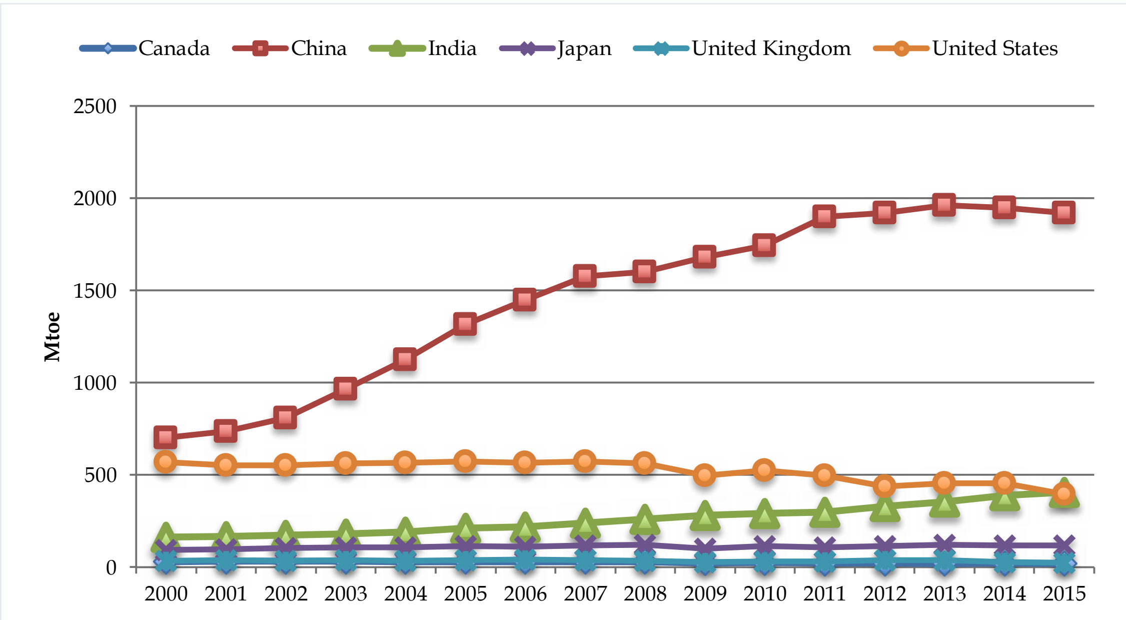
This section identifies broad trends in coal-fired generation. In particular, it reviews the trend away from coal-based generation in a number of countries, notably the US, Canada, the UK and Germany, while recognising the continued growth of coal-fired generation in other countries.

Overall, the message is that coal-fired power stations have been economically attractive in most countries, as long as the environmental costs were not included in the analysis. However, with growing concern over local and global environmental impacts of coal-based emissions, governments in many countries have introduced policies and regulations that have made coal-fired generation more expensive, or indeed ruled it out altogether. At the same time, the cost of alternative sources of electricity has fallen, including from natural gas in the US and from renewable power in most countries.

2.1 Many developed countries are phasing out coal-fired generation

Global coal consumption has risen significantly since 2000, especially in China and India, as illustrated in Figure 1 below. However, coal consumption growth has been flat or negative in many of the OECD countries, notably the US, Canada and the UK. It has also begun to fall in China since 2013.

Figure 1 Coal consumption in selected countries between 2000 and 2015 (Source:[13])



In most countries, with the notable exception of China,[14] coal is principally used for power generation and the trends for coal-based generation are very similar to those for coal consumption. The trends for power generation

[13] BP, 'BP Statistical Review 2016', 2016.
[14] IEA data shows that in OECD countries total coal primary supply was 1446 Mtce in 2014, final consumption was 161.2 Mtce (including industrial use, transport, others and non-energy use). Industry use was 130.3 Mtce, which accounted for about 9% of total coal consumption. (See IEA, *Coal Information*, edited, Paris, International Energy Agency, 2016.)

can be measured in two ways: as a share of total generation, and in terms of total generation.

2.1.1 *Coal as a share of total generation*

From Figure 2, the decline in coal-fired generation as a share of total generation is most evident in the US and Canada, but has also begun in the EU. That figure illustrates that, between 2000 and 2014, the share of coal in US electricity generation fell from over 50% to 40%, while in Canada it fell from 19% to about 10%. Since then, coal's share in the US has fallen further; the US Department of Energy forecasts coal's share of generation to fall to 32% in 2016, with natural gas rising to 33%, exceeding coal's share for the first time on an annual basis.[15]

The European Union has also experienced a decline in the share of coal-fired generation. In particular, the share of coal in UK generation has recently fallen very quickly, from almost 40% in 2012 to less than 6% in 2016-Q2. Indeed, in 2016-Q2, supply from coal-fired power stations had fallen by 71% year-on-year. This was driven by reduced capacity following the closures of Ferrybridge C and Longannet, along with the biomass conversion of the third unit at Drax. Overall, coal's share of the electricity supplied by major power producers stood at 5.8% in 2016-Q2, down from 20.3% in 2015-Q2. Indeed, the decline has been so significant that there are periods in the UK when no coal is running; this happened in the spring of 2016, for the first time since the 1880s.[16]

The share of coal in generation is also falling in Germany, but more slowly and with a continued high share of coal in the electricity mix, from 53% in 2000 to 42% in 2015. Utilities have shut about 18% of German hard coal-fired capacity since 2011. However, margins are now very low for a variety of reasons, including excess capacity and the penetration of renewables, and this is encouraging early closure. Bloomberg reports that over a quarter of the hard coal-fired generation may shut ahead of schedule if plant operators decide not to invest in upgrades.[17] In addition, of Germany's 21GW of lignite plants, 13% are to be shut before 2020.[18]

The experience in the UK and Germany reflects the trend away from coal in Western Europe.[19] In June 2016 Platts' *Power in Europe* listed no new coal-fired power stations for Western Europe in their 'New Plant Tracker' – the first time that has happened.[20]

The trend away from coal is not occurring everywhere in the OECD. Central and Eastern Europe continue to build new coal-fired power stations, with Platts listing four coal/lignite power stations under construction in Poland. Japan is also building new coal plants and the share of coal has been rising since the Fukushima nuclear accident. There, the share of generation from coal rose from 22% in 2000 to 33% in 2014. At present, Japan has 1.9 GW of coal capacity under construction and another 28 GW of coal capacity at various stage of planning. Caldecott et al.

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[15] EIA, *Natural gas expected to surpass coal in mix of fuel used for U.S. power generation in 2016*, http://www.eia.gov/todayinenergy/detail.php?id=25392, 2016, (accessed 11 November).

[16] BEIS, *Energy Trends: Electricity. September 2016.* , edited, London, UK Department for Business, Energy and Industrial Strategy 2016; BEIS, *Electricity: Chapter 5, Digest of United Kingdom Energy Statistics (DUKES)* edited, London, UK Department for Business, Energy and Industrial Strategy, 2016.

[17] Weixin Zha and Rachel Morison, *More German Coal Plants Face Early Closures as Profits Fade*, http://www.bloomberg.com/news/articles/2016-09-30/more-german-coal-plants-face-early-retirement-as-profit-dwindles, 2016, (accessed 11 November).

[18] Simon Göß, *Closure of German power plants*, http://ceenews.info/en/closure-of-german-power-plants/, 2016, (accessed 11 November).

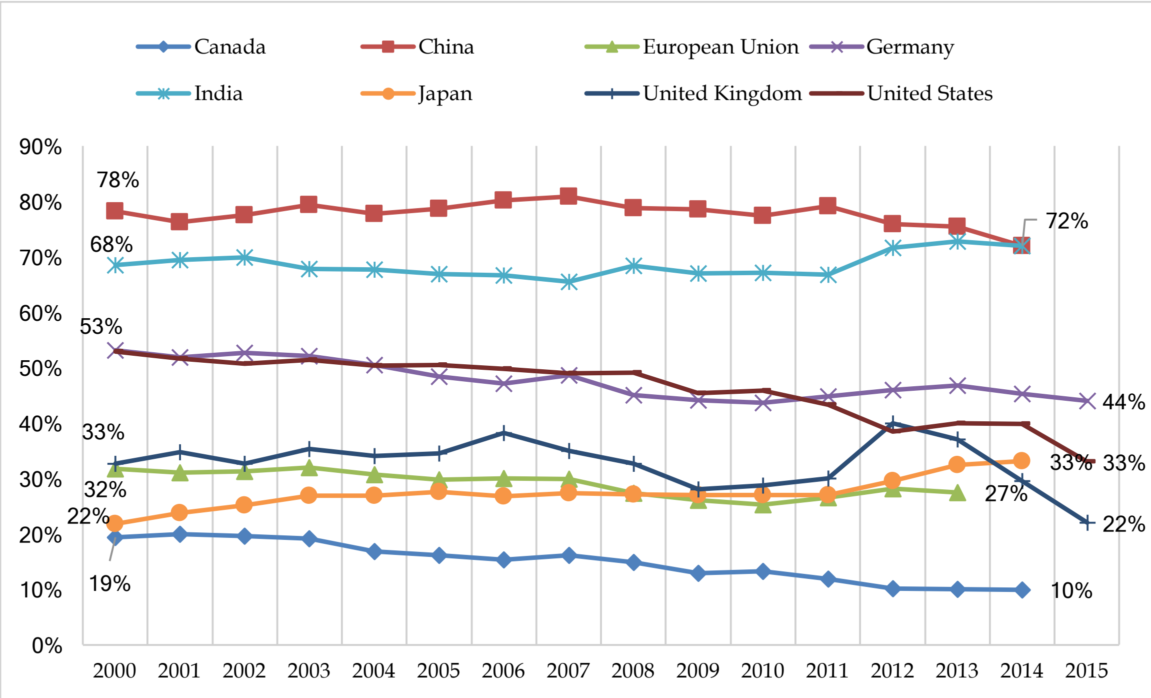
[19] Seven EU countries have phased out coal power: Belgium, Cyprus, Estonia, Latvia, Lithuania, Luxembourg, and Malta. Other EU countries are making the transition away from coal in the near future including Portugal (in 2020), Austria (2025) and Finland (at some point next decade) (See Climate Home, *Belgium quits coal power with Langerlo plant closure*, http://www.climatechangenews.com/2016/04/05/belgium-quits-coal-power-with-langerlo-plant-closure/, 2016, (accessed 23 November).)

[20] Platts, 'New Plant Tracker, June 2016', *Power in Europe,* vol. June 20, 2016, no. 728, 2016.

(2016)[21] highlight the potential risks of over-capacity since the planned and under-construction coal plant exceeds the capacity needed to replace the retiring fleet by 191%.

In the large emerging countries, coal's share of generation has been, and remains, very high. Indeed, in many Asian countries, we are witnessing rapidly increasing demand for coal from the power sector. In the light of the Paris Agreement and for their own domestic policy reasons, national governments across the region are reassessing power development plans, introducing more renewable energy sources, promoting energy efficiency measures, and reducing the contribution of coal to the electricity mix. However, in many countries, especially in South East Asia, coal still dominates the targeted additional capacity.

Figure 2 The share of coal power generation in total generation, 2000 and 2015 (Source: from various sources, see[22])

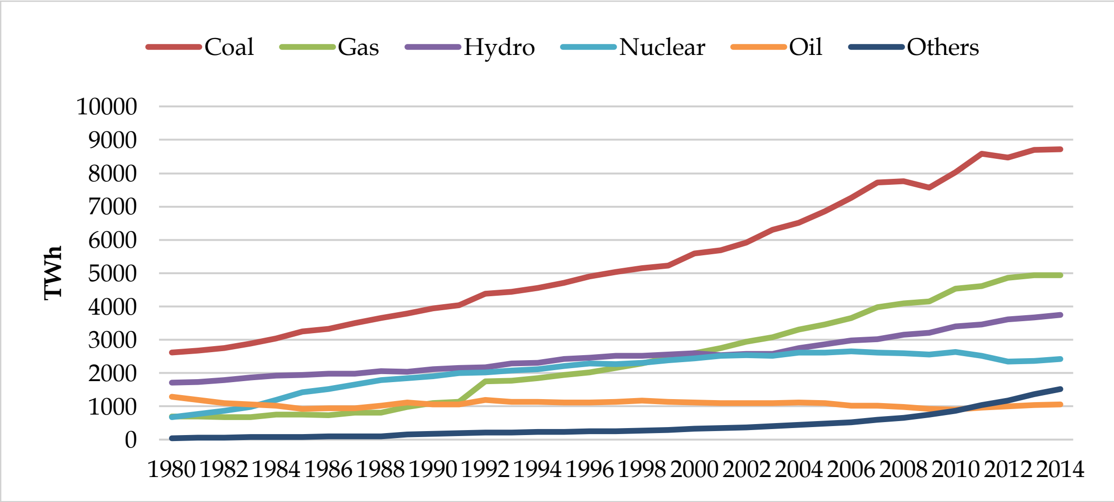


2.1.2 *Total coal-fired generation*

Globally, coal-fired generation has grown substantially since 1980 and has only recently begun to flatten out. Total coal-fired generation more than tripled, from about 2,618 TWh to about 8,726 TWh in 2014, which was 39% of total generation in that year.

[21] Ben Caldecott et al., *Stranded Assets and Thermal Coal in Japan: An analysis of environment-related risk exposure* edited, Oxford, Smith School of Enterprise and the Environment, 2016, Vol. Working Paper May 2016.
[22] Data between 2000 and 2014 are from (The World Bank, *Electricity production from coal sources (% of total)*, edited by IEA Statistics, 2016.). For 2015: UK data is from (BEIS, *Electricity: Chapter 5, Digest of United Kingdom Energy Statistics (DUKES)*); US data is from (EIA, *Natural gas expected to surpass coal in mix of fuel used for U.S. power generation in 2016*); Germany's data is from Craig Morris, *Germany is 20 years away from 100 percent renewable power – not!*, http://energytransition.de/2016/01/germany-is-20-years-away-from-100-percent-renewable-power-not/, 2016, (accessed 11 November).

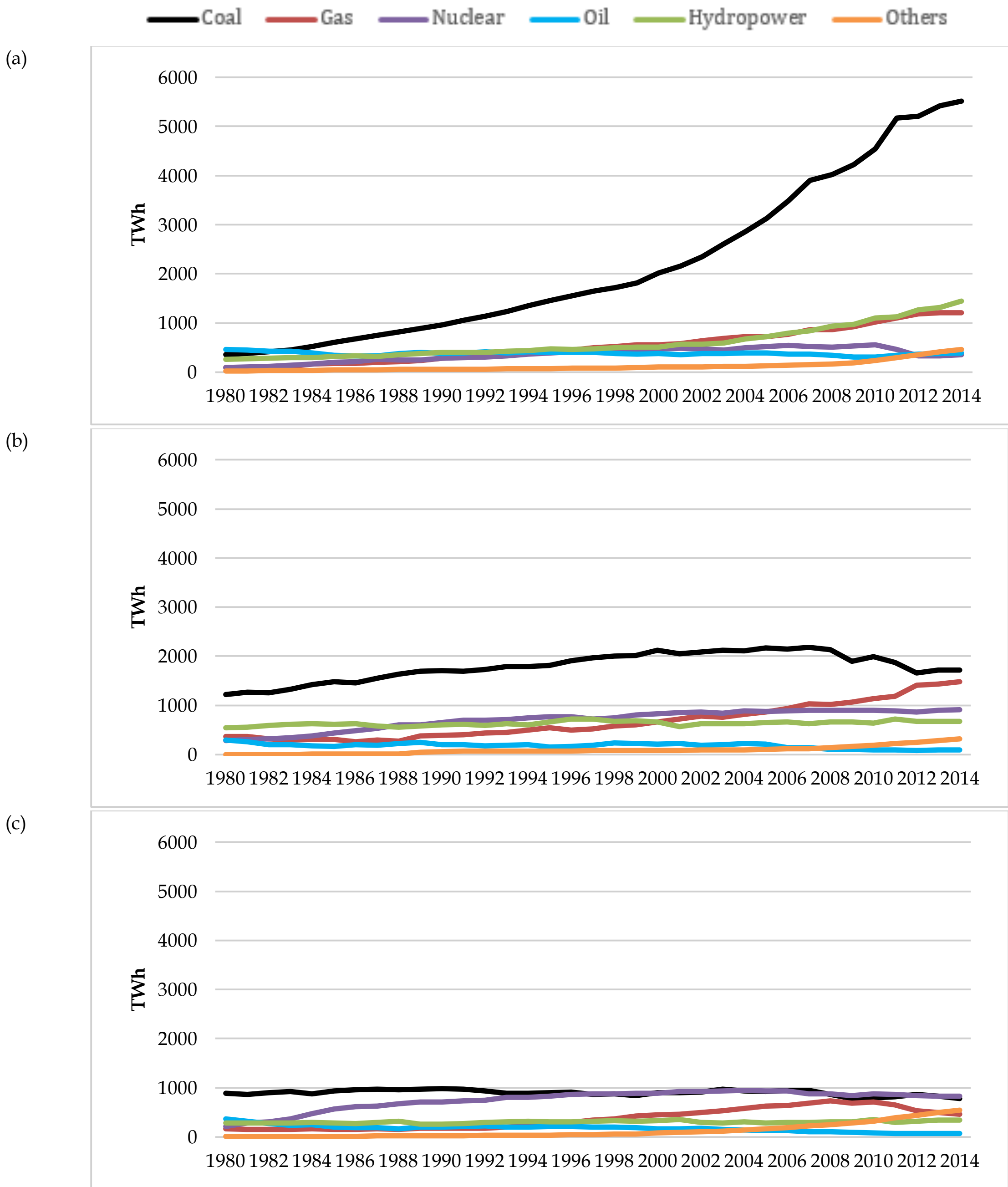
Figure 3 World electricity generation (TWh) (Source:[23]*)*



More than half of the net global increase in coal-fired generation occurred in Asia-Oceania, especially China. Meanwhile, the declines are apparent elsewhere, especially in North America since 2008 (see Figure 4). Furthermore, as mentioned above, the decline in coal-fired generation has accelerated since 2014, especially in the UK.

[23] The Shift Project Data Portal, *Datasets on Electricity Statistics*, in Available from: <http://www.tsp-data-portal.org/>, edited by The World Bank and US EIA Historical Statistics, 2015. Data based on the World Bank World Development Indicators and the US EIA Historical Statistics.

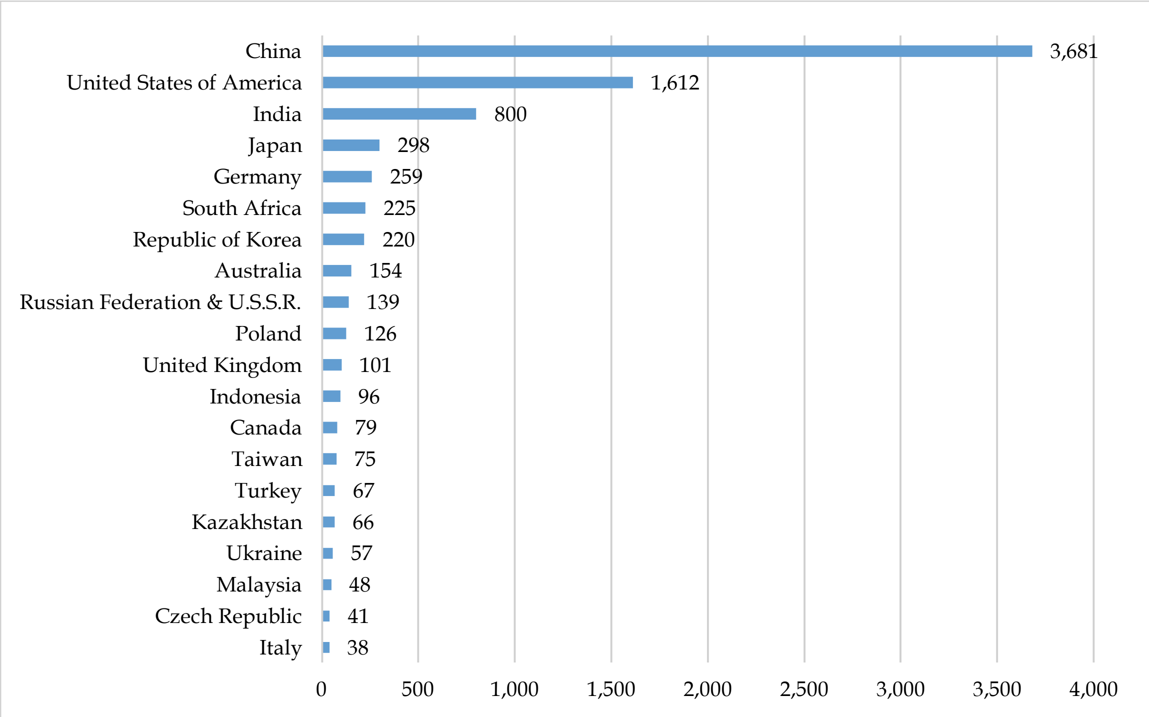
Figure 4 Generation in (a) Asia and Oceania, (b) OECD North America and (c) EU 27, in TWh (Source:[24])



In 2014, coal-fired generation was greatest in China, the US, India, Japan, Germany, South Africa and South Korea. Figure 5 shows the world's 20 highest coal power generation countries.

[24] Ibid. Data based on the World Bank World Development Indicators and the US EIA Historical Statistics.

Figure 5 World top 20 countries with highest coal power generation in 2014 (TWh) (Source:[25])



Looking forward, governments of six of the G7 members have decided not to support investment in coal power plants unless the plants include CCS facilities, or are carbon capture ready. The United Kingdom announced its plan to restrict the operation of coal power plants in 2023 and close all unabated coal power plants by 2025. The United States introduced its plan to reduce CO_2 emissions from power generation by 32% by 2030, compared to 2005.[26] Six states in the US have phased out coal-fired power generation (except combined heat and power facilities) –California, Hawaii, Idaho, Maine, Rhode Island and Vermont. Other states have plans to close coal power plants: Massachusetts, Oregon and Washington aim to close their remaining coal plant by 2025.[27] In a recent announcement (on 21 November 2016), Canada's Liberal government revealed its plan to virtually eliminate traditional coal-fired electricity by 2030.[28] In Canada one province has shut down all its coal plants (Ontario) and another (Alberta) has committed to doing so in 2030.

This report focuses especially on North America and the EU (in particular the UK and Germany) in order to illustrate how countries or provinces in these regions have encouraged and managed the transition away from coal-fired generation. Even though the election of Donald Trump could well weaken the regulatory pressure on coal in the US, the competitive pressure from natural gas and the risks associated with coal-fired generation are likely to continue to discourage investment in new coal plants and to encourage early closure of old plants in that country.

[25] Ibid. Data based on the World Bank World Development Indicators and the US EIA Historical Statistics.
[26] The Supreme Court has stayed implementation of this plan pending judicial review. See EPA, *Clean Power Plan for Existing Power Plants*, edited, U.S. Environmental Protection Agency, 2015, https://www.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants. The election of Donald Trump makes it unlikely that this plan will be implemented during his presidency.
[27] J. Fitzpatrick, *Coal Plants Are Shutting Down, With or Without Clean Power Plan*, https://morningconsult.com/2016/05/03/coal-plants-shutting-without-clean-power-plan/, 2016, (accessed 23 November).
[28] Reuters, *Canada speeds up plan to phase out coal power, targets 2030*, http://www.reuters.com/article/us-canada-energy-coal-idUSKBN13G1EK, 2016, (accessed 23 November).

2.2 What explains the transition away from coal-fired generation?

When trying to explain the trend away from coal in some of the richest economies, there are two common themes: existing environmental regulations along with the risk that these regulations will become more demanding; and the declining relative economic attractiveness of coal-fired plant compared to alternative investments. These trends are connected since policies and regulations often raise the cost of coal-fired generation while encouraging (and subsidising) investment in low carbon alternatives. Together these trends encourage or require early closure of plants and discourage further investment. Here is a brief summary of what is driving these trends.

First, coal-fired generation affects local air and water quality, and therefore health (through emissions of SO_2, NO_x and particulates), as well contributing to global climate change (through CO_2 emissions). The distribution of the costs and benefits from abating air pollution are local and realised in the very short term. However, the costs and benefits of abating CO_2 emissions are shared globally and with future generations, making solutions more complex and controversial than in the case of local pollutants. Concern over both local and global environmental issues increasingly drives energy policy in most countries and discourages private investment decisions related to coal-fired generation. In particular, governments have introduced taxes and prices on environmental emissions, as well as performance standards to limit those emissions. Where they do not prohibit coal-fired power stations altogether, these policies usually raise the costs and reduce the capacity factors of these stations. In some cases, for instance in Germany and Spain, low prices for coal and for European emission allowances mean that coal continues to operate ahead of natural gas – as a result, some very efficient gas-fired plants have shut while coal-fired generation continues to operate. In other cases, notably the UK, a floor price for CO_2 emissions makes coal-fired generation more expensive than electricity generated from natural gas, which accelerates the closure of coal plant. In Canada (Ontario and Alberta), governments explicitly rule out new coal-fired power stations and require early closure of existing plants. In general, the long-term trend in all these countries is a reduction in coal-fired generation.

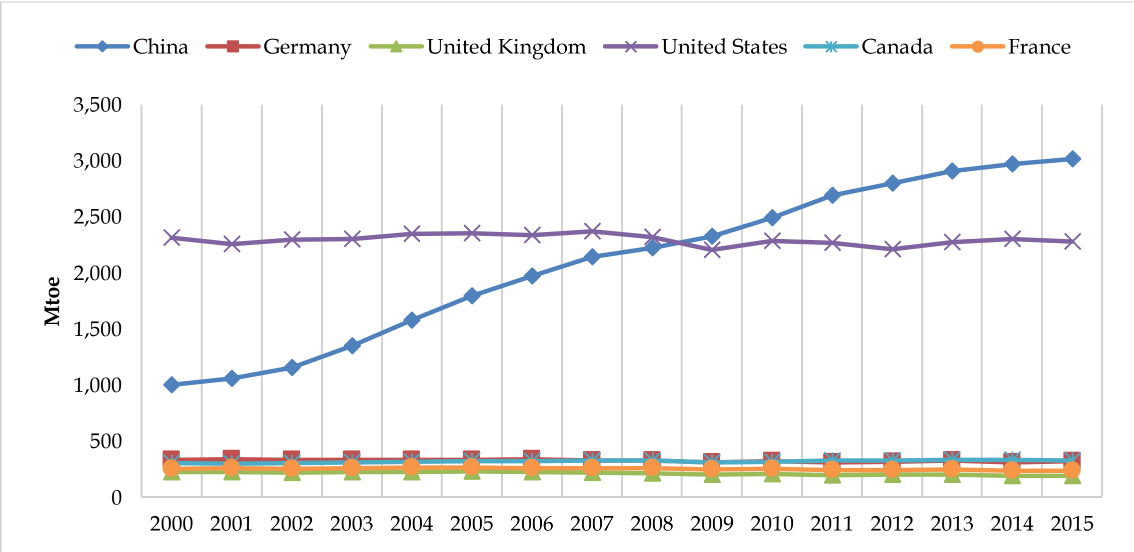
Second, coal is becoming less competitive because the cost of renewables has fallen a lot, and been subsidised (although often less than coal). For example, the global weighted average cost per kW of onshore wind power and utility scale solar PV projects declined by about 15% and 56% respectively between 2010 and 2015.[29] Furthermore, the IEA[30] expects a further reduction in costs for onshore wind (15% by 2021) and solar (25% by 2021); and these are probably underestimates judging from past experience. The same publication indicated that newly added renewable electricity capacity reached 153 GW in 2015, which accounted for more than half of the new generation capacity of all types. The accumulated renewable energy capacity is expected to grow by 42% (825 GW) by 2021. Once installed, renewables affect coal plants in two ways. First, they reduce coal's market share and running hours, since renewables have near-zero marginal costs and will run before coal in the economic merit order. Second, they reduce wholesale electricity prices earned by most conventional plants, like coal. This, along with the rising costs of coal-fired generation, explains why coal-fired generation is sometimes no longer profitable.

Coal is also facing competition from natural gas, although this is currently important mainly in the US. There, shale gas developments have driven the cost of natural gas well below the cost of coal on a $/MWh basis. If natural gas prices fall and emission prices rise in other countries, coal is likely to face more competition from natural gas as well as from renewables.

[29] IRENA, *the Power to Change: Solar and Wind Cost Reduction Potential to 2025*, edited, International Renewable Energy Agency, 2016.
[30] IEA, *Renewable Energy Medium-Term Market Report 2016*, edited, Paris, International Energy Agency, 2016.

Finally, in many OECD countries, the demand for energy is stagnant or falling. According to statistics that are summarised in Figure 6, primary energy demand in France, Germany, the United Kingdom and United States has been stagnant or falling since 2000. The same is happening to electricity demand in these countries. This exacerbates all the challenges just identified for coal. A shrinking market initially depresses wholesale prices if there is excess capacity, reduces capacity factors (running hours) for conventional plants and encourages premature closure of those plants.

Figure 6 Primary energy consumption in some OECD countries and China between 2000 and 2015 (in Mtoe) (Source:[31])



2.3 Coal-fired generation and climate change

Because climate change is the key driver (along with local air pollution) of policies that encourage the phasing out of coal, it deserves some additional analysis here. There is a growing consensus in the scientific community and among policymakers, that achieving the central aim of the Paris Agreement (to keep a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels)[32] requires an early capping and then a rapid decline in global unabated coal-fired generation.[33] This implies shutting down many existing coal-fired stations, or retrofitting them with CCS equipment, and requiring CCS or similar abatement on new plants.[34]

The IEA has defined its 450 Scenario to correspond to a global concentration of 450 ppm of CO_2, which they consider consistent with a 50% probability of limiting global temperature increases to 2ºC. Carbon capture and

[31] BP (2016). "BP Statistical Review 2016."
[32] 'The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius', UNFCCC, December 2015, The Paris Agreement, Available from <http://unfccc.int/paris_agreement/items/9485.php>.
[33] P.O. Davidson, S. Leone, and P.P.C. Frumhoff, *New unabated coal is not compatible with keeping global warming below 2 °C. Statement by leading climate and energy scientists*, https://europeanclimate.org/documents/nocoal2c.pdf, 2013, (accessed 12 October).
[34] CCS is a net emitter of CO_2. Nevertheless, significant CCS retrofits are assumed by the IEA in scenarios that it considers to be compatible with staying below the 2ºC limit.

storage (CCS) for new and most existing coal-fired power stations is a central assumption. However, it is notable that the most recent IEA World Energy Outlook[35] assumes a reduced role for CCS in the 450 Scenario compared to the previous World Energy Outlook[36]. This is due to the slow pace at which CCS projects are being demonstrated and tested. Nevertheless, CCS in China is still very important, accounting for 75% of the coal-fired plants assumed to be using CCS by 2040. (See Box 1.)

Box 1: Coal and CCS in the IEA 450 scenario

'In the 450 Scenario, world coal demand peaks in the current decade and then declines by 33% to return to the level of use in the early 2000s. This large reduction in coal use stems from the policies that governments worldwide, but especially in China and OECD countries, adopt towards setting the energy system on track to have a 50% chance of keeping the long-term increase in the average global temperature to below 2°C (see Annex B). By 2040 in the 450 Scenario, coal accounts for only 16% of the world's energy mix and 12% of electricity output. CCS plays an important role in reducing emissions from coal-fired generation, with three-quarters of the coal-based power coming from plants equipped with CCS.'[37]

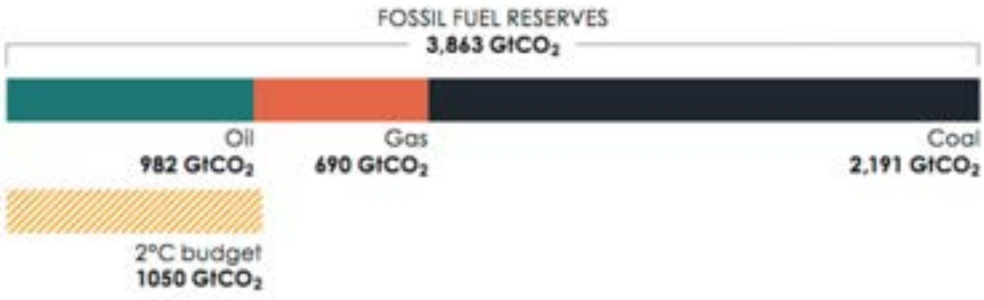
'In 2040, globally some 430 gigawatts (GW) of power plant are equipped with CCS in this scenario, 60% of which are coal-fired. By 2040, power plants equipped with CCS generate nearly 10% of the world's electricity. Around 75% of the coal-fired power plants using CCS are located in China. This highlights the key role that China is expected to take in advancing the technology in order to decarbonise its energy mix and to protect the value of its power generation assets and coal reserves.'[38]

The literature supporting the need for early capping and then a rapid decline in coal-fired generation is now quite extensive.[39] The starting point for the analysis is to emphasise the difference between carbon stocks and flows. What matters to climate change is the accumulated stock of atmospheric CO_2 rather than the flow of emissions in any given year. Since investments in coal-fired generation imply emitting carbon dioxide for many decades, it is important to consider what the investment means for future carbon emissions. Davis and Socolow (2014)[40] estimate the committed emissions from fossil fuel plants globally. Committed emissions refer to total emissions over the lifetime of fossil fuel power plants. This can be split into two parts: the realised emissions (that have already happened) and the remaining committed emissions (RCE) that will happen between now and the end-of-life. Under different assumptions of generator lifetime, the authors estimate the global RCEs from fossil fuel plants.

The next question is whether the remaining committed emissions from existing fossil-fired assets could be absorbed without having a dangerous impact on the climate. For instance, the IPCC concluded that, to have a 66% probability of remaining on the 2ºC pathway, the world could only emit a further 1050 $GtCO_2$. This is about a quarter of all known fossil fuel reserves, with coal accounting for more than half of the potential CO_2 emissions (See Figure 7). The carbon budget has declined to less than 900 $GtCO_2$ since the IPCC calculation.

[35] IEA, *World Energy Outlook 2016*, edited, Paris, OECD/IEA, 2016.
[36] IEA, *World Energy Outlook 2015*, edited, Paris, OECD/IEA, 2015.
[37] Ibid. page 274
[38] IEA, *World Energy Outlook 2016*. Page 222
[39] Davidson, Leone, and Frumhoff; Alexander Pfeiffer et al., 'The '2°C capital stock' for electricity generation: Committed cumulative carbon emissions from the electricity generation sector and the transition to a green economy', *Applied Energy*, vol. 179, 2016; S. Davis and R. Socolow, 'Commitment accounting of CO2 emissions', *Environmental Research Letters*, vol. 9, no. 8, 2014.
[40] Davis, S. and R. Socolow (2014), ibis

Figure 7 Fossil fuel reserves and the remaining global carbon budget under the 2ºC scenario (Source:[41])



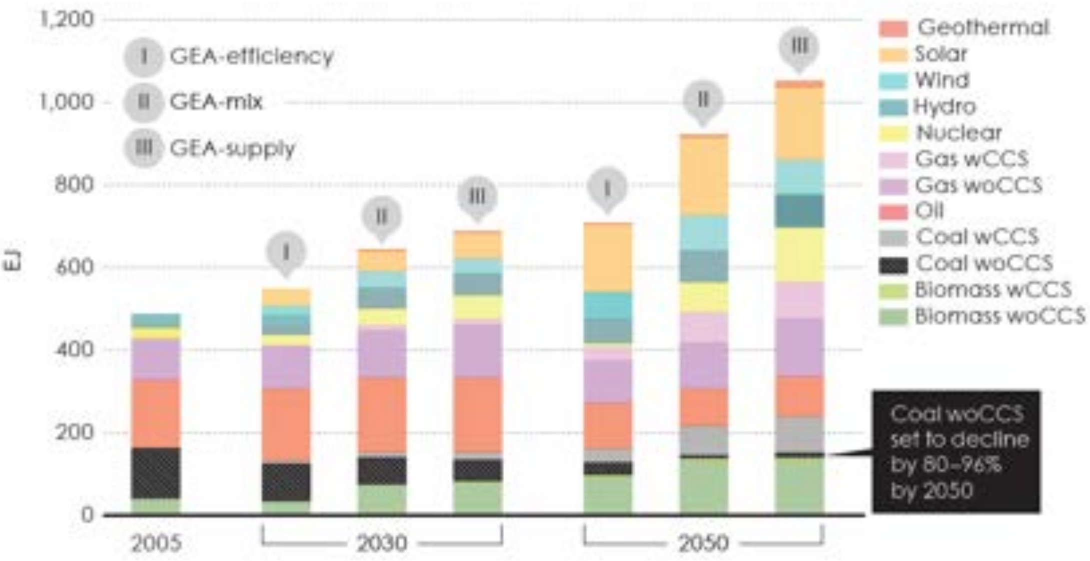
Third, although there is no simple way to allocate the remaining carbon budget among fuels, it seems reasonable to allocate a substantial part of the budget to sectors and uses where low carbon alternatives are unlikely to be widely available for some years, for instance liquid fossil fuels for aviation. Electricity is one sector with many lower carbon alternatives to unabated coal. Even the most efficient coal-fired station emits 740 gCO_2/kWh during its lifecycle (including both direct emissions from coal combustion and emissions associated with infrastructure and supply chain), while efficient gas-fired plants emit about 410 gCO_2/kWh and nuclear and renewables considerably less.[42] Only when coal is fitted with CCS does it have the potential to emit lower CO_2 emissions than an unabated gas-fired plant. IEA suggested that retrofitting existing coal power plants with CCS would reduce the emissions rate by about 90%, allowing coal plant to emit 75% less CO_2 than a combined cycle gas plant.[43]

Fourth, current trends in the power sector imply dangerous interference with the climate. Pfeiffer et al. (2016)[44] reach the conclusion, that '*… for a 50% probability of limiting warming to 2°C, assuming other sectors play their part, no new investment in fossil electricity infrastructure (without carbon capture) is feasible from 2017 at the latest, unless energy policy leads to early stranding of polluting assets or large scale carbon capture deployment.*'

Fifth, the Global Energy Assessment investigates scenarios for a transition that would limit temperature increases to 2ºC above industrial levels (See Figure 8). All the scenarios require reductions in global capacity of coal-fired power plants not equipped with CCS, so that coal without CCS falls by 80-96%. They also conclude that without strong reductions in demand and early closure of existing coal-fired plants there is no room for new high efficiency coal-fired plants. However, one scenario that is compatible with the 2ºC assumes the closure of two sub-critical plants for each efficient plant built.

[41] Davidson et al. (2013), ibis
[42] T. Bruckner Schlömer S., L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wiser, , *Annex III: Technology-specific cost and performance parameters*, in Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change edited, Cambridge, United Kingdom and New York, USA, Cambridge University Press, 2014.
[43] IEA, *The potential for equipping China's existing coal fleet with carbon capture and storage*, in Insights Series 2016, edited, Paris, France, OECD/IEA, 2016.
[44] Pfeiffer et al. (2016), ibis

Figure 8 Declining share of coal without CCS in the fuel mix in a range of scenarios that lead to a sustainable energy system (Source:[45])



Finally, a recent conference in Oxford[46] examined the challenges of limiting climate increases to the lower target of 1.5ºC. This target reinforces the arguments in favour of an early peak and then a rapid decline in coal-fired generation. The abstract for one of the presentations at this conference dealt specifically with this issue in China and the OECD.[47]

> *The scientific literature suggests that CO_2 emissions from coal use need to be zero globally around 2050 to limit warming to 1.5°C. …. Preliminary results suggest that for OECD, for the EU and for China, coal power plants presently operating will emit considerably more CO_2 than what would be in line with a least-cost budget in line with 1.5°C … These results clearly rule out new coal power plants coming online and point to the urgency of developing economic, political and social avenues to retire coal plants before end of lifetime.*

2.4 Conclusion

This section illustrates a trend away from coal-fired generation in some of the wealthiest OECD countries, along with increasing generation from coal in Japan and in a number of large emerging countries. However, the scientific evidence and policy scenarios imply that to have a reasonable (50%) probability of limiting global temperature increases to below 2ºC no new unabated coal-fired capacity should be built globally after 2017, and that significant investment will be required to fit CCS or other abatement equipment to existing coal-fired power stations that remain open. There will inevitably be debate about how to distribute the remaining carbon budget. Nevertheless, it should be clear from this analysis that all countries with substantial coal-fired generation will need to contribute

[45] Davidson et al. (2013), ibis
[46] International Conference*: 1.5 Degrees: Meeting the challenges of the Paris Agreement*, 20-22 September 2016, University of Oxford. http://www.1point5degrees.org.uk
[47] Marcia. Rocha et al., *What does the 1.5°c limit mean for coal plants in the OECD, China and the European Union?*, edited, Climate Analytics, 2016.

to the effort. And it should be even clearer to investors that there is a substantial financial risk associated with investing in unabated coal-fired assets.

3. China

This section provides a brief introduction to China's current policy related to electricity production from coal and the related emissions. It identifies two potential concerns related to stranded coal-fired assets. One involves the closure of assets. A second involves investment in new coal-fired plant. It also points to the importance, and the cost, of CCS or other abatement technology if China wishes to reduce CO_2 emissions while continuing to rely heavily on coal-fired generation.

3.1 China's policy on coal and climate change

Emission targets in China depend largely on finding a balance between environmental goals (local and global) and economic development. In the past, the two goals were in apparent conflict, with heavy industrial expansion and urbanisation rapidly increasing local air and water pollution as well as greenhouse gas emissions. However, the economy is now moving away from heavy industry and towards services and less energy-intensive industrial activities. This shift, along with slower economic growth, fuel substitution and greater efficiency, is reducing the use of coal in industry, which accounted for 55% of coal consumption in 2014.[48] In 2015, total coal consumption declined by 3.7%,[49] following a decline of 2.9% in 2014.[50] During the same period, coal power generation declined by 2.7% in 2015 and 0.3% in 2014. In summary, coal consumption in both industrial activities and power generation appears to have fallen in the last couple of years.[51]

China emitted about 8.6 billion tonnes of CO_2 emissions in 2014, with about half from coal-fired power generation. Remaining committed emissions from the existing 900 GW of coal-fired capacity amount to 85 Gt CO_2, if the operating factors remain stable until the end of their lives.[52] With another 200 GW of coal-fired capacity under construction, committed emissions are set to rise further. The IEA suggests that retrofitting existing coal power plants with CCS could be part of the solution to reducing committed emissions. Adoption of CCS could also avoid the need to write off productive generating capacity or limit their uses. On the other hand, CCS is not carbon neutral. It is also expensive both in terms of investment cost and the loss of efficiency.

China has already made a commitment, reaffirmed in its INDC under the Paris Agreement, to peak greenhouse gas by around 2030, increase non-fossil sources to 20% by 2030 and reduce carbon intensity 60-65% below 2005 levels by 2030. In addition, it has introduced cap-and-trade programmes covering a number of industries, increased substantially the role of renewable energy and taken steps to reduce coal consumption, including bans on new coal power plants in three industrial regions: Beijing-Tianjin-Hebei, Yangtze River Delta and the Pearl River Delta. It has also recently cancelled plans to build some coal-fired generation. However, despite the recent efforts in cancelling and delaying plants under construction, investment in new capacity is still occurring. For

[48] Own calculation. Data from National Bureau of Statistics, *China Energy Statistical Yearbooks 2015*, edited, Beijing, National Bureau of Statistics [in Chinese], 2015. Energy Statistical Yearbook 2015, Table 5-1 Energy Balance in China.

[49] National Bureau of Statistics, *Statistical Communiqué of the People's Republic of China on the 2014 National Economic and Social Development*, http://www.stats.gov.cn/english/PressRelease/201502/t20150228_687439.html [in Chinese], 2015, (accessed 23 November).

[50] National Bureau of Statistics, *Statistical Communiqué of the People's Republic of China on the 2015 National Economic and Social Development*, http://www.stats.gov.cn/english/PressRelease/201602/t20160229_1324019.html [in Chinese], 2016, (accessed 23 November).

[51] Electricity demand was weak in 2015 due to warm weather. In 2016, electricity demand increased by 4.8% until October (4.1% higher than the period in 2015) National Bureau of Statistics, *Electricity Demand speeds up in October, eonomic structure continues to optimize*, http://www.stats.gov.cn/tjsj/zxfb/201611/t20161117_1430505.html [in Chinese], 2016, (accessed 23 November). Thermal power generation increased by 12.2% and 11.9% in September and October 2016 respectively, compared to the same months in 2015.

[52] IEA, The potential for equipping China's existing coal fleet with carbon capture and storage, in Insights Series 2016, edited, Paris, France, OECD/IEA, 2016.

example, in a statement in September 2016, the NEA cancelled the construction of 15 coal power projects in nine provinces (Jilin, Shanxi, Shandong, Shaanxi, Sichuan, Jiangxi, Guangdong, Guangxi and Yunnan) with total capacity of 12.4 GW (NEA, 2016).[53] Furthermore, the *Financial Times* indicated that the NEA had cancelled the construction of 30 power plants with total capacity of over 17 GW in October 2016.[54] Although the announcements may indicate a policy shift away from investment in coal, our understanding is that the capacity that has been cancelled constitutes a small share of the total under construction.[55]

It is interesting to make rough estimates of what would be the implications of China adopting a policy to substantially reduce CO_2 emissions from coal-fired stations. That would involve shutting down some of the existing coal-fired plants and retrofitting many of the others with CCS or equivalent abatement technologies. The analysis below first considers the implications of reducing emissions without CCS, and then with CCS.

We have used the three IEA policy scenarios [56] for China to estimate the impact on generation, CO_2 emissions, capacity factors and potentially closed[57] assets for coal-fired generation, initially assuming no CCS retrofitting. The Current Policy Scenario (CPS) assumes no change in policy from the midpoint of the year of publication (2016); it is the reference scenario. For China's power sector, the CPS assumes a moderate growth in hydropower and renewables by 2020 (365 GW of hydropower, 200 GW of wind power and 100 GW of solar capacity). The New Policy Scenario (NPS) takes account of broad policy commitments and is the IEA's baseline scenario. For China's power sector, the NPS assumes: the establishment of an emission trading system in 2017; lower coal consumption per unit of electricity generation at 300 g/kWh in newly built coal-fired power plants; and an enhanced growth in renewables with 230 GW of wind capacity, 140 GW of solar capacity and 15 GW of biomass capacity by 2020. As we have seen earlier in this report, the 450 Scenario corresponds to a concentration of 450 ppm of CO_2, which is consistent with a 50% probability of limiting global temperature increases to 2ºC. For China's power sector, it assumes a larger capacity for wind (250 GW) and solar (150 GW) by 2020; in addition, nuclear capacity would continue to grow after 2020 and the deployment of CCS from around 2025. Based on the assumptions above, coal demand for electricity in China is projected to rise from 1046 Mtoe in 2014 to 1503 Mtoe in 2040 under the CPS, while in the NPS it is projected to fall to 998 Mtoe and in the 450 Scenario to 404 Mtoe.

[53] National Energy Administration, *Notice on cancelling a batch of coal power projects that does not meet approval conditions* http://zfxxgk.nea.gov.cn/auto84/201609/t20160923_2300.htm, 2016, (accessed 15 November).
[54] Steve Johnson, *China axes part-built coal power plants* https://www.ft.com/content/78db1ca6-96ab-11e6-a80e-bcd69f323a8b, 2016, (accessed 31 October).
[55] Over 200 GW of coal capacity were under construction at the end of July 2016 according to one report (SeeEndcoal, *Proposed Coal Plants in China – July 2016*, http://endcoal.org/wp-content/uploads/2016/08/ChinaMW-4.pdf, 2016, (accessed 1 November 2016).).
[56] IEA, *World Energy Outlook 2016*, edited, Paris, International Energy Agency, 2016.
[57] Some of the assets could be closed prematurely, in which case they may be referred to as potentially stranded assets.

Table 1 Approximation of the potentially underutilised or closed coal-fired generation assets in China based on IEA's Scenario projections, assuming no CCS

	Test 1 (CPS capacity and NPS generation)			Test 2 (NPS capacity and 450 generation)		
	2020	**2030**	**2040**	**2020**	**2030**	**2040**
Generation (TWh)	4199	4462	4324	3950	2606	1381
Capacity (GW)	1069	1309	1472	1040	1123	1137
Operating hours	3928	3498	2938	3798	2321	1215
Realised capacity factor	44.8%	38.9%	33.5%	43.4%	26.5%	13.9%
'Reasonable' capacity factor	57.1%	57.1%	57.1%	57.1%	57.1%	57.1%
Potential closed assets (GW)	229	417	607	250	602	861

Note: In both scenarios (CPS and NPS), installed coal capacity is lower than the projected capacity in the Thirteenth Five Year Plan on Electricity System Development (1100 GW).

We draw three conclusions from our analysis of those scenarios. The first is that there is a substantial difference in the remaining committed emissions (RCE) from China's coal fired stations under these scenarios. Assuming the plants operate until 2040, the RCE ranges from 76 Gt CO_2 for the 450 Scenario to 142 Gt CO_2 for the Current Policy Scenario. The RCE for the New Policy Scenario is 121 Gt CO_2.[58] These future emissions account for between 7.6 and 14.2% of the remaining global carbon budget of about 1,000 Gt, and an even higher percentage, obviously, if we assume a lower global carbon budget. We estimate that China's share of unabated coal-based emissions is approximately a third of the global carbon budget for electricity.[59]

Second, if the government chose to limit emissions more aggressively than under the NPS, without CCS, this would significantly lower capacity factors and/or lead to closure of assets. For instance (according to Test 2 in Table 1), if the assets were built according to the NPS and generation along with emissions followed the 450 Scenario, the capacity factor would fall to less than 14%. Under that same set of assumptions, if the aim were to maintain capacity factors at 57%, this would imply closure of 861 GW.

Finally, if the government decided to reduce emissions while minimising the closure of assets prematurely and lower capacity factors, it could encourage retrofitting CCS for a large part of the fleet, as assumed by the IEA in its 450 Scenario. Another IEA publication includes a figure that reflects the level of CCS retrofit corresponding to the emission levels in the 450 scenario.[60] Figure 9 assumes that China starts to adopt CCS in 2025. By 2040, about 280 GW of coal-fired power plants are retrofitted with CCS. Another 50 GW of new coal power plants will be built with CCS by then under that scenario. According to this IEA analysis, well over half of the 300 GW of coal-fired capacity has CCS fitted in 2040, and a significant amount of additional coal fired capacity has been shut.

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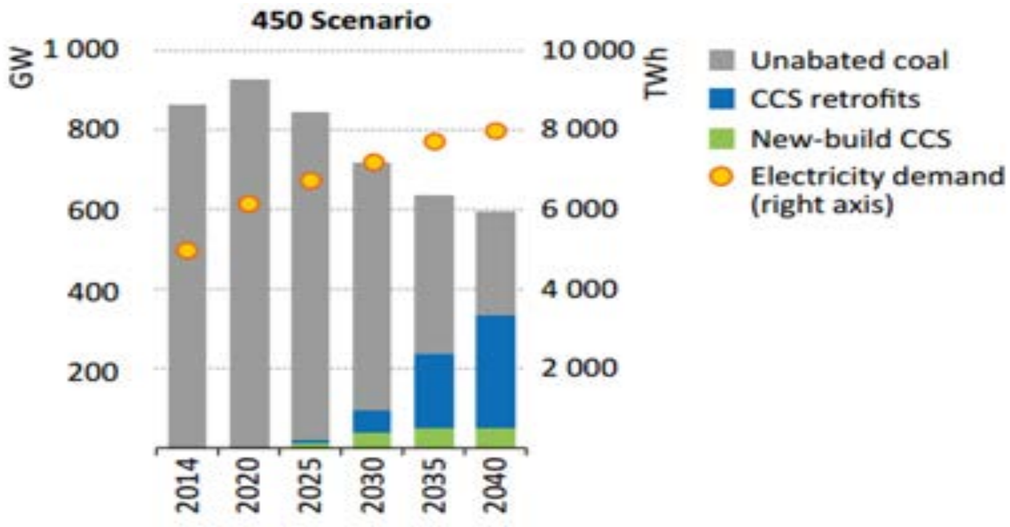
[58] This analysis only includes emissions before 2040. We calculate the RCEs in the following way, using data from the WEO 2016 as the basis for the calculation. In each scenario, WEO 2016 gives CO_2 emissions from coal power generation in 2014, 2020, 2030 and 2040. We calculate the annual growth rate of CO_2 emissions between these years (e.g. between 2014 and 2020, between 2020 and 2030 and between 2030 and 2040). Then we calculate emissions in years that have no emission data using the start year emission and the annual growth rate (e.g. 2015 CO_2 emissions equals to 2014 CO_2 emissions times annual growth rate of 0.98% under the Current Policy Scenario). For each scenario, the remaining committed emissions are the aggregation of CO_2 emissions in all years from 2014 to 2040.

[59] Davis and Socolow (2014) estimated the RCE for China's power sector at about 129.2 Gt of CO_2 under the 40-year lifetime assumption (which contrasts to our assumption that plants only emit until 2040). Pfeiffer et al. (2016) combined the concept of RCE with that of the carbon budget. Their study estimated the global carbon budget for the electricity sector at about 379.3 Gt of CO_2 emissions, based upon a 50% probability of limiting warming to 2ºC. Combining the results from these two studies, the contribution of China's unabated fossil fuel power plants to the global electricity-related carbon budget would be about 34% (129.2 divided by 379.3) if there is no change in policy.

[60] IEA, *Energy and Climate Change*, in World Energy Outlook Special Report, edited, Paris, International Energy Agency, 2015.

Figure 9 China installed coal-fired power generation capacity under 450 Scenario (Source: adapted from[61], Figure 4.5)



The 2016 World Energy Outlook projects a smaller contribution from CCS in the 450 Scenario, compared to the previous IEA study just mentioned. According to the 2016 World Energy Outlook 430 gigawatts (GW) of power plant will be equipped with CCS globally in the 450 Scenario, generating nearly 10% of the world's electricity. Of that total of CCS-fitted plants, 60% will be fitted on coal-fired plants. And around 75% of the coal-fired power plants using CCS are assumed to be in China. Although this implies less CCS in China than in previous studies, it still highlights the 'key role that China is expected to take in advancing the technology in order to decarbonise its energy mix and to protect the value of its power generation assets and coal reserves.'[62]

In terms of costs, the IEA maintains that over 100 GW of existing capacity could be retrofitted with CCS at an additional cost of USD 50/MWh.[63] The costs of retrofitting with CCS vary between USD 34 and 129 per MWh, depending on plant age, size, load factor, local and regional pollution control measures, and distance to CO_2 storage. In addition to capacity costs, CCS imposes efficiency costs that are a significant deterrent to using it. In other countries, these costs are considered to be prohibitive, especially where assets are relatively old. However, in China, where coal-fired assets are relatively new, there may be greater interest in developing CCS and other abatement technologies, and in searching for commercial opportunities to utilise the carbon emissions.

What has the Chinese government formally committed to with respect to the future of coal-fired generation? We know about the government's commitments as reaffirmed in the INDC, as well as the introduction of cap-and-trade, the banning of coal-fired stations in certain regions, the cancellation of some stations, and support for renewable energy among other measures. China's INDC also states that China will strengthen the research and

[61] Ibid.
[62] IEA, World Energy Outlook 2016, page 222
[63] This CCS cost is slightly higher than the assumed carbon price in another IEA publication: The Projected Costs of Electricity Generation (SeeIEA, *The Projected Costs of Electricity Generation* edited, Paris, International Energy Agency, 2015.). In that report, a carbon price of USD 38.88 per MWh is assumed for coal power generation in China. However, the existing carbon price in China's pilot carbon trading system varies between USD 1 and 6 per ton. Assuming the carbon emission factor for coal-fired power generation is 850 kg/MWh, the range of carbon prices under the pilot trading systems is between USD 0.85 per MWh and USD 5.1 per MWh.

development of a number of low-carbon technologies, including carbon capture, utilisation and storage.[64] Currently, there are four CCS projects in various stages of planning in China, including the PetroChina Jilin Oil Field enhanced oil recovery project, Sinopec Qilu Petrochemical CCS project, Sinopec Shengli Power Plant CCS project, and Yanchang Integrated CCS demonstration project.[65] The latter two projects are built to operate CCS at power plants.[66] We have also noted that the Thirteenth Five Year Plan on Controlling Greenhouse Gas Emissions includes an ambitious CO_2 performance standard for the major power generating companies (550 gCO_2/kWh).

However, we are aware of no official government plans with respect to the long-term role for coal-based generation, or on the requirement to retrofit existing power stations with CCS or equivalent abatement equipment.

3.2 Closure of existing assets

At the COP21, President Xi promised to cut emissions from coal power plants by 60% by 2020. According to the New China Press Agency, this initiative would help save 100 million tonnes of raw coal and prevent the discharge of about 180 million tonnes of CO_2 each year. The same source also said that, by 2020, China would have closed the power plants that do not meet its energy saving standards. However, this does not necessarily mean a reduction in total coal-based generation (or CO_2 emissions) compared to current levels. It would appear rather to imply an improvement in average energy efficiency (to achieve an average coal consumption rate of 300 grams per kWh by 2020) through the closure of plants, and increased output from more efficient plants, or from new ones. It is also likely that the 60% refers to a reduction compared to what emissions would have been in 2020 assuming a business as usual scenario (growth and efficiency), rather than compared to current absolute emission levels. If that interpretation is correct, it may imply little or no reduction in total coal-fired generation by 2020; rather, some assets will close, while others operate at higher capacity factors and new more efficient ones will be built.

Which assets will close? The China Electricity Council[67] indicated that 10.8 GW of coal power plant were retired or closed last year. These appear to be mainly small, inefficient old plants and are being replaced as part of China's strategy to improve efficiency. However, plants are also being closed for reasons related to local pollution. In 2013, the State Council introduced its Atmospheric Pollution Prevention Plan in response to severe pollution.[68] The plan acknowledges that the pollution is harming health and affecting social harmony and stability. The goal of the plan is to improve the country's air quality by 2017, while imposing new restrictions in three key industrial areas surrounding Beijing, Shanghai and Guangzhou. Among the measures the plan introduces are:

- Reducing PM levels in cities nationally by at least 10% from 2012 levels.
- Reducing PM 2.5 levels in Beijing/Tianjin/Hebei (BTH) by 25%, in the Yangtze River Delta (YRD) by 20% and in the Pearl River Delta (PRD) by 15%.

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[64] NDRC, *China's intended nationally determined contribution: Enhanced Actions on Climate Change*, edited, Beijing, National development and Reform Commission, 2015.
[65] The Huaneng IGCC project located in Tianjin can be regarded as partly a CCS project. The second phase of this project is to demonstrate a CO_2 capture system. In the third phase, the project will install a CO_2 capture system that will capture 2 million tonnes of CO_2 each year. For more information, refer to :<https://www.globalccsinstitute.com/projects/huaneng-greengen-igcc-project-phase-3>
[66] IEA, The potential for equipping China's existing coal fleet with carbon capture and storage, in Insights Series 2016, edited, Paris, France, OECD/IEA, 2016
[67] China Electricity Council, *China Power Industry Development in 2016*, http://www.cec.org.cn/guihuayutongji/gongzuodongtai/2016-08-24/157409.html [in Chinese], 2016, (accessed 13 Oct).
[68] B. Finamore, *China Pledges to Tackle Air Pollution with New Plan*, https://www.nrdc.org/experts/barbara-finamore/china-pledges-tackle-air-pollution-new-plan, 2013, (accessed 2 November).

- Prohibiting approval of new coal-fired plants in BTH, YRD and PRD (with the exception of CHP), while requiring existing coal consumption projects to reduce or substitute coal.
- Reducing the proportion of coal in the energy mix to 65% by 2017, compared to 67%.
- Achieving negative coal consumption growth in BTH, YRD and PRD by replacing coal with electricity generated from natural gas and non-fossil fuel energy.

Beijing is the most notable example.[69] In 2013, the Beijing government issued 'A work plan to accelerate coal consumption reduction and clean energy development between 2013 and 2017'.[70] The aim of the work plan is to improve air quality in Beijing. One of the primary targets is to reduce coal consumption by 8 million tons by 2015 and 13 million tons by 2017, compared to the 2013 level (23 million tons). To achieve that target, the Beijing government decided to close five coal power plants between 2013 and 2016, reducing annual coal consumption by 9.2 million tons. Total coal-fired capacity in 2013 was 2.7 GW, which accounted for 39% of the total generation capacity in Beijing. Coal had been the second largest generation capacity in Beijing, following gas.[71] Coal was replaced by gas as the government had proposed to build four gas power and heat co-generation centres during the Twelfth Five Year Period. In 2010, the Beijing Development and Reform Commission had also proposed to add 14 units of 350 MW gas power generators by 2015.[72] About 60% of Beijing's electricity supply has been dependent on power imports since the early 2000s. The closure of coal power plants apparently has not had a significant impact on Beijing's energy security, with some generators switching to gas as their primary energy source.

To the best of our knowledge, there is no information available about the impacts of the closure on system costs and power prices, or about compensation to companies and employees. However, these are certainly important issues. If similar coal power plant closures occur in the future, these and other issues, like security of supply, will need to be examined carefully. The international experience provides some insights that may be relevant to China.

3.3 Investment in new assets

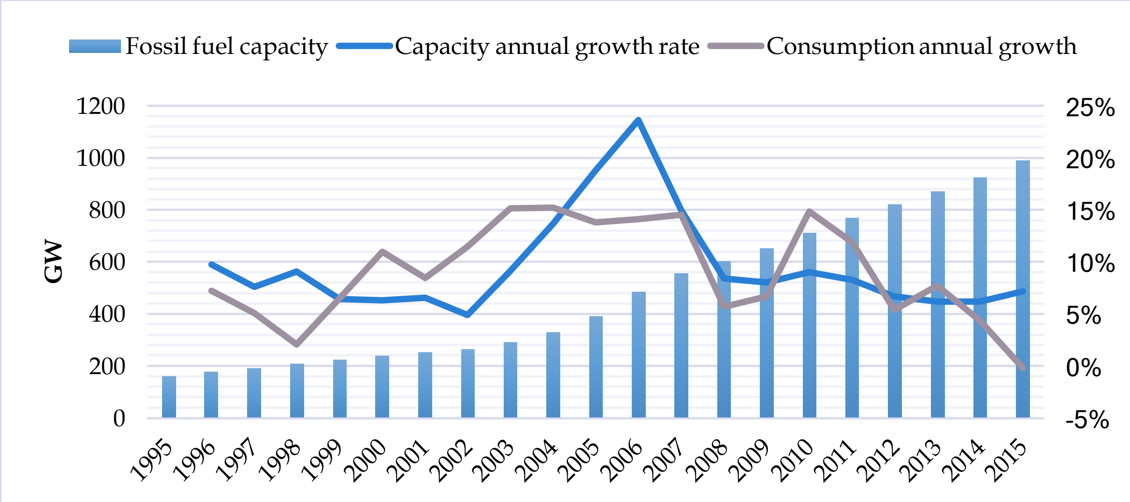
There is evidence in China of conditions that, in an economy driven by competitive market incentives, would normally encourage premature closure of coal-fired generation stations or at least limit new investment in coal-fired generation. In particular, we see evidence of declining coal power capacity factors, more stringent performance standards, and stagnant demand growth, all of which would normally discourage investment. On the other hand, investment in new capacity continues. Explaining this reveals some important challenges for China.

Recent data on electricity demand and investment plans suggest that China could find itself with a significant excess capacity of (relatively new) coal-fired generation in 2020. Figure 10 illustrates that total fossil fuelled capacity, mainly coal (over 90%), grew from 290 GW in 2003 to 990 GW by the end of 2015,[73] which means that most of the coal power plants are very far from the planned age of retirement of at least 40 years. We can also see

[69] Huaneng completed the transition in 2015 and closed its coal power units in 2016.
[70] Beijing Government, *A work plan to accelerate coal consumption reduction and clean energy development between 2013 and 2017*, http://zhengwu.beijing.gov.cn/ghxx/qtgh/t1321733.htm 2013, (accessed 13 October).
[71] X. Yan and B. Zhao, *An investigation of the environmental impacts of power generation plants in Beijing*, http://news.xinhuanet.com/zgjx/2014-06/16/c_133411385_2.htm [in Chinese], 2013, (accessed 13 Oct).
[72] F. Li, *The new era for Beijing's four power and heat co-generation centres*, http://paper.people.com.cn/zgnyb/html/2015-03/23/content_1546823.htm [in Chinese], 2015, (accessed 13 Oct).
[73] National Energy Administration, *Average operating hours for power plant over 600 MW in 2015* http://www.nea.gov.cn/2016-01/29/c_135056890.htm [in Chinese], 2016, (accessed September).

in this graphic that, in the last couple of years, China's power demand growth has declined to its lowest level. Indeed, in 2015, the annual growth rate was negative (0.2 per cent),[74] which is the first time that power consumption has decreased since 1968. These conditions are consistent with a declining capacity factor and lower margins for existing plants and lower anticipated profitability for new ones.

Figure 10 Fossil fuel capacity growth and power consumption growth/year 1995-2015 (Source:[75])



In a competitive power market, lower operating hours and lower profitability could delay, and even lead investors to cancel, investment in new capacity. However, in the first half of 2016, an additional 21.5 GW of coal capacity was installed (3.7 GW higher than the same time in 2015) in China. Furthermore, in 2015, 195 coal power plants with total capacity of 159 GW were approved (i.e. passed the environmental assessment that is the final step in coal plant approval). If these trends were to continue, the potential for excess coal-fired capacity in the near term would be significant.

Yuan et al. (2016)[76] estimated the coal power capacity in the Thirteenth Five Planning period by assuming a range of power demand growth in the next five years (between 3.5% and 4.9%) and that the non-fossil fuel targets were fulfilled. The study found that the 'reasonable scale' for coal power capacity in China (with plants operating on average 4,800 hours annually) would be between 910 GW and 960 GW by 2020 at the medium and high annual growth rate in demand (4.2% - 4.8%). The authors concluded that '*if all the coal power projects submitted for Environmental Impact Assessment approval were put into operation in 2020, capacity excess would reach 200GW.*'

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[74] There are discrepancies in data for electricity demand from different sources: some suggest a slight reduction of 0.2% (SeeNational Bureau of Statistics, *Value added for large-scale industries increased by 5.9% in December 2015*, http://www.stats.gov.cn/tjsj/zxfb/201601/t20160119_1306102.html [in Chinese], 2016, (accessed 13 October).), others suggest a slight increase of 0.3% (See National Bureau of Statistics, *Statistical Communiqué of the People's Republic of China on the 2015 National Economic and Social Development*.) or 0.5% (See IEA, *World Energy Outlook 2016*.)

[75] For fossil fuel capacity: See China Electricity Council, *Electric Power Statistics in 2014*, http://www.cec.org.cn/guihuayutongji/tongjxinxi/niandushuju/2015-11-30/146012.html [in Chinese], 2015, (accessed September). for 1995-2014 data and National Energy Administration, *Average operating hours for power plant over 600 MW in 2015* for 2015 data from; for consumption annual growth rate: own calculation, 1995-2014 data from China Electricity Council, *Electric Power Statistics in 2014*. and 2015 data from annual growth data from Y. Li, *China's Power Sector and the Economic 'New Normal'*, https://www.chinadialogue.net/article/show/single/en/8558-China-s-power-sector-and-the-economic-new-normal- [in Chinese], 2016, (accessed September).

[76] Jiahai Yuan et al., 'Coal power overcapacity and investment bubble in China during 2015–2020', *Energy Policy*, vol. 97, 2016.

The government is apparently concerned about the potential for excess capacity. The National Development and Reform Commission (NRDC) together with the National Energy Administration (NEA) issued a statement on the 'Orderly Development of Coal-fired Power Generation in China' in March 2016. The policy aims to delay construction of some new plants and cancel the construction of others in specific provinces due to lower operating hours and excess capacity. Xinhua (2016)[77] indicated that Ministry of Land and Resources has decided that the land use for new coal power plants would not be approved until the end of 2017. However, the recent addition of new coal power plants was approved three to four years before construction and our understanding is that almost 200 GW of new coal-fired capacity was under construction at the end of July 2016.[78]

The Thirteenth Five Year Plan on Electricity System Development was recently announced by the National Energy Administration.[79] The plan states that the government 'strives to control the total coal capacity within 1,100 GW by 2020'. It is based on a projected annual power demand growth between 3.6% and 4.8%, though demand growth in 2015 was negative. Huang Xuenong, director of the electricity division at the NEA, said that coal capacity would reach 1250 GW without the recent measures to delay and cancel coal power plant construction. The 1100 GW target therefore implies a 150 GW reduction due to these measures. The plan also refers to the closure of 20 GW of inefficient coal power plant between 2016 and 2020, which is very little by comparison to what is being built.

The State Council issued the Thirteenth Five Year Plan on Controlling Greenhouse Gas Emissions in October 2016.[80] It states that '*all major power generating companies need to control their electricity supply emission levels at 550 g/kWh*.' The target seems very ambitious, given the existing circumstances in China's power generation. Based on the WEO 2016, the average emission factor of coal power generation was 1035 g/kWh in 2014 (and 1021 g/kWh for all fossil fuels). Even the average emission factor of all power generation was still 768 g/kWh (total emissions were 4382 Mt, total generation was 5706 TWh in 2014).

Overall, the plan therefore reinforces the concern that China is building excess coal-fired capacity, and that investment is occurring in spite of low capacity factors and increasingly difficult emission standards. What could explain the investment in these adverse conditions? Many reasons have been suggested and most of them have a common theme: distorted incentives in the electricity sector, reinforced by a structure that discourages efficient decisions.[81] Another explanation is related to a continuation of China's strategy of replacing inefficient plants with more efficient ones, or by upgrading them to be more efficient.

3.3.1 *Industry structure*

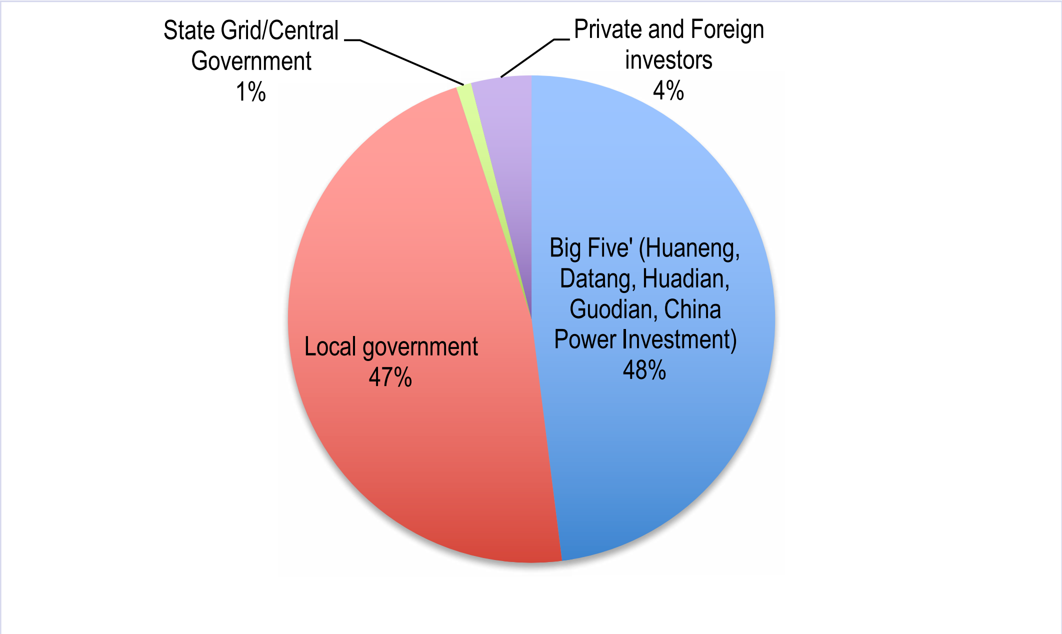
The industry's structure distorts incentives by limiting the potential for competition. First, as shown in Figure 11, the Big Five state owned enterprises (SOEs) account for approximately half of the total installed capacity. Local governments own an equivalent level of installed capacity. Private and foreign companies owned only 4% of the total generation capacity. Large fossil fuel energy SOEs receive significant subsidies from the government.[82] There

[77] Xinhua, *Ministry of Land and Resources: land use for new projects will not be approved for industries with excessive capacity*, http://news.xinhuanet.com/fortune/2016-09/05/c_129269524.htm [in Chinese], 2016, (accessed 12 Oct).
[78] Endcoal, *Proposed Coal Plants in China – July 2016*, http://endcoal.org/wp-content/uploads/2016/08/ChinaMW-4.pdf, 2016, (accessed 1 November 2016).
[79] National Energy Administration, *Press release on Thirteenth Five Plan on Electricity System Development*, http://www.nea.gov.cn/xwfb/20161107zb1/index.htm [in Chinese], 2016, (accessed 18 November).
[80] State Council, *The Thirteenth Five Year Plan on Controlling Greenhouse Gas Emissions*, http://www.gov.cn/zhengce/content/2016-11/04/content_5128619.htm [in Chinese], 2016, (accessed 23 November).
[81] Liu, *China, with too much power, keeps approving coal plants*, http://cocoliu.com/china-with-too-much-power-keeps-approving-coal-plants/#.V_4b85MrJD0 [in Chinese], 2016, (accessed 12 October).
[82] Chinadialogue, *Subsidies blamed for overcapacity in China's coal sector*, https://www.chinadialogue.net/article/show/single/en/8991-Subsidies-blamed-for-overcapacity-in-China-s-coal-sector, 2016, (accessed 12 October).

are several types of subsidies, including subsidies for resources (e.g. costs of land use, cost savings from government support) and credit. In addition, power generators receive subsidies when installing equipment for emission control purposes. When the Ministry of Environmental Protection introduced emission standards of air pollutants for thermal power generation in 2012, the NDRC gave generators an additional payment of 0.015 RMB/kWh, 0.01 RMB/kWh and 0.02 RMB/kWh[83] on the installation of control systems of SO_2, NO_x and dust emissions, respectively. The total subsidies related to the cost of emission control amounted to 112.7 billion RMB[84] in 2014.[85]

Another significant barrier to competition is the absence of competition among networks, and in retail sales to final consumers. In China, two grid companies were established following the power system reform in 2002: State Grid Corporation China and China Southern Grid. Each of these companies controls its networks as well as retail sales in its region. The two companies operate in parallel and do not compete.

Figure 11 Ownership of China's power generation capacity (Source:[86])



This favours coal-based generation in ways that raise the costs of the system. First, as discussed below, the major generators benefit from state subsidies and obtain prices that ensure cost recovery and annual quotas; this is certainly related to the concentrated nature of the industry, local government support and the barriers to competitive entry. Second, the large generators are supported by policies that do not incentivise flexibility in the operation of coal-fired plants. Third, fixed pricing on the demand side means that prices do not fall to reflect surplus generation (e.g. when the wind generation is high) and there is no incentive for consumers with flexible load to increase their consumption when a surplus is available.

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[83] 1 USD = 6.74 RMB at the end of October 2016. Therefore, 0.015 RMB/kWh, 0.01 RMB/kWh and 0.02 RMB/kWh are equivalent to 0.22, 0.14 and 0.3 cents per kWh, respectively.
[84] 1 USD = 6.74 RMB at the end of October 2016. Therefore, 112.7 billion RMB is equivalent to 16.7 billion USD.
[85] N. Zhang, *Government to Crack Down on Green Subsidy Fraud*, http://m.china.caixin.com/m/2016-05-18/100944677.html [in Chinese], 2016, (accessed 2 November).
[86] China Electricity Council, *Preliminary statistics of the national electric power industry*, edited, Beijing, China Electricity Council [in Chinese], 2014.

The industry structure and the corresponding policies and incentives help to understand why coal-fired generation continues to be attractive. On the other hand, the attractiveness of coal-fired generation also reflects a number of other distortions.

3.3.2 *Distorted incentives*

There are a number of incentives that protect coal-fired generators, raising system costs and acting as a barrier to the integration of renewable power. Furthermore, these incentives may be encouraging investment in coal-fired generation that is uneconomic.

First, 'on-grid' prices paid to the generators do not reflect short-term system costs. Chinese generators were very profitable in 2015 in spite of lower capacity factors and weak demand growth, because the generators paid low prices for their coal while maintaining comparatively high electricity prices.[87] The on-grid price aims to secure a return for potential investors in power generation assets. The power generator conducts research on the potential costs of power generation at a specific location and submits its results to the NDRC for approval. Zeng et al. (2016)[88] argue that the on-grid price is set at the higher end of the possible range due to the concentrated ownership structure of the power generation companies. The average price of coal for power dropped from 495 RMB per ton in January 2014 to 340 RMB per ton in July 2016.[89] Although the NDRC reduced the average on-grid price several times in the last couple of years, power generators were still better off even with lower operating hours.[90]

Second, dispatch does not reflect short-run system marginal cost, so coal-fired power will often run even when it is more expensive (see Box 2). Provincial yearly dispatch planning allocated generation quotas through a highly political process.[91] Since coal dominates the system, and renewable energy is very uncertain, most of the guaranteed quotas are allocated to coal-fired generation. This helps explain why coal-fired generation is selected in short-term dispatch ahead of wind and other near-zero marginal cost renewable energy; the generating companies (and the grid companies) have no incentive to replace coal-fired plants because this would breach the guaranteed quotas. Furthermore, the coal-fired power stations are not compensated for a loss of output, or for providing ancillary services to support the renewables. The absence of market signals not only ensures the profitability of coal-fired generation when demand falls, it also means that wind power is often off-line and does not receive the anticipated payments. China Energy News reported that as of the end of 2015, unpaid subsidies to renewables were about 50 billion RMB,[92] partly because the subsidies are linked to generation output from renewable plants.

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[87] Liu, C., *China, with too much power, keeps approving coal plants*, http://cocoliu.com/china-with-too-much-power-keeps-approving-coal-plants/#.V_4b85MrJD0 [in Chinese], 2016, (accessed 12 October).
[88] Ming Zeng et al., 'The power industry reform in China 2015: Policies, evaluations and solutions', *Renewable and Sustainable Energy Reviews,* vol. 57, 2016.
[89] NDRC, *China Power Coal Price Index in July*, http://www.sdpc.gov.cn/jjxsfx/201608/t20160816_814813.html [in Chinese], 2016, (accessed 12 October).
[90] Based on the electricity tariff in 2015. IEA, *World Energy Outlook 2016.*, estimates that investors could expect a positive return as long as coal power plants run more than 2800 hours per year.
[91] Xiliang Zhang and Weiming Xiong, *Power system reform to enable large-scale wind utilization in China*, in Oxford Energy Forum edited, Oxford, Oxford Institute for Energy Studies, 2016, Vol. Issue 104.
[92] 1 USD = 6.74 RMB by end of October 2016. 50 billion RMB are equivalent to 7.4 billion USD.

Box 2 Power Dispatch in China[93]

China's power generator dispatch adopts an 'equal share' approach. This means that coal-fired generators are allocated similar operating hours regardless of plant efficiency, emission intensity or marginal cost. The approach was adopted in the late 1980s when China had severe power shortages. In order to encourage investment in power generation assets, government provides a guaranteed return by defining on-grid prices paid to the generators and minimum operating hours. At the same time, annual operating hours for similar types of power generator are evenly allocated to ensure fairness among generators.

In recent years, the government started to pilot alternative dispatch systems. For instance, 'energy efficient' dispatch was introduced in five pilot provinces in 2007 by the State Council. The primary aim for this kind of dispatch is to improve energy efficiency, conserve natural resources, reduce pollution, reduce reliance on coal, maintain system reliability and promote sustainable growth in the industrial sector.[94] The NDRC issued measures on implementing energy efficient dispatch, including a pre-set dispatch order. Non-dispatchable renewables and hydropower, dispatchable hydropower and renewables are first in the efficient merit order, followed by nuclear, cogeneration units, and other fossil fuel plants. However, the implementation of energy efficient dispatch varies among pilot provinces has not been extended nationwide.[95] In addition, the Renewable Energy Law in 2006 stipulated that the grid company should purchase all renewable energy generation. However, there are significant curtailments in wind and solar power in provinces with high renewable energy potential, illustrating that renewable energy is not at the top of the dispatch merit order.

The recent electricity system reform proposals and other government policies indicate possible changes in generator dispatch. For example, Article 4 in Document 9 stipulates that the system should '*…support very low emissions units to generate more electricity through direct trading and scientific dispatch*'. Article 42 in the Air Pollution Control Act stipulates that '*electricity dispatch should prioritise clean energy in the dispatch order*'. It is also important to note the latest announcements by the NEA to the effect that trial spot trading will be introduced in China in 2018 and be fully operational by 2020.

Third, China's grid planning has not been well coordinated among regions. Consequently, planning of dispatch has occurred at a regional or provincial level. This limits the competition among generators from different regions, effectively protecting coal-fired generation in regions where the costs are higher. The inadequacy of transmission capacity to transfer the wind (and other) generation to load centres effectively protects coal-fired generators from competition.

Fourth, feed-in tariffs for wind power are an inflexible pricing mechanism that has caused problems for investors in wind power, while benefiting the grid companies and coal producers. These tariffs discourage large-scale investment in wind power at lower prices that reflect the latest technologies. Furthermore, since wind feed-in tariffs are higher than the tariff for coal power, there is no economic incentive for other provinces to promote large-scale importation of wind power. From the perspective of the grid company, there is no market signal (i.e. a low cost or low market price in areas with wind) to encourage investment in networks to transport electricity from a low-cost area to a high cost area. From the coal generators' perspective, an increase in the use of wind reduces the

[93] RAP, *Issues in China Power Sector Reform: Generator Dispatch*, edited, Beijing, The Regulatory Assistance Project, 2016. The RAP report provides a further discussion of the challenges of power dispatch reform in China.
[94] Fredrich Kahrl, James H. Williams, and Junfeng Hu, 'The political economy of electricity dispatch reform in China', *Energy Policy*, vol. 53, 2013.
[95] RAP.Ibid

output from coal. In the absence of any compensation, coal generators have an incentive to understate their ability to reduce generation at short notice in order to avoid a decline in their utilisation.

Fifth, regulators may also have political incentives to encourage new coal-fired power stations in their geographic areas. In 2015, 195 coal power plants with total capacity of 159 GW were approved (i.e. passed the environmental assessment that is the final step in coal plant approval). By comparison, 48 GW of coal capacity were approved in 2014. The difference corresponded to the transfer of approval rights from the National Ministry of Environmental Protection to its counterparts at provincial level in March 2015.[96] Local governments often welcome the construction of coal power plants as they contribute to the growth of local GDP, which is a significant indicator in the evaluation of the performance of local governors.

3.3.3 *Efficient new plants replacing inefficient older plants*

A further reason why coal-fired generation continues to attract investment is that the government wishes to encourage more efficient coal-based generation. This could include replacing older and inefficient plants, but also upgrading existing plants. The upgrading option was included in the latest development plan and mentioned by China's Environment Minister.[97] More efficient plants may operate at higher capacity factors and hence be more profitable. Furthermore, companies may anticipate a continuation of government support, for instance relatively easy access to government subsidies. By investing in more efficient plant, companies may also be seeking to increase their share of the market before the government decides to begin shutting capacity. China has been successful in closing old and inefficient plants and replacing them with new, larger and more efficient ones. However, this policy raises questions about the risk of stranded assets, especially since it entails extending the life of existing power stations, or building new power stations, and therefore locking in a higher level of committed carbon emissions.

3.4 Conclusion

It is clear that the Chinese government has taken many important steps to address concerns about local pollution and global climate change, and that these decisions have led to the closure of some coal-fired assets. It is interesting to see the recent announcements with respect to the Thirteenth Five Year Plans which suggest a liberalisation of the electricity sector and the introduction of ambitious CO_2 emission performance standards; in other countries, these measures would encourage early closure of power stations and discourage further investment. However, China continues to build significant amounts of new unabated coal-fired capacity. The messages are therefore mixed and it is unclear what are the China's plans with respect to coal-fired generation over the coming decades.

There are two sets of issues related to stranded coal-fired assets in China. In the longer term, there is potential for significant stranded coal-fired assets, or a requirement for major investment in CCS, if the country decides to cap and then reduce its emissions from this generation. In the short-term, the premature closure of coal-fired stations in major industrial regions has already occurred. International experience offers some ideas that are potentially

[96] Greenpeace, *Consequences of China's excessive coal power investment in 2015*, edited, Beijing, Greenpeace, 2016, http://www.greenpeace.org.cn/wp-content/uploads/2015/11/The-consequences-of-coal-investment-in-china.pdf.
[97] Climate Home, *China backs 'revolutionary' clean coal*, http://www.climatechangenews.com/2016/03/11/china-backs-revolutionary-clean-coal/, 2016, (accessed 12 October).

relevant for China, both to facilitate the closure of existing assets and to discourage investment in new unabated coal-fired assets that may become stranded.

4. Reducing costs and smoothing frictions from closing unabated coal-fired stations

This section analyses relevant international experience in addressing issues related to the closing of unabated coal-fired plants.

4.1 Security of supply: resource adequacy and flexibility

There are two central concerns that are related to security of electricity supply. One is related to the adequacy of generation and network capacity. This is usually referred to as the need to ensure 'resource adequacy', for instance by installing sufficient capacity to meet anticipated peak demand with a reserve margin of about 10-15% to cope with unanticipated outages on the supply side or unexpectedly high peak demand. The second is related to the need for flexibility to cope with increasing or decreasing net system load, for instance due to changing output from intermittent renewables (e.g. wind and solar PV) and from uncertain demand.

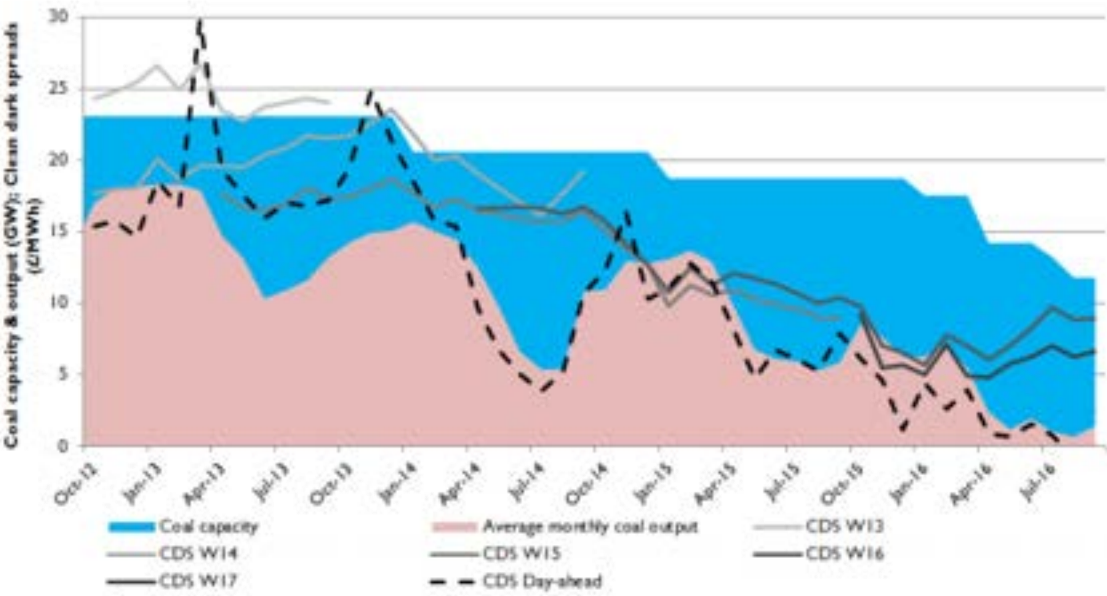
4.1.1 *Resource adequacy*

Closure of coal plants sometimes poses concerns with respect to resource adequacy. A good example of this is in the United Kingdom (UK), where closure of coal plants in the past few years has reduced significantly the level of capacity and the reserve margin. In 2012, the UK had about 23 GW of coal-fired plant; now the figure is closer to 12 GW (See Figure 10). This has raised concerns about whether the lights will go out and the risk of exceptionally high prices; this has led to policies to manage these concerns.

On the risk of the lights going out, National Grid's winter consultation said that, without buying reserves, the de-rated margin for the coming winter would have been just 0.1% per year, which corresponds to 13.7 hours loss-of-load expectation per year, which is very high.[98] Tightening reserve margins have also led to major price spikes. In the day-ahead over-the-counter market, prices increased to £158/MWh, for delivery on Monday 19 September, the contract's highest level since 2006. On the APX and N2EX power exchanges, prices in the day-ahead half-hourly auction reached £1000/MWh, probably the highest ever exchange price in the country.[99] Furthermore, on 31 October this year, on a day when there would normally be no concern about inadequate generation capacity, the grid company issued a capacity market notice that the margin was very tight, indicating a higher than normal probability of system stress.[100]

[98] National Grid, *Winter Consultation 2016*, edited, 2016.
[99] T. Dixon, 'The coal capacity crunch: Will the lights stay on?', *Cornwall Energy's Energy Spectrum* vol. Chart of the week 9, 2016.
[100] Energy Spectrum, *Daily Bulletin*, edited, 2016, Vol. 1 November 2016.

Figure 12 Coal capacity, output and clean dark spreads since winter 2012 (Source:[101])



It is important to note the role of market mechanisms to address the challenge of closing coal-fired power stations. For instance, GB has a new Contingency Balance Reserve (CBR), which is managed by National Grid Company (NGC). Here is NGC's summary of the two different balancing services that form the CBR[102] (See Box 3).

Box 3 Two balancing services from the CBR

'Two new balancing services have been developed to support National Grid in balancing the system during the mid-decade period when capacity margins are expected to tighten. The new services are Demand Side Balancing Reserve (DSBR) and Supplemental Balancing Reserve (SBR).

DSBR is targeted at large energy users who volunteer to reduce their demand during winter weekday evenings between 4 and 8 pm in return for a payment. SBR is targeted at keeping power stations in reserve that would otherwise be closed or mothballed. These services will act as a safety net to protect consumers, only to be deployed in the unlikely event of there being insufficient capacity available in the market to meet demand.'[103]

National Grid has purchased 3.5 GW of SBR, including 1.3 GW of coal, and this has increased the de-rated capacity margin to 5.5% for the upcoming winter. This is equivalent to a loss-of-load expectation of 0.9 hours per year, in line with levels seen last year.

In addition to the additional reserve offered by the CBR, short-term day-ahead markets provide signals for generators when prices are high and for consumers to reduce their demand.

[101] Dixon. Ibis
[102] National Grid, *Contingency Balancing Reserve*, http://www2.nationalgrid.com/UK/Services/Balancing-services/System-security/Contingency-Balancing-Reserve/, 2016, (accessed 13 October).
[103] Ibid

The UK government also introduced a capacity market for Great Britain to address concerns about resource adequacy.[104] The general theoretical arguments in favour of capacity markets include scepticism about whether competitive energy-only markets will deliver the quantity and the mix of capacity that political leaders want, and whether energy-only markets are designed in a way that will compensate (allow recovery of) the fixed costs of investment. Successive UK governments had been strong proponents of energy-only markets for over 20 years, but concerns about climate change led the government to change its mind, essentially to ensure that there would be sufficient firm capacity to provide backup to the growing volume of intermittent generation from wind and sun to meet system peak demand, and to limit price spikes related to tighter capacity margins. Government concerns were compounded by an impending tightness of conventional capacity, due to the closure of coal plants and because many nuclear plants were also due to reach the end of their scheduled lifetimes. There were also major environmental uncertainties, such as whether new coal plants would be permitted and whether the government was prepared to support nuclear power.

Capacity markets are just one of the mechanisms that policymakers are considering to induce investment and ensure resource adequacy in the context of the rising penetration of intermittent renewable power and the closure of coal and gas-fired power stations. This reflects a tension between existing short-term energy-only markets, which were designed for a fossil-fuel based system and assume that investors can recover their fixed costs entirely through revenues earned in these markets, and two other facts: that short-term energy prices are falling as a result of the penetration of renewable energy with near-zero marginal costs, and that governments are making out-of-market payments to the renewables. This has led many experts to conclude that energy-only markets are not serving the purposes for which they were built. The challenge is to develop new mechanisms that will allow for fixed cost recovery of an efficient mix of plant, without relying on out-of-market payments. Many approaches are now under consideration.[105]

4.1.2 *Flexibility*

It is very difficult to separate the closure of coal-fired generation from the penetration of intermittent renewable energy and other new electricity resources, such as demand response. Both are part of the process of decarbonisation, which changes the technical and economic fundamentals of the electricity sector, effectively turning the industry upside down.[106] One of the most important changes has to do with the need for greater flexibility from a range of energy resources.[107]

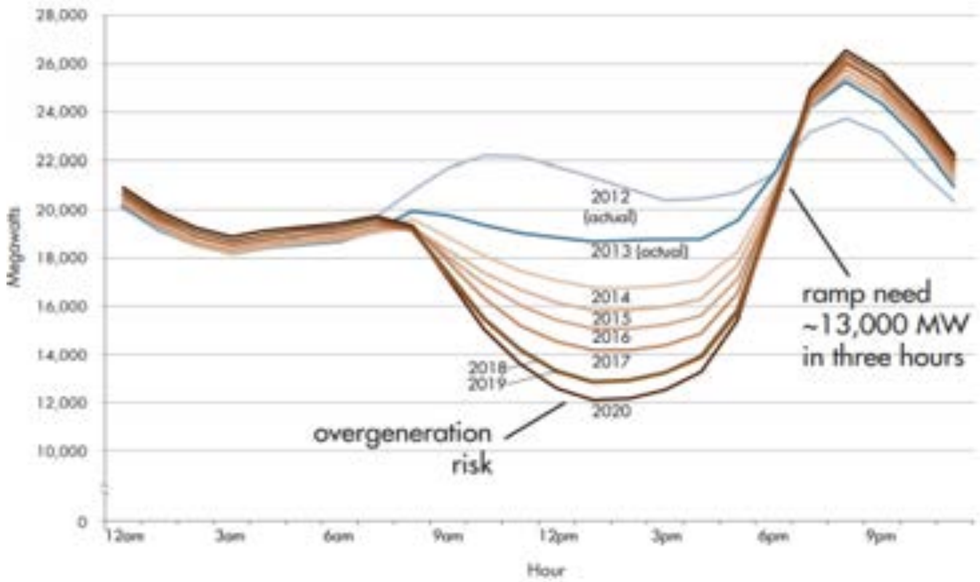
Before the penetration of intermittent renewables, generation supply was considered to be predictable and flexible. This was because there was sufficient dispatchable generation to cope with variations in demand and with unexpected outages on the supply side. However, with the penetration of wind and solar, along with the decentralisation of energy resources (with consumers generating their own power and adjusting their demand) there is a need for more flexibility.[108] This is for three reasons.

[104] Alberta, a province in Canada, has decided to reform its electricity system. The existing deregulated energy-only market will be replaced by a system that includes a capacity market in 2021, with the first auction for capacity in 2024. The move aims to reduce the risk of power shortages, and the level of price increases, as coal power is gradually phased out by 2030 (See M. Bellefontaine, *Alberta changing electricity market system starting in 2021* http://www.cbc.ca/beta/news/canada/edmonton/alberta-changing-electricity-system-2021-1.3864609, 2016, (accessed 25 November).).
[105] M. Keay, 'Electricity Markts are Broken - Can they be fixed', *OIES Working Paper*, 2016.
[106] Ibid
[107] See Poudineh (2016) for more details on the importance of flexibility and ways that it can be introduced. This section draws extensively on that article.
[108] R. Poudineh, 'Renewable integration and the changing requirement of grid management in the twenty-first century', *Oxford Energy Forum 104,* vol. February 2016, 2016.

- The stochastic nature of intermittent generation leads to greater uncertainty related to the net load forecast, and this increases the need for additional flexible resources.
- The penetration of renewables displaces conventional generation and this reduces the amount of flexible generation available to balance the system.
- The lack of flexibility can result in more frequent occurrence of negative prices, which poses problems of cost recovery for conventional and renewable plants.

California offers a good example of the main problem, as illustrated by the 'duck' curve (so called because it looks like a duck) in Figure 13. In California, the penetration of intermittent renewables has introduced quick and steep ramps, so that the system operator needs to bring on or shut down power plants in a very short period of time in order to meet variations in net load. The 'over-generation risk' corresponding to the belly of the duck reflects periods when net system demand is low due to significant solar energy output. The need to increase production rapidly is represented by the neck of the duck. Additionally, when there are a lot of renewables online and a limited number of flexible plants, the system has limited frequency response, which is necessary for a system to recover from faults (such as a sudden failure of a power plant).

Figure 13 The CAISO duck chart (Source:[109])



On the one hand, as the electricity system becomes more reliant on intermittent renewables and distributed energy, there is less need for base-load power, like coal and nuclear. On the other hand, there is a greater need for flexibility. Coal and nuclear plants can provide some flexibility, although this is limited and depends on making investment to enable that. Furthermore, if the running regime does not involve base-load operation, these plants will often not be able to recover their fixed costs.

[109] California Independent System Operator Corporation, *What the duck curve tells us about managing a green grid*, https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf, 2016.

In order to operate reliably under these circumstances, new practices and markets have been introduced. For instance, new reliability metrics are needed. An example is the insufficient ramping resource expectation (IRRE), which can supplement traditional metrics, such as the loss of load expectation (LOLE), to assess whether planned capacity is sufficiently flexible to respond to short-term variations in net load.

There are many new sources of flexibility to provide: quick response and sustained operations over a period of time; quick changes in ramping direction; storage of energy for later use; and better forecasting of demand and resources. Flexibility services can be provided by various resources, including: fast ramping thermal generation, such as open cycle gas turbines; storage; interconnection; demand response; network capacity; and curtailment of renewables.

For these resources to be available and used efficiently, the resource owners need to have the appropriate incentives. Regulations and markets help to provide those incentives. For instance, existing markets can be modified to make efficient use of existing flexible resources, with explicit incentives for providing flexibility and defining flexibility products. Currently, many US markets use hourly dispatch and sub-hourly variations are met with frequency regulation services – using the fastest and most expensive flexible service. Other systems, notably those operated by independent system operators in the US and the EU, have sub-hourly markets that facilitate competition among the many different sources of flexibility, resulting in lower costs.

Defining standardised tradable flexibility contracts is also important. The California ISO (CAISO) is working on a new product called the flexible ramping product (FRP). These have a five-minute ramping capability that can be dispatched to meet very short variations in net system demand.

Another example is from the UK, where the cash-out price for balancing markets will reflect sharper marginal system costs, rather than average costs. This will encourage players to invest in and provide more flexible services, both on the demand side and on the supply side. Balancing markets can be local or regional, provided there is sufficient interconnection capacity and the incentives exist to build that capacity and to procure flexibility services; this is important because as the market increases in size, the potential for competition among flexibility services will grow.

Apart from the design of new markets and contracts, regulation is also a way to introduce greater flexibility into the system. For instance, regulation should ensure that all potential resources can compete on a level playing field to provide flexibility, including demand response, storage and all supply side options. An interesting example is the Spanish decision to allow renewable energy to compete in the market to relieve technical constraints. Previously, conventional power stations earned very significant revenues providing this sort of service because there were no alternatives. When renewables were allowed to compete in this market, the cost of resolving transmission constraints initially halved. If that ratio were to continue on an annual basis, it would mean a reduction in cost from about €800 million to €400 million per year.[110]

Other regulatory examples to encourage new sources of flexibility come from the US and the UK. In some US systems, such as the PJM ISO,[111] demand response participates actively in many different ancillary service markets. The UK is also trying to integrate the demand side into its balancing service under the Frequency Control

[110] Ramón. Roca, *Los renovables acaban con el 'chollo' de los ciclos; el precio de las restricciones técnicas se disploma a más de la mitad* http://elperiodicodelaenergia.com/las-renovables-acaban-con-el-chollo-de-los-ciclos-el-precio-de-las-restricciones-tecnicas-se-desploma-a-mas-de-la-mitad/, 2016, (accessed 31 October).

[111] This is the independent system operator in the Pennsylvania, New Jersey and Maryland region, which now includes many other states.

Demand Management (FCDM) scheme, under which frequency response is provided through automatic interruption of contracted consumers when system frequency transgresses the low frequency relay settings. In both countries, aggregators often help to coordinate many smaller suppliers of these demand-side services so that they can be effectively integrated into wholesale markets.

Finally, this brings us back to the issue of resource adequacy. The flexibility of resources needs also to be taken into account in capacity markets that aim to meet resource adequacy for system peaks. The UK capacity market, for instance, does not value flexibility and instead favours low-cost resources that lack the capability to respond to short-term changes in load. Future capacity markets should be designed to obtain both capacity and operational flexibility (and potentially also to reflect carbon emissions).

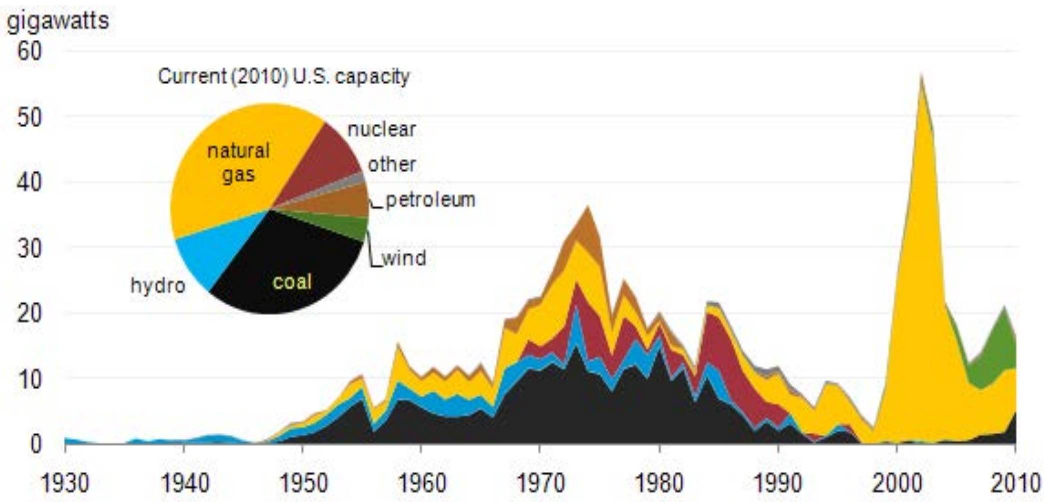
4.2 National Security

This refers to the challenge associated with closing plants that use indigenous energy resources, sometimes referred to as 'war fuel'. The international experience differs widely but generally countries that choose to reduce their reliance on domestic coal, such as the US, select alternative sources that do not leave the country exposed to reliance on imported fuels or technologies. Some countries, like Poland, are very reluctant to reduce their reliance on coal because the main alternative is natural gas, which comes from Russia, a country on which Poland does not wish to rely.

Most countries that reduce their reliance on domestic coal consider renewable energy as an important part of the answer. This is certainly one of the reasons why the EU decided to encourage the development of renewable power, thinking that this would not only reduce reliance on imported oil and gas, but also encourage the development of new technologies and businesses – such as wind turbines – that have growing global markets. However, it is now well understood that intermittent renewable energies on their own cannot fully replace generation based on fossil fuels (domestic or imported). Renewable power must be combined with a range of other services, including storage, demand response and interconnections. Investment in those other services is growing quickly.

The US also considers renewable energy to be a secure source of domestic energy, but there, the availability of domestic low-cost shale gas has enabled the US to reduce reliance on coal-fired generation without any concern about the loss of national security. Since about 2000, new generation capacity has been either from natural gas or from renewable power (See Figure 14).

Figure 14 US generation capacity by initial year of operation and fuel type in 2010 (Source:[112])



The costs of natural gas in the US declined substantially over the last ten years, both in absolute terms and compared to the price of coal. Until May 2016, the price of natural gas at Henry Hub had been lower than the price of Central Appalachian coal on a dollar per MWh basis for seventeen consecutive months.[113] The cheap and abundant gas together with its lower environmental impact has supported the growth of gas in power generation. Between 2005 and 2013, the share of natural gas in power generation increased 9%, offsetting the decline in the share of coal (10.5%).[114] [115] estimated that a further displacement of coal by natural gas in the power sector (a reduction of 42 million tons in annual demand by 2020) would happen at the gas price of $3.3/Million British thermal units.[116] At the same time, non-hydro renewables (such as wind and solar) have been growing fast due to the falling renewable energy costs and favourable government policies. Renewables represented 7% of the total power generation in 2015, replacing hydropower as the fourth largest power source in the US after coal, gas and nuclear.

From a national security perspective, the potential to export natural gas and coal is an added source of strength. This enables the US government to exert pressure on rivals and to support allies, by influencing the global supply and prices of both those products.

4.3 Electricity cost and prices

One of the consequences of closing coal plants in most countries has been to introduce new costs, including for investment in renewable power sources along with additional transmission networks and backup capacity. Even in the US, where natural gas replaces coal in the power sector due to low natural gas prices, there are often

[112] EIA, *Age of electric power generators varies widely*, http://www.eia.gov/todayinenergy/detail.php?id=1830#, 2011, (accessed 13 October).
[113] EIA, *Electricity Monthly Update: May 2016*, edited, U.S. Energy Information Administration, 2016.
[114] Dimsdale, Taylor, Julian Schwartzkopff, and Chris Littlecott, *G7 Coal Phase Out: United States* in A Review for Oxfam, edited, London, E3G, 2015.
[115] S. Rehbach and R. Samek, *Downsizing the US coal industry: Can a slow-motion train wreck be avoided?*, in Metals and Mining Practice, McKinsey & Company, edited, 2015.
[116] For US gas price, see <https://www.eia.gov/dnav/ng/hist/n3045us3m.htm>. Conversion from MMBtu to 1000 cubic feet: $ per MMBtu multiplied by 1.032 = $ per Mcf. Available from < https://www.eia.gov/tools/faqs/faq.cfm?id=45&t=8>.

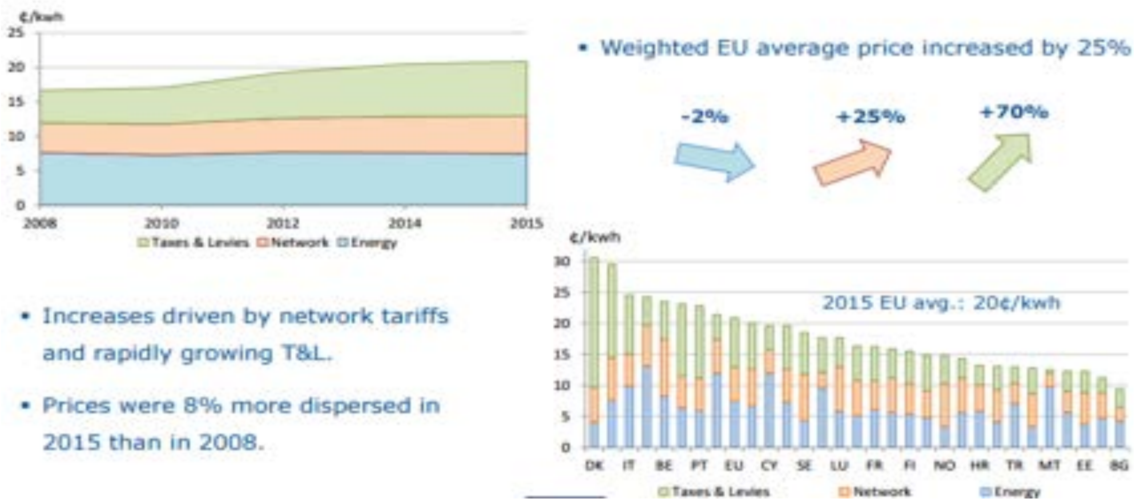
additional system costs, for instance new plants to provide system stability in certain locations on the network. The question is how countries are addressing the recovery of these new system costs.

There are basically two models for recovering the extra costs: including them in electricity prices or recovering them through the taxation system. The former is the standard approach in the EU, whereas the latter is the main approach in the US and parts of Canada, at least with respect to the costs of renewable power.

4.3.1 *EU approach to recovery of public policy costs*

In most EU countries, the additional costs of public policy are passed on to electricity consumers through taxes and levies included in the electricity price. Figure 15 below illustrates that taxes and levies have risen over 70% since 2008, whereas energy costs have fallen and network costs have risen about 25%. This increase in taxes and levies mainly reflects the rising cost of subsidising renewable power.

Figure 15 Electricity price for households in the EU (Source:[117])



Incorporating subsidies in electricity prices is sometimes done very transparently, but not always. By way of illustration, the UK approach is transparent. UK accounting regulations require clarity with respect to 'tax and spend'. The relevant guidance under the levy control framework[118] is that a number of government policies, e.g. the Renewables Obligation (RO), place the obligation of financing on energy companies; the latter then pass on the obligation to the consumer. The Office of National Statistics classifies the cost of these policies as taxes and the money that is spent on them as public expenditure. For example, the RO involves placing an obligation on energy suppliers to pay a premium to renewables generation. As this funding is mandated by the government, it is classified as public expenditure. The cost of the RO, which is passed through to energy consumers, is classified as a tax since the transfers are compulsory and not a direct payment for a good or service. The tax and spend generally net to zero automatically, with no money actually passing through government. In some countries, the

[117] A. Magyar, *The 2016 Ad-Hoc Data Collection and Its Results*, http://ceoe-tenerife.com/wp-content/uploads/2016/04/ENER_prices_2nd_Stakeholder_meeting_22_03_2016.pdf, 2016, (accessed 13 October).
[118] DECC, *Control Framework for DECC levy-funded spending*, edited, Department of Energy & Climate Change, 2011.

size of these subsidies is very clear and called a levy, as in Germany. In other countries, the subsidies are hidden, as in Spain where they are reported to Eurostat as part of the cost of networks or energy.

There are some good reasons to charge consumers a higher price to reflect these policy costs. Efficiency requires that consumers should pay the long-run marginal cost of a low carbon energy system, which may be more expensive than the old system. Furthermore, higher prices encourage conservation and more efficient use of energy. Ramsey pricing theory also suggests that it is efficient to tax the good or service with the most inelastic demand, such as electricity. More fundamentally, governments have been able to use electricity as a means of tax collection because consumers had little choice but to pay.

However, there are some serious problems with taxing electricity so heavily. There are obvious concerns about the distributional impact on the poorest households and about the impact on competitiveness of industry and commerce. It is also now increasingly feasible for consumers to bypass the taxes through own-generation or in other ways. However, the main problem is that the growing tax wedge in the electricity price discourages effective competition between (increasingly decarbonised) electricity and fossil fuels in end markets, like transport and heating. Most policymakers and experts expect low-carbon electricity to replace fossil fuels in these markets through the process of 'electrification'. Raising the price of electricity to finance renewable energy and other public policies gets in the way of this process and more generally distorts competition among energy vectors.

Optimal taxation theory aims to minimise distortions in the economy while collecting sufficient revenue to cover expenditure. This justifies the financing of public goods through general taxation (VAT, income tax) or by spreading these costs among competing energy products, rather than by raising the price of a single product in a competitive energy market.[119] In this specific case, fighting climate change through promotion of renewable power would constitute a public good and would justify financing the additional costs of supporting renewables through the budget. This would allow for more effective competition among energy vectors and help to lower the cost of decarbonising the economy.

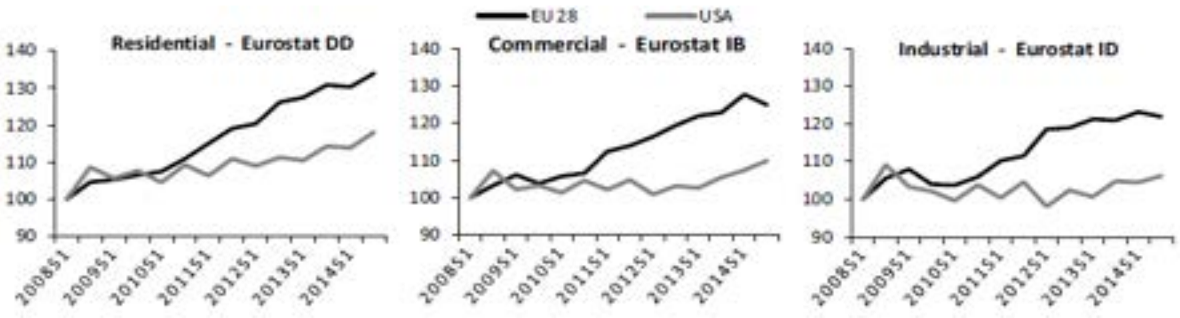
It is interesting to note that there is increasing pressure in the EU to share the costs of renewable energy subsidies more widely. For instance, Germany, which has the highest renewables levy in the EU, is considering sharing these costs among all energy vectors. A similar debate is underway in Spain, where proposals include sharing these costs among all energies, and recovering some of these costs through general taxation.

4.3.2 *Recovery of public policy costs in the US and Canada*

The US has taken a different approach from the EU. There, the extra costs of renewable power, smart grids and some other public policies have been financed in large part through federal and state budgets. This is the main reason why US electricity prices have risen by substantially less than EU electricity prices since 2008 (See Figure 16). In both regions, wholesale electricity prices have fallen, and network costs have risen by approximately the same amounts. The only major differences have been the size of the subsidies (the EU has invested more in renewables than the US) and the US policy of financing these public costs through general taxation.

[119] David. Newbery, *Reforming UK energy policy to live within its means*, in EPRG Working Paper 1516, edited, 2015.

Figure 16 Evolution of average final electricity prices in the EU and the US, 2008-14 (Source:[120] see Figure 1)



In Ontario, where coal power plants were closed, the average costs of power generation increased by 51% between 2004 and 2013. The additional energy costs for households and business amounted to CAD 5 billion per year.[121] Initially, the Ontario Clean Energy Benefit provided a 10% rebate to low-income households to ease the transition towards a greener electricity system in 2011. The scheme lasted five years until the end of 2015. But in order to reduce electricity prices further, the Ontario government recently pledged an 8% rebate for residential bills, which will take effect from the beginning of 2017.[122] The cost reduction will be deducted directly from consumers' bills and remove the portion that the province should receive from its sales tax. The total costs to the Ontario government will amount to CAD $1.3 billion annually. The government estimated that the annual savings for the five million households, farms and small business would amount to CAD130 per year.

4.4 Environmental regulations and coal

Environmental regulations have been an important reason for early closure of coal-fired generation in the US and the EU. It is interesting to examine that experience with a view to understanding how this regulation can help generators to make efficient decisions about whether and when to close their assets.

4.4.1 *EU experience*

In the EU, both the Large Combustion Plant Directive (LCPD) and the Industrial Emissions Directive (IED) give the owners of fossil-fired generation stations the option of 'opting in' (complying with the new standards), or 'opting out'. Opting in implies investment to upgrade plants, unless the plant already meets those standards. Opting out typically means that the company chooses not to make the investment because it is not profitable to do so; in that case, the plant will face a restricted operating regime before shutting.
The LCPD was issued in 2001. It introduced environmental standards that required fossil fuel-fired plants with generation capacity over 50 MW to comply with emission standards for sulphur dioxide, nitrogen oxides, and dust. For coal plant, the LCPD usually implied fitting flue gas desulfurization (FGD) equipment. In some cases, it also required the introduction of other technologies to limit emissions of NOx and particulates. From 2007,

[120] D. Robinson, 'A comparison of US and EU electricity prices: the relevance of the government wedge', *Oxford Energy Forum 104,* vol. February 2016, no. 104, 2016.
[121] M. Harris, M. Beck, and I. Gerasimchk, *The End of Coal: Ontario's coal phase-out*, edited, Manitoba, Canada, International Institute for Sustainable Development, 2015.
[122] Reuters, *Ontario government pledges lower electricity costs*, http://uk.reuters.com/article/canada-ontario-electricity-idUKL1N1BO12E, 2016, (accessed 13 October).

combustion plant could either agree to comply with the emission standard, or opt out. Many plants made the necessary investment. Many others chose to opt out. Opting out allowed them to operate for an agreed number of hours (maximum 20,000 hours) from early 2008 until the end of 2015. By 2009, a total of 205 power plants in 17 EU countries had opted out.[123] In the UK, six out of 17 coal-fired power stations operating at the beginning of 2012 had opted out, amounting to 8 GW in total capacity.[124]

The IED was issued in 2011. This directive specified more stringent emissions requirements for fossil-fired power plants, especially for nitrogen oxide emissions. It was effective from 1 January 2016. Similar to the LCPD, the IED allows for power plants to either opt in or opt out. The IED allows has other options that permit a plant to generate above the IED emissions standards, but with very limited operating hours. These are the options.

- Opt in by accepting the IED emission standards from 1 January 2016. This implies that the plant already can meet those standards by that date. In this case, there is no requirement to shut.
- Opt out and limit the total operating hours to 17,500 between 2016 and 2023. This decision had to be taken before January 1, 2016. This regime requires that the plant shut by the end of 2023.
- Participate in a Transitional National Plan (TNP), which allows a gradual adjustment to emission standards. This involves agreeing to a limited number of emissions, declining until 2020. During that period, the plant can make the investments required to comply with the IED, in which case it may continue operating after 2020. Alternatively, the plant will not make the necessary investment (i.e. will opt out) and shut by the end of 2020.
- A plant may also agree to operate below 1500 hours per year, with less demanding emissions standards, or below 500 hours with no emissions standards. In those cases, there is no obligation to shut.

Typically, the plants that choose to opt-out are older and technically difficult to adapt to the new standards.

The EU's most important policy to combat climate change – and which in principle should discourage the use of coal – has been the introduction of the Emissions Trading System (EU ETS). This system works on the cap-and-trade principle. It sets a cap on the total amount of certain greenhouse gases that can be emitted by power stations and other large stationary facilities (accounting for about 45% of these gases), and the cap is reduced over time so that emissions fall. Within the cap, companies receive or buy emission allowances, which they can trade. Each year, each company covered by the system must surrender enough allowances to cover its emissions, or fines are imposed. The price of the emission allowances depends on supply and demand. In theory, the price will support decarbonisation, for instance replacing coal by less carbon intensive energies in the merit order and through investment.

In practice, there has been an excess supply of EU ETS allowances, whose prices have been so low as to be almost irrelevant for short-term decisions, such as replacing coal by natural gas in electricity merit order dispatch. Furthermore, due to the lack of certainty about future emissions prices, and the lack of political credibility surrounding the willingness to raise these prices, the EU ETS has had less influence on investment than was intended. One of the consequences of low emission prices – along with low coal prices and relatively high gas prices – has been an increase in the share of coal-fired generation in the EU, at the expense of natural gas, especially in Germany and Spain. The UK has been an exception to this, with natural gas gaining market share at coal's expense, partly due to the introduction of a forward-looking, rising floor for carbon emission prices. The British

[123] Reuters, 'UK and Poland top dirty coal list, closures loom.', 2009.
[124] UK GOV, *Large Combustion Plant Directive (LCPD): Running hours during winter 2014/15 and capacity for 2015/16* in Special Feature - Large Combustion Plant Directive, edited, 2016.

example, however, does not sit easily within the European context because it introduces more than one emission price for industries within a single market (at least while the UK remains in that market).

An important development in a number of EU countries has been to extend CO_2 prices to non-EU ETS sectors, including buildings and transport. In particular, carbon taxes have been introduced in many European countries, including Finland, Sweden, Denmark, Norway, Slovenia, Switzerland, Ireland, Iceland, the UK and Portugal. In many cases, these taxes apply to all non-EU ETS sectors, and in other cases they apply to a selection of products.[125]

4.4.2 *The UK*

The UK is an interesting example because the country is making an early transition from very heavy reliance on coal-fired generation (40% of the mix in 2012) to very little coal-fired generation (6% in 2016-Q2) in a matter of a few years. By 2025, there will be no unabated coal-fired generation. Over 23 GW will have been shut or converted to run on biomass.

What accounts for this change? First, a significant amount of coal-fired capacity recently closed as a result of company decisions not to meet the requirements established by the LCPD. The deadline for closing plants under the LCPD was 2015. Second, the introduction of a floor on the price of CO_2 emission allowances (much higher than the price of EU ETS emission allowances) meant that existing coal-fired stations had higher marginal costs than natural gas. This explains why natural gas has replaced coal in the merit order in the UK. Third, the government introduced incentives for coal-fired power stations to convert to biomass.

The case of Drax is worthy of note. This was the largest coal-fired plant in the UK, with the largest CO_2 emissions. The station has progressively been converted to biomass (woodchips) for two commercial reasons. First, the plant does not pay the emission allowance price for electricity generated from biomass. Second, the biomass plant receives a feed-in tariff. (See Box 4 on Drax.)

Box 4 Drax Power Station

Drax power station was built in the mid-1970s after the discovery of Selby Coalfield in 1967. It was expanded in the mid-1980s, reaching a total generating capacity of 3,960 MW, making it the largest coal-fired station in the UK. In 2012, Drax committed to converting three of its coal-fired generating units (1,980 MW) to be biomass-fuelled generators, using compressed wood pellets as the primary energy source. Three units have been converted and a fourth is ready for conversion. By July 2016, 70% of the total power generation in Drax power station came from biomass units, which represented around 20% of the UK's renewable power.

The conversion was initially a response to UK government regulation that awarded tradable renewable obligation certificates for coal power plants that are converted to burn biomass.[126] Today, Drax earns a feed-in tariff and avoids emission allowance prices for the biomass-fuelled generation.

[125] European Environment Agency, *Environmental taxation and environmental policies*, in EEA report, edited, Luxembourg, 2016, Vol. No 17/2016, pp 28 - 32.
[126] S. Connor, *Green energy: How one power plant chips away at the UK's carbon footprint*, http://www.independent.co.uk/environment/green-energy-how-one-power-plant-chips-away-at-the-uks-carbon-footprint-a6796716.html, 2016, (accessed 11 November).

On 9 November this year, the UK government initiated a consultation exploring options to close unabated coal-fired power stations by 2025. The consultation seeks views on two options. One option would transfer the regime for new coal power stations to existing stations from 2025; this would necessitate the installation of CCS technology on a proportion of a station's capacity. The other option is to modify the existing Emissions Performance Standard (EPS) to apply a concentration-based limit on emissions per unit of generated electricity, rather than setting an annual limit on emissions, taking effect from 2025. This could be set at the current statutory rate of emissions of 450g CO_2/kWh.

4.4.3 *US experience*

In the US, the Environmental Protection Agency (EPA) is responsible for the regulation of emissions from power stations. As in the EU, generators are free to decide whether to meet EPA emission performance standards, or to shut, and are given advanced notice of the requirements so that they can make the necessary investments. Because the average age of coal-fired power plants in the US was about 45 years at the end of 2013, in many case companies decided to shut their plants rather than invest.

Existing coal-fired stations have to meet the EPA's Mercury & Air Toxic Standards (MATS). The costs to comply with MATS, including flue gas desulfurization (FGC) and dry sorbent injection (DSI), are significant and influence the decision to retrofit or to retire plants. For example, the electricity generators can choose to comply with the MATS through the installation of emission control facilities, such as baghouses, scrubbers, dry sorbent injection systems, and activated carbon injection systems. Alternatively, they can choose to switch to other energy sources that have lower emission levels such as gas or biomass. Table 2 below gives the potential range of compliance costs associated with control facilities. The additional costs to comply with the MATS standards would make the coal plants economically unviable; this explains the decision to close down those plants earlier than original planned.[127]

Table 2 The potential range of costs of each compliance option (Source:[128])

Compliance options	Cost ($ per KW)
Baghouses	200 - 500
Scrubber	450 - 900
Dry sorbent injection systems	40
Activated carbon injection systems	20 - 30

There are other environmental regulations that encourage the early retirement or retrofit decisions for coal power plants, including the Regional Haze Rule (which aims at reducing emissions of particulate matter, SO_2 and NO_x), National Ambient Air Quality Standards (NAAQS); Cross State Air Pollution Rule; Non-EPA Renewable Portfolio Standards; and others related to water toxics, and coal ash.[129]

[127] The installation of emission control equipment leads to higher costs for the coal power generators, especially small and medium-sized coal power plants. M. Celebi, 'Coal Plant Retirements and Market Impacts', *Wartsila Flexible Power Symposium 2014*, Vail, Colorado, 2014. Celebi estimated the levelised cost of installing wet and dry scrubbers at a 200 MW unit (with 15-year recovery and a 15% capital charge rate). The additional costs amounted to $50.8/MWh for wet scrubber and $43.6/MWh for dry scrubber at 30% capacity factor; the costs dropped to $22.9 and $20.1 per MWh at 70% capacity factor, respectively. The report also estimated the dispatch costs of an existing coal plant at between $20 and $35 per MWh, and wholesale power prices in PJM West (around $45/MWh), Midwest (around $35/MWh) and Southeast (around $35/MWh).
[128] Ibid.
[129] Dimsdale, Taylor, Julian Schwartzkopff, and Chris Littlecott, *G7 Coal Phase Out: United States* in A Review for Oxfam, edited, London, E3G, 2015.

Faced with the costs of compliance with MATS, and the potential costs of meeting other environmental regulations, many owners announced their intention to shut plants. Of the existing coal-fired capacity of about 310 GW in 2013, The Brattle Group forecast closure of between 59 GW and 77 GW – 19-24% of coal-fired capacity – by 2016,[130] depending on the stringency of the environmental requirements. This was consistent with the EIA 2014 Reference Case, which estimated that about 60 GW of coal plants would shut between 2012 and 2020.[131]

The EPA and President Obama introduced the Clean Power Plan[132] on 3 August 2015, in order to reduce greenhouse gas emissions from existing assets in the power sector by specifying lower carbon emission performance standards (gCO_2/kWh) for the power sector in each state. States are left to decide how to meet these targets, but the plan basically encourages the closure of coal-fired power stations and their replacement by renewable power and gas-fired plants. The flexibility offered by the plan introduces the potential to reduce costs, especially through regional coordination among states. PJM[133] estimates the costs of compliance for the entire PJM region. Their report concluded that regional compliance leads to lower costs compared to compliance by individual states. The lower cost from regional compliance is due to the need for fewer retirements and less investment in new CCGTs.

4.5 Are affected electricity companies compensated for stranded assets?

When the electricity sector was liberalised in the EU and many US states, it was common to allow the affected electricity to recover some of what were referred to as the 'stranded costs' associated with generation assets that would be uncompetitive in the liberalised markets. The argument in favour of compensation for 'competition transition costs' (CTC) was related to the government breaking a regulatory pact that had offered reasonable assurance of cost recovery in return for the company undertaking the investment. There are diverging views on whether companies had a legal entitlement to compensation, but payment of CTCs was a way of encouraging investor-owned utilities to accept the transition to a more competitive regime.

The question is whether and when a similar treatment might apply to early closure of coal-fired power stations. Generally, the answer is 'no' in countries with liberalised electricity markets. This is because generation is one of the activities open to competition and where there are typically no guarantees of cost recovery. Furthermore, in the EU and the US, governments give investors many years to decide whether to opt in or opt out of new emission performance standards, and plants are usually quite old.

In some circumstances, however, there has been compensation. For instance, in Germany, the European Commission has authorised the payment of €1.6 billion to the owners of eight lignite plants that are shutting prematurely between 2016 and 2018. The payment is a compensation for lost profits.[134]

Another example when compensation may be paid is where the government has decided to phase out coal-fired power altogether, as in Alberta. In that province, there are two companies with coal plant: ATCO and Transalta.

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[130] Celebi, M. Ibid
[131] Gas-to-Power, 'Tougher EPA Rules Spark Rise in US Coal Plant Retirements', *GTP Journal*, no. 21 March 2014, 2014.
[132] On 9 February 2016, the Supreme Court stayed implementation of the Clean Power Plan pending judicial review. This decision was not on the merits of the rule, according to the EPA.
[133] PJM, *EPA's Final Clean Power Plan Compliance Pathways Economic and Reliability Analysis*, http://www.pjm.com/~/media/documents/reports/20160901-cpp-compliance-assessment.ashx, 2016, (accessed 14 November).
[134] Göß, Simon *Closure of German power plants*, http://ceenews.info/en/closure-of-german-power-plants/, 2016, (accessed 11 November).

The former has relatively old coal-fired stations, but Transalta built a plant that came online a few years ago. Transalta will argue for compensation on the grounds that their investment has not been amortised and that they had no reason to anticipate the change in government policy since all previous Alberta governments had been strongly supportive of fossil fuels. However, policymakers in Alberta will need to decide whether any compensation is justified in a fully liberalised electricity market where no guarantees were given. The government could well argue that Transalta should have recognised the risks, especially given the growing concern in Canada and the US over the environmental impact of coal-fired plants and the reasonable prospect of some regulatory decision to limit output from them. If compensation is paid, it will probably not be due to a legal obligation, but rather as part of a package to facilitate the transition away from coal.

If compensation is paid for stranded assets, this should be related to historic obligations and should not condition future operations, which should depend on forward-looking costs. However, there are instances, in Germany for example, where compensation involves paying for a plant to remain open or be mothballed (ostensibly as reserve) even though it is never called on to generate.

4.6 Potential relevance for China

The international experience on the closure of existing assets may be relevant for China in a number of ways.

First, the closure of plants will raise concerns about resource adequacy especially in those areas that do not immediately have alternative sources available to them. Specifically, early closure of plants for environmental reasons will usually mean more electricity imports from other regions. Grid infrastructure may be reliable most of the time, but there are extreme events, such as storms, that damage grid infrastructure. The market mechanisms for capacity and flexibility that have been introduced in other countries, notably the US and the UK, to cope with resource inadequacy are worthy of consideration, including auctions for demand-side and supply-side resources. Until security can be ensured, mothballing of plants rather than permanent closure may be an insurance policy worth considering.

Second, flexibility will be especially relevant in provinces with large proportions of renewable energy generation, such as Inner Mongolia and Gansu. The high curtailment rate for both wind and solar power in these regions is due in large part to the lack of flexibility in the system. Policies and market mechanisms that promote investment in flexibility are worth further consideration, for instance sharper short-term pricing signals, as well as products and markets that reward flexibility. We strongly support China's recent announcements of plans to introduce spot market trading.

Third, countries that rely heavily on domestic coal are often concerned about the effect on national security of closing plants that rely on that fuel. One could argue that national security depends on winning the battle against climate change, and that cutting coal-based emissions is a central part of that battle. There are different ways to achieve that, including replacing coal plants with alternative sources of 'indigenous' lower carbon generation (hydro, nuclear, natural gas, renewables), converting coal plants to run on biomass, and relying more on demand-side resources.

However, if China wishes to retain coal as an important part of its electricity system and to abate significantly the CO_2 emissions, CCS or other abatement technologies are the logical way forward. Given the high cost of CCS and the inefficiency it introduces, there is growing interest in finding commercially viable ways to capture and use some of the CO_2. This is referred to as carbon capture and utilisation (CCU), which includes both conversion and non-conversion options. Conversion involves converting CO_2 into commercial products through mineralisation, chemical and biological processes. CO_2 can also be used directly for desalinisation and to enhance oil recovery, geothermal and coal-bed methane.[135]

Fourth, with respect to the recovery of the additional costs associated with early closure of power stations and investment in renewable power, China currently incorporates these costs (i.e. subsidies) as levies in the electricity price. However, these levies are not transparent: investors in renewable power are not certain when they will receive the subsidies and this discourages future private investment. Best practice in North America and Europe includes greater transparency concerning subsidies and their payment, for instance through explicit levies in power prices (with regulatory or contractual assurance of payment to the investor), or the payment of subsidies to investors through tax credits.

Fifth, environmental regulations are a powerful tool to encourage accelerated closure of coal-fired power stations. The UK example suggests three possible approaches to consider: incentives to convert coal-fired plants to biomass (as at Drax) or other lower carbon fuels; obligations to fit CCS to existing power stations in future; and the introduction of an emission performance standard (e.g. 450 gCO_2/kWh) that is inconsistent with unabated coal-fired generation. Best practice involves giving companies maximum flexibility with respect to how they reduce their emissions from existing plants. Emission performance standards (gCO_2/kWh) are more flexible than technology-specific regulations; and we support China's proposal to introduce ambitious performance standards of this kind. Indeed, setting long-term targets for reduced emission performance standards for generators, along with trading mechanisms to meet those targets at least cost, provides good signals for generators to adopt the most efficient low-carbon technologies.[136]

A system for pricing environmental emissions introduces even greater flexibility, but has not provided high enough and credible long-term price signals for investment decisions in the EU. China has been developing its own CO_2 emission allowance trading system and we strongly support that. But for these prices to have an impact, we would encourage China to consider a long-term rising price floor for its emission prices, and to apply the carbon price to all sectors of the economy. Furthermore, China may wish to consider how the funds raised through auctioning emission allowances or through environmental taxation could be recycled within the economy, either to reduce the impact of higher energy costs on vulnerable consumer groups or to support investment in decarbonisation projects.[137] The idea of fiscal revenue neutrality – where any additional revenues are recycled in the economy – also deserves consideration, not least because it may help to reduce opposition to a tax.

China may want also to consider determining the lower price limit of emission allowances by reference to the concentration of greenhouse gases in the atmosphere, so as to provide a sharper carbon price signal if needed. Since this is an idea that makes sense if adopted at a global level and, if adopted in one country, has consequences for that country's industrial competitiveness, China might consider making this a proposal for most countries to adopt in future UNFCCC negotiations.

Sixth, international practice usually involves giving existing plants many years notice of any changes in environmental regulation that will require additional investment to meet new emission performance standards.

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[135] Pembina, *Carbon Capture and Utilization*, https://www.pembina.org/reports/ccu-fact-sheet-2015.pdf, 2015, (accessed 14 November).

[136] Malcolm. Keay, John. Rhys, and D. Robinson, *Decarbonisation of the electricity industry – is there still a place for markets?*, in OIES Working Paper Series, edited, Oxford, Oxford Institute for Energy Studies, 2012, Vol. EL9.

[137] The EU ETS is a good example of this; at least 50% of revenues is used for climate or energy related purposes. See <http://ec.europa.eu/clima/policies/ets/auctioning/index_en.htm>

Regulations in the US and the EU typically offer investors the option to make the investments required to continue operating, or to opt out and cease operations. If the owner chooses to opt out, the plant is typically given a transition period and a controlled operating regime before it shuts down, usually enabling it to recover its original investment costs.

Finally, the international experience in liberalised electricity markets normally does not involve compensation for assets that are closed prematurely. However, for new assets that were built with explicit government or contractual guarantees for cost recovery, there may be a case for compensation. Given the importance of reducing CO_2 emissions from existing coal-fired stations, we think China should consider the option of compensating plant owners for premature closure or for fitting CCS or equivalent abatement equipment, especially in the case of relatively new power stations. In that case, compensation should not distort decisions about operation of plants, which should be based on forward-looking efficiency criteria.

5. Discouraging investment in coal-fired generation assets

This section is related to investment in new coal-fired assets or in existing assets, for instance to meet new environmental regulations. It analyses ways in which governments and markets have discouraged this sort of investment, especially when there is a risk of stranded assets.

5.1 Regulatory, fiscal or political limitations

Regulatory or political intervention can discourage investment in coal-fired power stations in many ways. The most obvious is a decision to phase out coal-fired power altogether, as in the UK, Alberta and Ontario. More common are regulatory limitations that introduce emission performance standards (EPS), related to CO_2 or other pollutants, or the pricing and taxation of those emissions. All these forms of intervention raise the cost of investment in new coal-fired power stations.

5.1.1 *Political decisions to end coal-fired generation*

Ending coal-fired generation is typically motivated by environmental policy reasons. The decision to phase out coal-fired generation causes problems related to the closure of existing power stations and we have already examined ways to reduce the related costs and frictions. Most of the same lessons apply – e.g. how to provide resource adequacy and flexibility – to a system that has decided to rule out future investment in coal-based generation and to encourage low carbon alternatives, such as renewable power.

The EU has made a political commitment (not legally binding) to reduce greenhouse gas emissions by at least 80% in 2050 compared to 1990 levels, and has binding legislation requiring a reduction of 40% in 2030 compared to 1990 levels. Some individual member states have introduced legislation to give effect to, or go beyond, the EU legal commitments. For instance, the UK Climate Change Act 2008, requires the secretary of state to ensure that the net UK carbon account for all six Kyoto greenhouse gases for the year 2050 is at least 80% lower than the 1990 baseline.

The UK decision to require closure of unabated coal by 2025 was different from the Alberta and Ontario decisions because it was essentially announcing something that was happening already. Closure of existing stations was related to corporate decisions already made to opt-out of EU directives (LCPD and IED), as well as to the rising UK floor price for CO_2 emissions. Future investment in coal-fired generation was conditional on the fitting of CCS, which was considered too expensive even to justify public subsidies (which were offered and then withdrawn). The decisions in Ontario and Alberta were more clearly political decisions.

5.1.2 *Regulation that raises the cost of coal-fired generation*

The regulatory signals that discourage future investment in coal-fired generation are typically those that that raise the cost of coal-fired generation or otherwise reduce or eliminate potential profitability. Tighter emission performance standards and emission taxation are the most powerful signals.

5.1.2.1 The EU

In the EU, LCPD and IED Directives implied additional investment costs for coal-fired plants, and in many cases these standards are too expensive to justify investment in existing plants. In a few countries, particularly in Germany, existing coal-fired generation stations meet and beat the EU's emission performance standards.

Investment in existing coal plant is still being contemplated to meet IED requirements. This raises a question about whether there is any case for the government to provide financial support for that investment. In Spain, the regulator has ruled out any special support and so it is likely that the investment will not proceed. This is consistent with best practice as described in the last section. However, the main generating companies in Spain argue that if the coal plant is shut, then the country will be short of firm capacity, which in turn will require investment in new firm capacity. They argue that it would be better to keep a coal-plant operating for ten years than to build a new CCGT plant that would operate for 30 years. This serves as a reminder that efficient investment decisions in the power sector require clear long-term policies with respect to energy and the environment.

In any case, investment in new coal-fired stations is very unlikely today in Western Europe. The economics are no longer attractive, which explains why no new plants are being built. The economics are unattractive in large part because of the anticipation of higher EU ETS prices, lower wholesale electricity prices, tightening regulatory standards (such as a requirement to fit CCS to new plants) and the related difficulty of financing coal-fired generation. For the first time, Platts 'New Plant Tracker', from June 2016, lists no new coal-fired power stations for Western Europe,[138] although it does list four coal/lignite power stations under construction in Poland.

5.1.2.2 The UK

Successive governments have passed legislation that discourages investment in new coal-fired power stations, including: the climate change law that requires almost full decarbonisation of electricity by 2030; the requirement for new plant to be carbon capture ready (without specifying when CCS would have to be installed); and the introduction of an emission performance standard of 450 gCO_2/kWh that rules out conventional unabated coal-fired stations.[139]

5.1.2.3 The US

In the US, the main regulatory signal discouraging future investment in coal-fired plant is the EPA regulation of CO_2 emissions. On 23 October 2015, the Federal Register published the EPA's Final Rule on greenhouse gas

[138] Platts. Ibis

[139] For information on carbon capture readiness, see DECC, *Carbon Capture Readiness: A guidance note for Section 36 Electricity Act 1989 consent applications*, edited, Department of Energy and Climate Change, 2009.; For information on the emission performance standard, see DECC, *Annex D: Electricity Market Reform: Update on the Emissions Performance Standard*, in Electricity Market Reform: Policy Overview, edited, Department of Energy and Climate Change, 2012.

performance standards for new, modified and reconstructed stationary sources for electricity generating units.[140] The emission standard for newly constructed steam generating units (with an efficient supercritical pulverised coal utility boiler) is 1,400 lbs CO_2/MWh-g (635 gCO_2/kWh). The ruling states that this would require 'partial fitting of CCS equipment'.

In practice, the debate over EPA regulations for new plants is unlikely to affect whether new coal plants are built in the near term because demand is growing so slowly that new capacity is not required in most regions and in any case is being met through increased generation from natural gas and renewable power.

5.2 Regional coordination

There are often restrictions on where coal-fired plants can be sited. Some of them are related to a political jurisdiction, such as Ontario, which has ruled out coal-fired generation. Others are related to municipal or local zoning and environmental authorisations. However, this is part of a wider issue related to regional coordination of investment and operations to ensure that power is generated where it is most efficient to do so, taking account not only of the generation costs but also the costs of transporting electricity to markets.

As explained earlier, planning in the Chinese electricity system occurs at a provincial level, which is inefficient and protects local coal-based generators from competition. One interesting model to consider for coordinating planning and operation among regions is that of the North American Independent System Operators (ISOs) and the Regional Transmission Organizations (RTOs).[141] ISOs were the result of Federal Energy Regulatory Commission (FERC) orders that suggested ISOs as one way for regional power pools to satisfy the requirement of providing non-discriminatory access to their transmission networks. The current ISOs are: CAISO (California), NYISO (New York), ERCOT (Texas), MISO (Midcontinent), ISO-NE (New England), AESO (Alberta), IESO (Ontario). They act as market place operators in wholesale power, for instance the design and operation of energy, capacity (reliability) and ancillary service markets.

The FERC subsequently encouraged the voluntary formation of Regional Transmission Organizations to administer the transmission grid on a regional basis throughout North America (including Canada). Most of the ISOs are also RTOs. An RTO coordinates, controls and monitors an electricity transmission grid. Its functions include, *inter alia*, transmission tariff administration and design, congestion management, planning and expansion and interregional coordination.

The EU also has established regional institutions to coordinate investment and operations among member states. ENTSO-e coordinates the transmission network planning between independent transmission system operators (TSOs) from each country or region in ways that correspond to the RTO function in the US.[142] However, the European model integrates many different countries, each of which is ultimately free to decide what capacity to build and where to build it. In Europe, there are also regional market operators (like OMIE for the Iberian Peninsula) that design and oversee wholesale markets, along similar lines to the US ISOs.

[140] For details about the regulation of CO_2 emissions on new plants, see EPA, 'Federal Reigister', *Standards of Performance for Greenhouse Gas Emissions From New, Modified, and Reconstructed Stationary Sources: Electric Utility Generating Units; Final Rule* https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22837.pdf, 2015, (accessed 14 November).
[141] For details on ISOs and RTOs, See FERC, *Regional Transmission Organizations (RTO)/Independent System Operators (ISO)*, https://www.ferc.gov/industries/electric/indus-act/rto.asp, 2016, (accessed 14 November).
[142] See this website for details about Entso-e: <https://www.entsoe.eu/Pages/default.aspx>

5.3 Information disclosure for capital markets

Financial institutions and other investors are increasingly concerned about the risks associated with climate change, as they are about other risks that could affect the profitability of their investments. In particular, the view that the global carbon budget is limited has focused attention on the likelihood of restrictions on the amount of coal, oil and natural gas that can be used. Companies exposed to carbon intensive activities like coal are also at risk of reputational damage. This prospect raises risks for all industries that rely on fossil fuels. Investors and public authorities are increasingly interested in having better information about the risks faced by companies involved in coal-based activities. This explains the pressure for fuller public disclosure of the risks related to investment in coal-fired generation.[143]

A number of public figures have called for the financial sector to recognise its fiduciary responsibilities to reduce carbon exposure. In a speech in 2014, the UNFCCC chair, Christiana Figueres, said the financial industry would be 'blatantly in breach of their fiduciary duty' if they failed to accelerate the greening of their portfolios.

In the UK, 2014 guidance on fiduciary duty published by the Law Commission recommended that where trustees think environment, social and governance issues are financially material, they should take them into account in investment decision making, although it did not recommend a change in the law that would require this.[144]

Mark Carney, Governor of the Bank of England, went further, arguing that climate change posed a threat for financial stability and that the assets of fossil fuel companies could be left stranded by tougher rules to mitigate climate change. He suggested that a 'climate disclosure task force' could be set up to create a voluntary standard for the information that companies producing or emitting carbon should disclose. Information about companies' carbon footprints would give investors a better idea of the potential risks that they faced.[145]

The Financial Stability Board (FSB), whose objectives and mandates were endorsed by the G-20 in 2009, has established a Task Force on Climate-related Financial Disclosures (TCFD). In their words, the TCFD 'will develop voluntary, consistent climate-related financial risk disclosures for use by companies in providing information to investors, lenders, insurers, and other stakeholders. The Task Force will consider the physical, liability and transition risks associated with climate change and what constitutes effective financial disclosures across industries'.[146] The TCFD will be presenting its conclusions to G-20 countries in 2017. As a member of the G-20, China will no doubt want to consider seriously the recommendations made by the FSB.

With this sort of information, financial institutions and other investors will be in a better position to assess the risk of investment in coal-fired generation before deciding whether to invest and on what terms.

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[143] L. Smart, *Carbon Risks: how do we measure and manage it?*, http://www.theactuary.com/features/2015/06/carbon-risk-how-do-we-measure-and-manage-it/, 2015, (accessed 13 October).
[144] Climate Home, *Fund managers must account for long term risks – UK Law Commission*, http://www.climatechangenews.com/2014/07/01/fund-managers-must-account-for-long-term-risks-law-commission, 2014, (accessed 14 November).
[145] FT, *Mark Carney warns investors face 'huge' climate change losses*, https://www.ft.com/content/622de3da-66e6-11e5-97d0-1456a776a4f5, 2015, (accessed 13 October).
[146] TCFD, *About the Task Force*, https://www.fsb-tcfd.org/about/#, 2016, (accessed 25 November).

5.4 Long-term planning

A key determinant of the risk of stranded assets is related to future demand and supply for the electricity sector and the need for additional capacity. These forecasts are often provided by an ISO/RTO in North America, or TSOs in the EU. For networks, these forecasts usually lead to regulatory decisions to approve investment and to agree a rate of return on assets. For generation, however, plans are often indicative since generation is, in principle, a business open to free entry and competition.

5.5 Reducing or eliminating subsidies

Governments sometimes signal their opposition to unabated coal-fired generation by restricting subsidies for coal. In the EU, subsidies for the domestic coal mining industry have been closely tied to the power sector, but are being phased out. In Spain, for instance, the government obliged a number of electricity companies to generate using a minimum amount of domestically mined coal. To compensate the electricity companies, their coal-fired generation was given priority in dispatch and they were able to recover the additional costs of burning domestic coal. However, EU competition legislation has ruled out that kind of subsidy. There are, however, continued efforts by countries with important coal-mining industries to protect those industries and to use domestic coal in the power sector, notably in Germany and Poland.

5.6 Limits on public credits

Another way to signal government's wish to mitigate climate change is to limit publicly financed credit for technologies that damage the environment. For instance, both the US and the UK decided to end government financed credit for power stations that do not meet certain emission performance standards (450 gCO/kWh in the UK). In practice, these standards rule out financial support for coal plants that do not capture and store CO_2 emissions, while allowing gas-fired plants without CCS. Furthermore, these governments and especially the US government have used their influence in the World Bank to introduce similar restrictions on the financing of coal plants around the world. Although the OECD also introduced restrictions on export credit finance for coal power, they are weaker than those introduced by the US and the UK. Together, these restrictions on public credit influence private financial markets, which respond by limiting their own exposure to these risks.

5.7 Public opposition

Local opposition to coal-fired power stations has had a powerful influence on investment decisions, especially in the US. This opposition is largely because local or regional air and water pollution directly affect health and welfare, but there is also growing concern related to climate change. One example of this activity is the Sierra Club campaign to close existing coal-fired plants and to stop the building of new ones. Here is their map (Figure 17), which celebrates the victories and identifies the next targets.[147] Other sources suggested that 184 new coal plants with a total investment value of $273 billion have been cancelled due to the campaign by the environmental groups.[148]

[147] More information can be found from <http://content.sierraclub.org/coal/>
[148] Dimsdale, Taylor, Julian Schwartzkopff, and Chris Littlecott, *G7 Coal Phase Out: United States* in A Review for Oxfam, edited, London, E3G, 2015.

Figure 17 The Sierra Club's ongoing campaign to wean the United States off coal (Source:[149])

(Red markers: active or upcoming plants; Yellow markers: progressing plants; Green markers: defeated plants)

5.8 Potential relevance for China

First, best practice in North America and the EU involves providing clear long-term signals and political direction with respect to climate change and the role of coal-fired generation. In some instances, this involves climate change legislation (as in the UK) or explicit prohibition on coal-fired generation (as in Ontario and Alberta). In other cases, such as the US, the guidance is based on requirements to meet emission performance standards for new plants that imply at least partial fitting of CCS equipment. China has made a number of commitments with respect to fighting climate change. However, we are not aware of any policies specifically referring to the long-term (2050) role of coal-fired generation. The continued investment in new coal-fired generation raises concerns about the potential for stranded assets in the sector, the need for CCS retrofitting and the possibility that emissions will not fall as assumed in scenarios like the IEA 450 Scenario that are consistent with the objectives of the Paris Agreement.

There are different ways of reinforcing policy decisions once they are announced. In the UK, for instance, climate change legislation was supported by the adoption of various regulations, including a rising carbon price floor and the requirement that new coal-fired plant be 'carbon capture ready', without specifying when the CCS would have to be fitted. China may want to consider these and other regulations if it wishes to discourage further investment in unabated coal. Emission performance standards (CO_2g/kWh) may also be preferable to China's efficiency standards if the aim is to limit emissions, because the same efficiency standard implies very different emissions depending on the coal source. We are therefore encouraged by the recent news that China intends to introduce ambitious emission performance standards; it will be important to ensure that these standards are achieved as efficiently as possible.

Second, the US Clean Power Plan offers potentially valuable insights into how Chinese provinces might coordinate to meet provincial emission performance targets more efficiently. At the same time, we strongly support China's plans to adopt a national carbon emission trading system, which should favour the most efficient and lowest

[149] Sierraclub, *Check out our progress with our coal plant tracker*, http://content.sierraclub.org/coal/, 2016, (accessed 13 October).

carbon technologies, while penalising the most inefficient and carbon intensive plants, regardless of where they are. For it to do so, the emission prices need to rise and be predictable at levels that are sufficiently high to influence dispatch and investment decisions.

Third, China may want to consider the experience of North American TSO/ISOs and their European equivalents. The relevance of these regional institutional models for China is that they offer a way for the national government to regulate interregional planning and operations, while promoting wholesale competition and more efficient investment and operations in generation and transmission. These models are based upon least cost planning of investment, and merit order dispatch that reflects short-term marginal costs. Introducing this institutional model may provide a basis for moving towards a more efficient system in China, with the national government overseeing the creation of regional ISO/RTOs and their coordination.

Fourth, information disclosure for potential investors is important. This includes information for capital markets to measure risk as well as information on national long-term electricity system plans. In particular, the risk of stranded assets is beginning to be more widely understood in North America and the EU. We think private investors will be particularly interested in understanding the issues and how the government is addressing them, especially the long-term plans with respect to emissions from coal-fired power stations. As a member of the G-20, China will no doubt be interested to consider the recommendations of the FSB Task Force on Climate Related Financial Disclosures.

Finally, there are other ways to send signals to the market, should the government wish to discourage investment in unabated coal-fired plants. These include limiting publicly financed credit and reducing subsidies for these assets. We understand that such limitations would require action both at the national level and at provincial levels.

6. Opportunities

The transition away from coal creates opportunities as well as challenges. Here are some of the opportunities that have been exploited in countries that are making the transition. The general message is that the public discourse is moving quickly towards recognition that decarbonisation is an important business opportunity as well as being popular with citizens who worry about their health and about climate change.

6.1 Improved local air and water quality, leading to improved health

In most countries that are closing coal-fired power stations, local air and water quality, along with improved health, are probably the most important motivations from a domestic political perspective. The costs and benefits of climate change are shared globally and among generations, whereas air and water pollution is immediate and local or regional. Policies favouring reduced output from coal usually emphasise these local 'co-benefits', especially the positive impact on health. The US Clean Power Plan, for instance, estimated the economic co-benefits for health, which compensated for the additional system costs of replacing coal. Recent reports by the OECD and the IEA have also highlighted these co-benefits.

For instance, the EPA fact sheet for the US Clean Power Plan emphasises strongly the health benefits of cutting greenhouse gas emissions as well as the hundreds of thousands of pounds of harmful particle pollution, sulphur dioxide and nitrogen oxides.[150] Indeed, the economic assessment relies very heavily on the estimated health benefits related to the plan:

- These reductions will lead to climate and health benefits worth an estimated $55 billion to $93 billion per year in 2030. This includes avoiding 2,700 to 6,600 premature deaths and 140,000 to 150,000 asthma attacks in children.
- These climate and health benefits far outweigh the estimated annual costs of the plan, which are $7.3 billion to $8.8 billion in 2030. From the soot and smog reductions alone, for every dollar invested through the Clean Power Plan, American families will see up to $7 in health benefits.
- This flexible proposal protects children and other vulnerable Americans from the health threats posed by a range of pollutants and will move us toward a cleaner, more stable environment for future generations while ensuring an ongoing supply of the reliable, affordable power needed for economic growth.

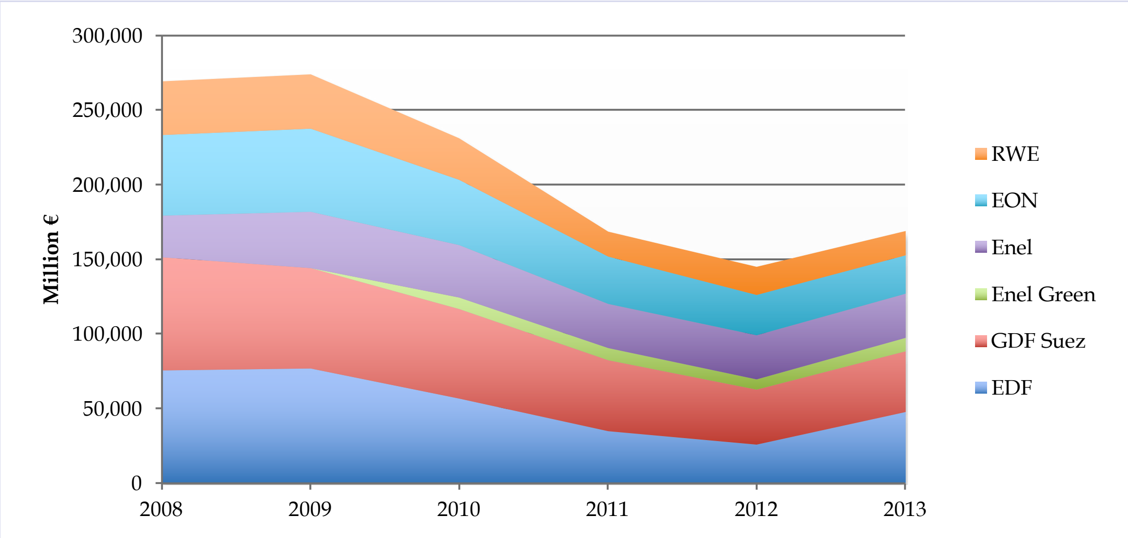
6.2 New and sustainable energy company strategies

The closure of coal-fired power stations has created new business opportunities, notably to replace the energy supplied by coal, but also as part of a parallel decentralisation and liberalisation of the electricity sector. The traditional utilities in the EU have seen their profitability decline, especially for large-scale generation from conventional sources like coal, gas and nuclear. The share value of the main European electricity utilities in 2015 was significantly below their value in 2008, before the economic crisis, in spite of the macroeconomic recovery. As explained in a recent report, margins have been hit especially for conventional generation that relies on wholesale

[150] EPA, 'EPA Fact Sheet: Clean Power Plan', *Why we need a cleaner, more efficient power sector*, https://www.epa.gov/cleanpowerplan/fact-sheet-clean-power-plan-benefits#print, 2014, (accessed 13 October).

markets. RWE declared a net loss of €2.8 billion in 2013, the first time it had declared a loss in 60 years. E.ON posted a loss of €3.2 billion in 2014 and a record loss of €7 billion last year.

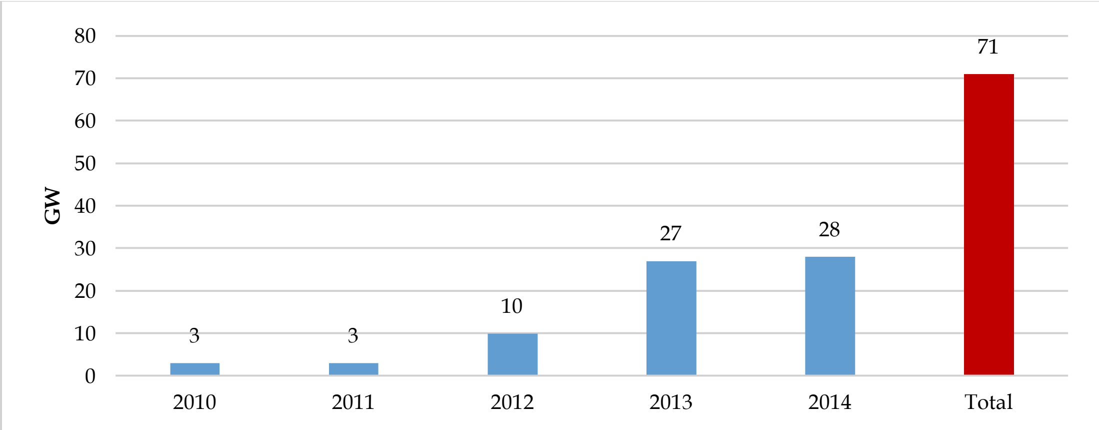
Figure 18 Selected European electric utilities: market capitalisation 2008-13 (Source: Own Figure, based on Bloomberg LP data, reproduced in Coal: Caught in the EU Utility Death Spiral, Carbon Tracker, June 2015)



In response, the utilities have been shutting conventional power plants (e.g. coal, gas) and investing instead in renewables, networks and consumer-focused businesses (such as assisting consumers to build their own generation or to become more efficient). Figure 19 shows the acceleration in capacity closures since 2010, with 71 GW having closed since 2010 (out of a total of about 1000 GW). This trend seems likely to continue, with one report forecasting additional closures of over 50 GW of coal and gas-fired plant and another predicting significantly more closures than that.[151]

[151] D. Robinson, *The Scissors Effect: How structural trends and government intervention are damaging major European electricity companies and affecting consumers*, edited, Oxford, Oxford Institute for Energy Studies, 2015.

Figure 19 Coal and CCGT closures show acceleration over time (vertical axis is the number of GW of capacity that have been closed in Europe) (Source: Adapted from: Giles Parkinson, 'UBS: closures of coal and gas fired power plants in Europe accelerating', Carbon Tracker, 4 May 2015)



Companies are also restructuring their businesses to reflect changing industry economics. Two of the most relevant corporate restructurings are E.ON and RWE. Both companies have very substantial exposures to coal-fired generation.[152] Each has restructured its business to separate traditional generation activities, including coal, from the new and more promising ones. However, their approaches were different. E.ON announced its restructuring in 2014: a new company, Uniper, would keep the conventional plants and energy trading, while Eon retained renewables, energy distribution and customer solutions. The plan was to list 53% of the new company in 2016. However, the German government required E.ON to keep the nuclear reactors, giving both companies a share of the old and problematic generation assets. RWE took a different approach. Instead of creating a new company to hold the older, dirtier assets, it split off the more attractive ones – renewables, grids and retail operations – into a new subsidiary, Innogy. The senior management team also joined the new subsidiary. RWE floated 25% of Innogy in early October 2016, with market prices valuing the subsidiary at about €20 billion.[153]

While the traditional utilities are restructuring and changing their business models, new entrants are disrupting the sector throughout the value chain. In particular, Google, Apple, Enernoc and many other companies are developing technologies and services that support the trends of decarbonisation and decentralisation. They threaten the traditional companies, but are also evidence of the potential opportunities, especially at the interface of the system with final consumers.

The focus on the consumer reflects a trend towards the creation of 'energy citizens' who participate actively through self-generation, storage (e.g. batteries) and demand response. The initial focus has been on larger consumers, but is now moving to smaller ones. The companies' new business models offer to share the value that consumers can offer to the electricity system – for instance by selling capacity, energy and flexibility services from their own homes, offices and industrial sites.

[152] J. Vasagar, *Germany's RWE slides into €2.8bn net loss for 2013*, https://www.ft.com/content/70ed184a-a375-11e3-aa85-00144feab7de, 2014, (accessed 31 October).
[153] T. Andresen, *Energy Provider EON Posts Record Net Loss of €7 Billion in 2015*, http://www.bloomberg.com/news/articles/2016-03-09/eon-posts-record-loss-on-german-power-plant-writedowns, 2016, (accessed 31 October).

6.3 Transformation of energy markets implies electrification

Decarbonisation and decentralisation of the electricity sector are occurring throughout the world. In parallel, we are witnessing the electrification of energy end markets, notably in heating (e.g. heat pumps) and transport (e.g. electric vehicles). This transformation of the energy sector requires: policy decisions (e.g. on taxation to be aligned with environment goals) to guide investment decisions; new markets and regulation to encourage low-carbon innovation and the development of new services and products; as well as new business models that reflect the new technologies and the role of new players, especially energy consumers. This electrification is underway but still very much in the early stages. It is creating enormous opportunities for existing and new companies, such as Tesla's entry into electric vehicles and batteries.

6.4 Potential relevance for China

First, in most countries, concern over local pollution is widely shared among the affected population. While it is true that some of this local pollution can be addressed with technology to capture the emissions, policymakers keen on making a transition away from coal often emphasise the impact on health and welfare of local populations. Regulations that focus on limiting local pollution can accelerate closure of coal-fired stations and, at the same time, win public support for closure or mothballing of plants.

Second, the need to address coal-fired emissions drives innovation of different kinds. On the one hand, it has encouraged (although not sufficiently) innovation in CCS and CCU. As a major coal-fired generator, China has a strong incentive to develop CCS/CCU and related capture technologies, especially if the intention is to continue generating with coal. On the other hand, concerns about coal-based emissions and the substantial costs of abatement technologies should incentivise innovation to develop low carbon alternatives, including renewable energy, smart grids, storage (i.e. electric vehicles, heat) and demand response.

All of these technologies and services, as well as new business models to deliver them, correspond to the trend of decarbonisation. There are many business opportunities for Chinese companies that are able to seize them. Just as Chinese companies were able to exploit opportunities around the world related to renewable power, so can they now benefit from developing the technologies and services related to decentralisation and the growing importance of the energy citizen.

Finally, China is particularly well placed to exploit the trend of electrification, which is the logical consequence of the other trends just mentioned. China is still growing quickly and its infrastructure is still under construction, so it may be easier to adopt new technologies and ideas than in countries with slower demand growth and mature systems. China may therefore have a comparative advantage to exploit.

7. Conclusions: best practice and potential relevance for China

The report began with evidence of a growing consensus, in the scientific community and among policymakers, that achieving the central aim of the Paris Agreement requires an early capping and then a rapid decline in global unabated coal-fired generation. With respect to existing power stations, this implies shutting down many existing coal-fired stations, or alternatively retrofitting others with CCS/CCU, converting them to become low-carbon stations (e.g. by converting to biomass) or finding other more efficient ways to abate CO_2 emissions. It also implies building no new unabated coal-fired stations. This consensus drives policymaking and financial decisions in a number of countries, which are the central focus of this report.

In spite of the growing consensus, coal-fired generation has continued to grow, especially in the large emerging nations. This is because coal-fired power continues to be economically attractive in many countries, as long as the environmental costs are not included in the analysis. However, with growing concern over local and global environmental impacts of coal-based emissions, more governments are introducing policies and regulations that threaten the economic viability of unabated coal-fired generation. This raises questions about how to facilitate an efficient transition away from coal. International experience offers some guidance that could be useful in countries that are making this transition or would like to do so.

For the many reasons mentioned in the introduction to this report, China is different from most countries that have adopted policies to phase out coal in the power sector. Consequently, we are mindful that much of the international experience may not be directly applicable to China. Nevertheless, international best practice may have potential relevance for China as it considers the future of coal-fired generation as part of its long-term strategy to fight climate change and improve the welfare of its citizens.

7.1 Credible long term policy signals

Best practice involves governments sending clear policy signals with respect to long-term intentions for coal. If the intention is to reduce coal use significantly, and the related CO_2 emissions, there needs to be an overall policy for phasing out coal and the related emissions in all sectors, not just in the power sector. Otherwise, there is a risk that placing the policy burden on the power sector will give incentives for industry to use coal, rather than to electrify or to use less carbon intensive fuels. Within that wide framework, clear signals are also required with respect to the future role of coal-fired generation.

The evidence of China's commitment to addressing local and global environmental challenges is impressive, but we have not seen any official plan related to the long-term (2050) future of coal and coal-fired generation in China. Nor have we seen official policies with respect to fitting CCS (or other abatement technology) on new plants or retrofitting existing plants. China should consider ways to provide those signals.

Long-term policy signals are usually sent through one or more of the following: (a) the introduction of legislation that phases out coal altogether or that defines steep emission reduction targets that are incompatible with continued unabated coal-fired station operations; (b) emission performance standards that effectively require CCS or similar abatement equipment for new and/or existing power stations; (c) the requirement for plants to be 'carbon capture ready'; (d) a credible, long-term CO_2 emission price floor which rises over time; (e) refusal to provide public finance for unabated coal-fired power; and (e) disclosing to financial markets information on the risk of stranded assets.

If China plans to maintain coal-fired generation while reducing emissions significantly, it is important to be clear about specific policies related to existing plants, new plants and CCS. It is important to bear in mind that retrofitting of CCS has little support in the US and the EU because most plants are very old and inefficient. Because China's plants are on average very new and efficient, the potential economic interest in retrofitting is much greater, especially if the government aims to cut emissions.

A key issue here is credibility – which is probably easier to achieve in China because of its political continuity. One dimension of credibility is backing up general policy statements with specific measures. For instance, the Chinese government could send a clear signal by announcing that all non-CCS enabled plants (or plants with emission performance above a certain threshold) would have to close by a certain date, and that all new plants had to be 'carbon capture ready'. However, this would raise many questions: would people believe the government was serious or just go ahead and assume they would never actually require CCS?; and if they did believe the government was serious, would they build any coal plants (in the UK, no one has since the rule was introduced)? So this approach by the government should be compared with others, such as tightening the absolute emissions cap in relation to electricity, setting an emission performance standard that would rule out unabated coal-fired generation, or making a stronger commitment to higher and rising carbon prices.

7.2 Accelerating market reform

Most of the international experience referred to in this report occurs in systems that are liberalised and that make use of competitive market mechanisms, for instance to support least cost dispatch, retail competition, regional trading, integration of renewables, resource adequacy and flexibility. China began its electricity reform at the beginning of the century, but the system is very rigid in ways that effectively protect coal-fired generators and discourage competition from renewable energy, demand response and other sources of cleaner energy. This rigidity promotes the use of coal and is inconsistent with the objective of efficient decarbonisation.

Fortunately, additional reform is now being discussed in China, especially taking on board the ideas in Document 9, which was released by the State Council in May 2015. For example, the recently announced Thirteenth Five Year Plan on Electricity System Development indicates that China will start trial spot market power trading by 2018 and that spot market trading will be fully operative in 2020, after reforming transmission and distribution tariffs. These reforms are broadly consistent with the use of the market mechanisms in other countries. Key ideas in Document 9 are to set separate tariffs for transmission and distribution based on the principle of earning 'cost plus reasonable profit', and to separate retail from network activities. These ideas are important because they allow for greater competition both in the retail market and in the wholesale generation market; they also support least cost dispatch and prices that reflect short-term marginal costs. With or without structural changes, it is important to introduce merit order dispatch. This would permit the introduction of short-term price signals (through the spot market trading that has been recently announced) to encourage demand response and other sources of flexibility, which in turn would support the integration of renewables and facilitate regional trade. The reform could also help to significantly reduce, or even eliminate, guaranteed annual 'non-market' coal quotas.

In short, an important message from international experience is that competitive electricity market mechanisms improve efficiency and can help to reduce the cost of phasing out coal. More generally, the challenges of climate change and local pollution are good reasons to accelerate the process of reform in China.

7.3 Carbon emission allowances prices and trading mechanisms

China is introducing a national cap-and-trade system for carbon in 2017, building on over ten years of experience with the Clean Development Mechanism and its seven pilot carbon markets. No doubt, China has learned from the success and the failures of other carbon markets. Nevertheless, we would highlight three messages from international experience.

First, credible, long-term carbon price signals are important to encourage investment and innovation in low carbon technologies. This could be done through the introduction of a forward-looking and rising carbon price floor for emission allowances. An alternative is a central banking system that adjusts the supply of allowances to ensure that prices remain within upper and lower limits.

Second, China may want to consider determining the lower price limit for emission allowances by reference to the concentration of greenhouse gases in the atmosphere, so as to provide a sharper price signal if needed. Since this is an idea that makes sense at a global level and has consequences for a country's industrial competitiveness, China might consider making this a proposal for most countries to adopt in future UNFCCC negotiations.

Third, the funds raised through auctioning of allowances or through environmental taxation could be recycled within the economy, either to reduce the impact of higher energy costs on vulnerable consumer groups or to support investment in decarbonisation projects. At least half the funds from the EU ETS must be dedicated to climate change or energy related purposes. The idea of fiscal revenue neutrality – where additional auction or tax revenues are fully recycled in the economy – also has considerable merit, not least because it reduces opposition to pricing or taxing carbon emissions.

7.4 Regional coordination and competition

The EU and North America offer interesting institutional models to support regional coordination and competition in the electricity sector. The ISO/RTO model may be of particular interest for China because it enables coordination of inter-regional planning and operations, while promoting wholesale competition and more efficient investment and operations in generation and transmission. It also offers a structure that has been successful in incorporating a range of demand-side and supply-side alternatives in competitive wholesale markets. These models are based upon least cost planning and merit order dispatch reflecting marginal costs. Introducing a similar institutional model, alongside a national emissions trading system, would encourage the development of a more efficient low-carbon electricity system in China. It would also enable the national government to oversee the creation of regional ISO/RTOs and their coordination, as well as to define the regulations that apply to them.

7.5 Ownership structure and governance

Most of the international experience studied in this report refers to privately owned companies operating in markets where networks are separately owned from generation and retail activities, and where generation and retail are subject to competition. Governments define the laws and regulations, but privately owned companies for the most part make investment decisions based on the economic merits of the investment, and are free to change their business model and company structure, as we have seen for E.ON and RWE.

In China, on the other hand, the ownership structure and the monopoly over networks and retailing may blunt important economic signals and distort decisions. For instance, public ownership of coal-fired plants may make it even more difficult than for private companies to shut those plants due to the consequences for local communities. It may also encourage the building of new plants when they are not needed, since the consequences of stranded assets are farther down the road and may be ignored in the short term. In this respect, we support the structural reform ideas identified in Document 9 and other measures that lower the barriers to entry by private investors and encourage competition in all stages of the electricity value chain.

7.6 Regulation of local air pollution is a powerful reason to phase out coal

Although climate change is a powerful reason to phase out coal-fired generation, one message from international experience is that local air pollution and related health concerns have triggered regulations and public opposition that contribute to the decline of coal. This is of course also true in China.

7.7 Compensation for owners of existing plants?

International practice in liberalised electricity markets normally involves giving the owners of existing plants many years notice of any regulatory changes that will require additional investment to meet new emission standards. Owners are given the option either to make the investments, or to opt out. If the owner chooses to opt out, the plant is typically given a transition period and a controlled operating regime before it shuts down, enabling the recovery of fixed investment costs. Furthermore, the normal practice is not to subsidise the required investment. This approach has good incentive properties and is especially suitable for systems with relatively old and inefficient plant.

However, governments sometimes agree to compensate owners for the early closure of coal plants, or to help finance the investment needed to meet new environmental standards. The case for compensation is greatest when plants are relatively new and when owners have been given explicit guarantees of cost recovery. In the interest of encouraging early closure of coal-fired generation, or retrofitting of CCS for relatively new and efficient plants, China may wish to consider some form of financial compensation to affected shareholders.

7.8 Discouraging investment in new unabated coal-fired plants

Closure of existing plants, especially when they are relatively new as in China, is much more difficult than discouraging investment in new unabated coal-fired plants. Closing plants prematurely means that investors do not recover sunk investment costs. This is likely to lead to strong opposition from investors, employees and the local community. The case for closing older, inefficient, plants is much easier to make and China has been expert in replacing old with new plants. Likewise, it is easier to make the case for closure of plants that are causing local pollution, as China has also done very recently.

Investment in new plants involves putting at risk potential returns, not the loss of sunk costs. The decision not to proceed with the investment usually implies very limited losses related to expenses incurred before the investment in undertaken. In cases where investment in new plant is being considered, investors should make their assessment taking account of the risks that could devalue the asset once it has been built. Government can help by providing clear long-term signals for investors.

7.9 Exploiting opportunities of the transition

Governments and companies in Europe and North American are finding ways to exploit the opportunities afforded by the transition away from unabated coal. That transition corresponds to a fundamental transformation of the energy sector, involving decarbonisation and decentralisation of the electricity sector, as well as electrification of key end markets, such as transport and buildings. This transformation is broadly beneficial for society, and also offers an opportunity to promote the development of new low-carbon technologies and business models that are sustainable and have global markets.

What does this mean for China? First, as a country with a fleet of efficient and relatively new coal-fired plants, CCS/CCU (and other abatement) technologies are of particular interest if the government intends significantly to reduce CO_2 emissions without closing a large proportion of the coal plants. Given the continued operation of new coal-fired plants elsewhere and the need to reduce sharply the emissions from those plants and from other fossil fuel activities, we would support more international cooperation in developing these technologies.

Second, reforms of the kind identified in Document 9 – especially those that support efficient merit order dispatch and prices based on short-run marginal costs – could open the door to the creation of competitive wholesale markets for energy, capacity, flexibility and other services. These reforms and markets would encourage more efficient use of existing resources, regional coordination of investment and operations, the integration of renewable power and generally lower system costs and prices. Furthermore, they would encourage investment in digital technologies (including blockchains) and new business models that would allow consumers to participate as 'energy citizens' in the electricity markets through self-generation, demand response and storage. And they would support the process of electrification of final energy markets, lowering China's reliance on imported fossil fuels.

We have seen how this transformation is changing business models in other countries. It explains the restructuring of incumbent electricity utilities, such as E.ON and RWE, in order to separate potentially stranded assets (like coal generation) from those activities with the greatest potential (networks, renewables and consumer services). It explains entry into the electricity sector by new players, like Tesla, Google and Apple, not to mention the companies that specialise in renewable power. As it did in the renewables business, China has the potential to exploit the opportunities afforded by embracing the transformation of the energy sector.

We are now seeing a public narrative focused on how best to exploit the opportunities of building a low carbon economy. As low carbon technologies move into the market, the nature of the climate policy debate is changing.

The challenge now is how to make the economy work better – smarter, cheaper and cleaner – and pick up all the climate benefits on the way.

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