

## Thermal Coal in Asia – Stopping the Juggernaut

The power sectors of China and India together combine to be one of the most significant sources of emissions on the planet due to the use of thermal coal plants. Indeed relative to other sources of carbon the potential unneeded carbon generated by these sectors relative to a 2°C scenario is the most significant of any source.

While in China coal consumption appears to have peaked already, in both China and India coal demand will still exceed IEA carbon budgets for thermal coal before 2050.

Indeed, the International Energy Agency (IEA)<sup>1</sup> carbon ‘budgets’ for their power sectors call for a near complete decarbonization by 2050. While this can help with air pollution and water stress too, carbon capture and storage plays a key part in that budget.

After a strong surge in 2015, the pipeline of all planned coal plants has fallen in India and China but the level remains unrealistically high relative to demand and the development of cleaner power sources.

Our analysis shows that in China in particular the current build out of coal plants under construction can cause an overshoot of the IEA thermal coal budget by 2020 on an annual basis and use up the

Thermal Coal power plants under construction continue to rise in China at alarming levels. The amount of plants under construction in China (205GW) and India (65GW) are the numbers to watch. In the case of China, our analysis shows less than half of the capacity presently under construction would be sufficient to break the IEA annual thermal coal carbon budget by 2020 and the total budget by 2036. Stranded assets are likely to emerge as load factors continue to fall.

Thus, while growing renewable power plus falling coal power load factors have contributed to slowing or peaking emissions growth in China, further policy action in the power sector is still needed. Policies can complement positive trends in the relative cost of renewable energy, and reduce pressure on these sources from excess generating capacity, which is forcing curtailment.

Extending short-term moratoriums on new coal plant permits and new construction, accelerating retirements of old plants and Electricity Market Reform to prioritize low carbon dispatch are all on policy makers’ radars in China and India.

Carbon capture and storage (CCS) needs to be implemented in government plans if it is to be taken seriously. As yet there is little evidence of action. Without CCS for coal plants, just deploying High Efficiency Low Emissions plants will not meet 2°C.

Reflecting the Paris Agreement, a cap on coal consumption and emissions in the power sector, tied to robust carbon markets, is a longer-term option. Looking at more granular caps through Performance Standards in the power sector with load factor management is also a viable pathway. Removing subsidies for coal production and consumption is consistent with all these policies. Promoting energy efficiency is highly effective and important too.

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<sup>1</sup> Interpolated from ETP 2016.

whole of the budget available till 2050 by 2036. India does so in the 2030s even with no new power plants developed post those under construction now.

While India, in particular, believes it needs more room in carbon budgets for equity reasons - implying further cuts to OECD coal use - this paper looks at the power sector solutions that are both viable (renewable energy) and need further proving (Carbon Capture and Storage).

There is no doubt that both India and China have comprehensive policies to stimulate cleaner energy, efficiency and further policy changes would be highly desirable to support these trends by constraining unneeded thermal coal and developing green financing markets.

*This summary is linked to the more detailed paper found at [et-advisors.com](http://et-advisors.com)*

**Co-Authors and Sources<sup>2</sup>:**

- Ted Nace, Christine Shearer and Aiqun Yu from [CoalSwarm](http://CoalSwarm) provided underlying data and comments from [Global Coal Plant Tracker](http://GlobalCoalPlantTracker).
- [Carbon Tracker](http://CarbonTracker) provided the Carbon Budget analysis.
- Lindee Wong from [Ecofys](http://Ecofys) prepared the High Efficiency Low Emissions Analysis.
- Shelagh Whitely at [ODI](http://ODI) provided the Subsidies' analysis.

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<sup>2</sup> The paper references and cites many sources, notably: [Bloomberg New Energy Finance](http://BloombergNewEnergyFinance); [EndCoal.org](http://EndCoal.org); [Greenpeace.org](http://Greenpeace.org); [IEEFA.org](http://IEEFA.org); [IEA.org](http://IEA.org); [Regulatory Assistant Project](http://RegulatoryAssistantProject) ; [The Oxford Martin School](http://TheOxfordMartinSchool); [EnergyInnovations.org](http://EnergyInnovations.org); [nrdc.org](http://nrdc.org); [edf.org](http://edf.org).

## Editorial and Executive Summary

This study finds that China is perilously close to surpassing a crucial ‘reference’ carbon emission budget while India will do so over time as emissions continue to grow, throwing a focus on additional climate action where a critical choice is looming between carbon mitigation with or without large-scale carbon capture and storage (CCS). The International Energy Agency (IEA) has laid out carbon budgets, which represent the cumulative carbon emissions consistent with limiting global average warming to below 2°C at a 50% probability. There is no easy way to allocate such a budget between countries, given issues of equity and fairness, but the IEA is in many senses the key reference point starting from least cost and technology standpoints. On this standpoint, China is on course to surpass its thermal coal budget by 2020 and exhaust the whole budget by 2036, even if it proceeds only with coal power plants already under construction, disregarding many more in the planning pipeline. These findings highlight how recent efforts to slow new permitting, and a peaking of coal-fired power generation and carbon emissions in China, are encouraging but need further effort. Even in India, with fewer power plants under construction, the coal sector will surpass its IEA budget in the 2030s – but again with no new power plants at all being built. BNEF see the coal consumption IEA budget being overshoot from 2020 by a large margin.

Where does this leave us? Pursuing energy efficiency is generally at the top of everyone’s list to curb emissions. But if carbon is a priority, both countries must take urgent action to curb coal power growth, even if the OECD also steps up. First, they should extend or introduce moratoriums on coal power permits, and where feasible, halt current construction. Electricity market reforms, which dispatch renewables first in the merit order, are low hanging fruit. Second, additional action will be required to limit emissions from existing power plants. This study finds painfully slow progress towards deployment of CCS. In China, four large-scale CCS projects are awaiting final investment decisions. If these went ahead they would capture 6 million tonnes CO<sub>2</sub> annually, compared with IEA assumptions for 240MT CO<sub>2</sub> in China and India by 2030. Without CCS, however, China and eventually India will require equally urgent and radical action, if the world is to meet the 2°C target. This will include: potential caps on coal consumption being achieved through more specific caps on emissions in the power sector, early retirement of existing coal plants; and scrapping of fossil fuel subsidies. The potential for stranded assets and financial impacts remains substantial.

\* \* \*

What happens to thermal coal in Asia, in terms of supply and demand and consumption, in many senses holds the key to global emissions and hence the climate. According to the IEA’s *2°C Emissions from Fossil Fuel Combustion*, India and China electricity and heat sector emissions were near 5.3 gigatonnes (GtCO<sub>2</sub>) in 2013, of a world total of 13.7Gt CO<sub>2</sub>, which itself was a subset of combustion by all sectors of 32.2GtCO<sub>2</sub>, and around 50Gt of all global emissions.<sup>3</sup> No other sector has such a concentrated impact as this. Coal dominates the power sector in China and India.

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<sup>3</sup> <http://edgar.jrc.ec.europa.eu/overview.php?v=GHGts1990-2012>

Section 1 in this study reviews how the past year has seen positive developments. China and India have sought to pull back the huge pipeline of planned coal fired power plants that drive demand for thermal coal, while continuing to push for scale up of renewable energy. Even so, this still leaves some 1,020 thermal coal plants in China and India which are planned, pre-permitted, permitted or under construction, with 566GW of potential capacity<sup>4</sup>. This is a massive pipeline still in place, which would result in cumulative emissions of 57Gt by 2050 at 50% load factors. The pipeline has to fall following a particularly strong rise in China in 2015, as the proposed plants simply are way beyond the electricity needs of China and India in the foreseeable future, and will therefore operate at lower, less economic run rates, while still giving rise to excess emissions.

The most important category is the 521 plants under construction, with a capacity of 270GW. These plants would lead to cumulative emissions of 30Gt, or some 3% of the global carbon budget outstanding. China dominates with 389 plants and 205GW capacity under construction, ahead of India's 132 plants with 65GW capacity. Indeed as we go to press, there have been further announcements of another 6GW approved in China<sup>5</sup>. This leaves a coal juggernaut operating and actually developing in Asia that in emission terms is sufficient to significantly affect the global carbon budget. In economic terms, load factors down at 46% in China raise the issue of stranded assets even before any carbon budget squeeze is considered. Only generous electricity tariffs are providing a buffer. A potential knock-on impact on those funding these stations makes the threat of systemic risk relevant. Estimates range up to \$200bn of unneeded capex by 2020<sup>6</sup>. Importantly, choosing a low carbon pathway is still consistent with economic growth and development, and in the case of India solar is very much aligned with energy access.

The IEA in its recent World Energy Investment<sup>7</sup> publication said:

*“With recent investment in renewables-based and nuclear power capacity now largely covering electricity demand growth, signs of overinvestment in coal-fired generation have emerged in China.”*

Analysis from Bloomberg New Energy Finance (BNEF) in Chapter 2 shows that coal consumption in Asia overall would outstrip the IEA 450 PPM thermal budget for that region some two and a half times – indicating just how enormous the pressures are. India, in particular, is seen to be a huge source of increased thermal coal use and emissions, as it accelerates to be the world's fastest growing consumer of thermal coal.

Section 3 sets out the IEA carbon budget for thermal coal in India and China in more detail, and looks at the role of carbon capture and storage (CCS). The number of coal plants assumed to be operating with CCS accelerates from 47GW in 2030 to 315GW in 2050. By 2050, that allows the Asian power sector to move towards being almost fully decarbonized. However, if those coal plants turned out to be only very

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<sup>4</sup> Coal Plant data source [CoalSwarm](#), Emissions [Ecofys](#)

<sup>5</sup> <http://news.bjx.com.cn/html/20161008/777915.shtml>

<sup>6</sup> Greenpeace [Burning Money](#)

<sup>7</sup> <https://www.iea.org/Textbase/npsum/WEI2016SUM.pdf>

efficient Ultra Super Critical (USC) plants without CCS, they would emit cumulatively 21Gt of emissions by 2050, and be running at 1.4Gt pa compared to the IEA budget of 0.19Gt pa.

The question of equity in the carbon budget itself ultimately becomes moot as time goes on and the emissions cap declines dramatically. However, the amount of cumulative budget is important particularly to India where there is concern there is not enough room for growth. This might imply a further reduction in the OECD coal budget, or more help in funding a rapid build-up in cleaner energy. The connection to other pollution issues in air quality and water stress is not a focus of this paper, but is certainly another set of important issues.

The IEA has set out CCS potential in China – where it would be most needed – but this still requires major government involvement in transport and storage infrastructure, and so is risky until it is fully laid out and implemented. In effect, by 2020 ‘action is louder than words’. Renewable energy costs continue to fall, as demonstrated by CTI’s recent paper<sup>8</sup>, and flexible smart grids with storage are starting to emerge.

Section 4 of this document looks at the role that High Efficiency Low Emissions (HELE) power plants could play, combined with retirements, in replacing older, less efficient coal plants. Importantly, we assume operating load factors of coal plants at 50%, in line with BNEF expected global averages. Even then our, country coverage shows at best<sup>9</sup> emissions running at 3.3Gt per year in 2050. That compares with an annual total carbon budget by then of close to zero, and indeed is about 4% of the current 2015 budget.

In cumulative terms, according to our analysis, there are 161Gt of emissions on this most efficient pathway, around 18% of the total carbon budget of 900Gt. Under all scenarios tested, the IEA 2°C carbon budget is broken, in China by 2019<sup>10</sup>, and by 2039 in India<sup>11</sup> even assuming no new coal plants are developed after the current 65GW.

**So what can be done?** Section 5 looks at policy options in the face of such an enormous task. Many important policies are in place in China and India already. Specific to thermal coal, there is a moratorium of sorts in China on new permits and construction, which could be strengthened and extended. India is also seeing more push-back on plant construction. Electricity market reform is also a key policy area. Running low-cost, low-carbon energy first in electricity dispatch is a key priority that is often lacking in Asia. China could further enforce already existing laws, as a key focus for policy makers right now. Far more aggressive retirements of old plants could be carried out as well, to manage the stranding of those. Continuing to push for energy efficiency remains crucial in the whole equation.

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<sup>8</sup> CarbonTracker, [End of the load for coal and gas?](#)

<sup>9</sup> Allows for retirements in China and replacement of older plants by Ultra Super Critical and only under construction in terms of new plants.

<sup>10</sup> Based on existing emissions plus impact from coal plants under construction at 50% load factors less 18-20GW of retirements a year and the remaining fleet evenly converted to Ultra Super Critical stations.

<sup>11</sup> Based on existing emissions plus impact from coal plants under construction at 50% load factors with older plants evenly converted into Ultra Super Critical stations.

In the longer term, the main priority measure remains to apply effective emissions caps that can be associated with a consumption cap on coal<sup>12</sup>, in the power sector. Indeed China mentions caps, in its national contribution to the Paris Agreement. The political economy, with push-back from incumbents, will be a major factor in implementation. The most market-based response is around carbon markets that would allow both CCS in the most promising applications and regions, and renewable energy, in a flexible smart grid with storage to scale. China is establishing a national carbon market<sup>13</sup>.

Another mandated option is to use Performance Standards to set emissions at the level of individual power plants. This forces technologies to prove themselves and accelerate: CCS; renewables; nuclear (with caveats on public acceptance); and energy efficiency. This fits more with recent moratoriums on new coal power permits and construction in China, and to some extent India, that could be extended and, where possible, current construction could be halted.

Finally, it is inconsistent with decarbonization to continue to subsidize fossil fuels, as set out in analysis which shows that support remains, through public finance for fossil fuels (domestic and international); support through state-owned enterprises (SOEs); links between production and consumption subsidies; and failure to price externalities.

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<sup>12</sup> See NRDC <https://www.nrdc.org/experts/barbara-finamore/how-capping-coal-can-help-china-peak-its-co2-emissions-2025-and-contribute>

<sup>13</sup> <https://www.scientificamerican.com/article/china-will-start-the-world-s-largest-carbon-trading-market/>  
<https://www.iea.org/publications/insights/insightpublications/emissions-trading-in-the-peoples-republic-of-china-a-simulation-for-the-power-sector.html>  
<http://www.edf.org/sites/default/files/india-case-study-may2015.pdf>

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## Setting The Context – The Importance of Thermal Coal in Asia for The Climate.

### The Carbon Tracker Initiative “Danger Zone” – Analyzing potential supply in the context of the climate

When considering potential climate impacts in terms of carbon budgets, it is helpful to identify the carbon contained in unexploited fossil fuel supply and so identify the relative impact on the climate from future production. And by comparing their capital intensity, it is possible to gauge the impact on investors if capital investments become economically stranded.

The Carbon Tracker Initiative’s (CTI) November 2015 work “Danger Zone” focused on the potential fossil fuel supply, in the context of the IEA 450 ppm carbon budget to limit global average warming to 2°C by constraining carbon dioxide levels to below 450 parts per million in the atmosphere. The focus was on unneeded supply using Wood Mackenzie and Rystad ‘Business As Usual’ supply curves vs. the 450 ppm budget globally. Part of the focus was looking for more specific ‘carbon traps’ that would have the most significant impacts if developed.

Table 1 below set out the amounts of potential oil production by category out to 2035, in terms of needed and unneeded supply, expressed in Gigatons (a billion tons) of CO<sub>2</sub> emissions, to meet the 450 ppm pathway.

Table 1

450 Scenario: 2015-2035 Carbon Emissions (GtCO <sub>2</sub> )			
Category	Needed	Not needed	Total
<b>Oil</b>	<b>221</b>	<b>28</b>	<b>249</b>
Arctic	1	1	3
Coalbed methane	0	0	0
Conventional (land/shelf)	144	13	157
Deep water	16	4	19
Extra heavy oil	7	1	8
Oil sands	11	3	14
Oil shale (kerogen)	0	0	0
Tight/shale liquids	30	3	34
Ultra deep water	12	2	14

*Source Carbon Tracker*

Apart from all conventional (onshore and continental shelf) globally, no category comes close to the potential emission levels and unneeded carbon being generated by the Chinese and Indian coal power plants, as shown in Table 2, and based on the analysis contained in section 4. This is in effect comparing the use of coal supply to the source of oil supply, but makes the point.

Table 2

ETP Scenario: 2015-2035 and 2050 Carbon Emissions (GtCO <sub>2</sub> )		
India and China	Existing Plants Plus:	
	All Planned	Under Construction
<b>2035</b>		
Needed	97	97
Emissions Level	119	108
Not Needed	22	11
<b>2050</b>		
Needed	108	108
Emissions Level	196	169
Not Needed	88	61

Source IEA, CoalSwram/CTI/ETA analysis

As the CTI report stated in relation to fossil fuel supply, high-cost “carbon traps” pose the highest risk to investors, especially if they are capital intensive, which is the case for oil and gas

**High-cost carbon traps:** The project *categories* which pose the highest risk to investors are those with high costs, high carbon content and long reserve lives. This is because high-cost and high-carbon projects have high operational gearing to price volatility and long-life projects are exposed to carbon risk for a far greater period (potentially 50 years for oil sands, LNG and coal). Shorter lead-time projects, such as shale oil, have less “time” risk but can still be high-cost. We term these “high-cost carbon traps” and draw particular attention to the categories below:

- Oil sands – in Canada
- Arctic oil and gas – US, Russia and Canada
- Deep and ultra-deep water oil and gas – key areas include Mexico and Brazil.
- LNG – key countries include Qatar, Australia and Indonesia

But from the point of view of the climate, to limit global average warming, it is also relevant to identify less capital intensive carbon traps that contain massive amounts of carbon.



**Additional carbon traps:** We also highlight other “carbon traps” that have lower capex exposure but high climate exposure. Many of these are state-controlled and hence are subject to government decisions:

- Seaborne coal – produced by exporters in countries such as Australia and Indonesia, areas with significant private-sector exposure
- US coal – with resources often on public lands but production controlled by private-sector companies
- Chinese domestic coal – significant (~50%+) government ownership of production
- Indian domestic coal – 85% of current production controlled by one company, Coal India, which is 79% owned by the government of India (though with plans to reduce this share to around 69%)

Combining carbon content and capital intensity in this way, we can see that Chinese and Indian coal supply, along with the seaborne market that mostly goes to supply power plant demand into these countries, dominate the potential carbon overhang on the fossil fuel carbon budget, while also being less capital-intensive than oil and gas.

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### High Cost High Carbon Traps by Category

Capex (2015-2025,\$bn) and CO<sub>2</sub> (2015-2035, GtCO<sub>2</sub>) associated with unneeded production from new assets only, selected categories

Carbon is production x carbon intensity of fuel type

"New" means discovery/undiscovered for oil and gas, future production for thermal coal

Gas and thermal coal figures are for covered markets only, rather than global coverage

		Unneeded potential supply over 450	
		2015-2025 capex (\$bn)	2015-2035 carbon (GtCO <sub>2</sub> )
Fuel	Category		
Oil	DW + UDW	244	5.3
	Oil sands	154	3.3
	Arctic	69	1.2
Gas	LNG	254	4.6
Thermal coal	Seaborne	56	21.5
	China domestic	79	32.1
	India domestic	16	7.3

Source: Rystad, Wood Mackenzie, CTI/ETA analysis

As in previous studies, we find that in oil these "traps" are concentrated in oil sands, Arctic, deep and ultra-deep water, gas in LNG, and in thermal coal by seaborne markets and domestic production in China and India.

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## Section 1: Recent Demand and Supply Trends in Thermal Coal in China and India

### 1.1 Summary

In China, 2016 has seen a trend towards an increase in pre-construction power stations being shelved or cancelled, but also an increase in actual plants under construction. Meanwhile, evidence is growing that coal consumption may have peaked in the past two years, with the energy intensity of GDP falling as a result of the rebalancing of the economy<sup>14</sup>.

Recent announcements, including a partial moratorium on new power plant permitting and construction, have been encouraging. Some 114GW of pre-construction coal power plant capacity has been cancelled or shelved this year. Nevertheless, 2015 saw a massive surge in permitted thermal coal fired stations at the local level in China, as permitting powers were passed to the provinces. That surge leaves 205GW still under construction today, even while the economics of the sector look challenging.

Low coal prices and supportive tariffs allow many coal plants to be profitable even at low load factors. However, tariffs are falling in China, as regulators send a signal to curtail new build, which leaves the sector increasingly vulnerable to economic stranding, given falling load factors that have already fallen to 46%. Estimates have put unneeded coal plant expenditures at around \$200bn by 2020. Renewable energy continues to scale up but dispatch has been curtailed, a problem which needs to be addressed in dispatch reforms.

Indian developments remain ambivalent, reflecting an 'all of the above' energy policy approach that includes renewables, but also still seeks to develop coal aggressively with 65GW under construction, even after a reduction of the pre-construction in the pipeline of 40GW up to July this year. Indeed there have been announcements of cancellations of 'mega' projects, and local opposition around land use is evident in India. Renewable energy has seen strong gains and can go much further. However, longer-term demand for electricity remains high.

In both India and China, there is a tussle between domestic coal production and imported seaborne coal. China was reducing domestic production earlier in the year, while India has been trying to boost domestic production. Seaborne coal prices have been rising, but very recent announcements to increase domestic production in China again put this under pressure.

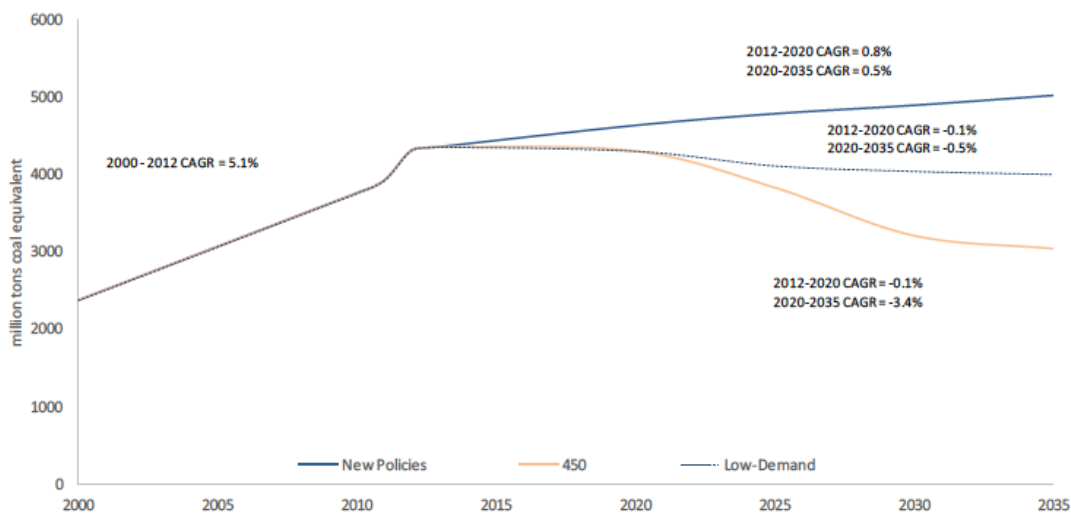
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<sup>14</sup> Key references in this section are EndCoal.org and IEEFA .org

## 1.2. The CTI thermal coal context

In September 2014, CTI published its Carbon Supply Cost Curves for Thermal Coal. CTI argued that Chinese coal demand could peak in 2016. But global coal demand would continue to see support from India and ASEAN countries, in particular, and therefore remain inconsistent with a 450 ppm global pathway.

Figure ES-2 Global thermal coal demand in Carbon Tracker Low-Demand Scenario vs. IEA New Policies and 450 Scenarios, 2012-2035 (mtce)



Source: IEA, IEEFA, Carbon Tracker analysis 2015

## 1.3. Supply, Demand, Policy and Price

Respected commentators on China and India have noted positive developments in the energy system during 2016. We survey those initially.

### 1.3.1 China

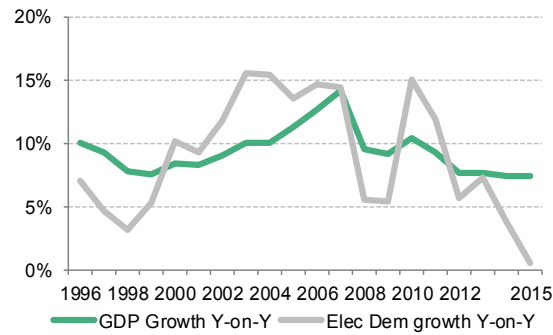
Data for China in particular has shown a more pronounced slowdown in coal consumption in the face of the country's economic rebalancing and push to reduce air pollution, impacting thermal coal plants and domestic coal production. This has led to a reduction in energy intensity, as shown below in terms of GDP.





## CHINA GDP & ELECTRICITY DEMAND GROWTH (%)

NEW ENERGY OUTLOOK 2016



Source: National Bureau of Statistics, Bloomberg New Energy Finance

**Bloomberg**  
NEW ENERGY FINANCE

3

When looking at short-term data, domestic coal production, imports and demand indicators are all relevant.

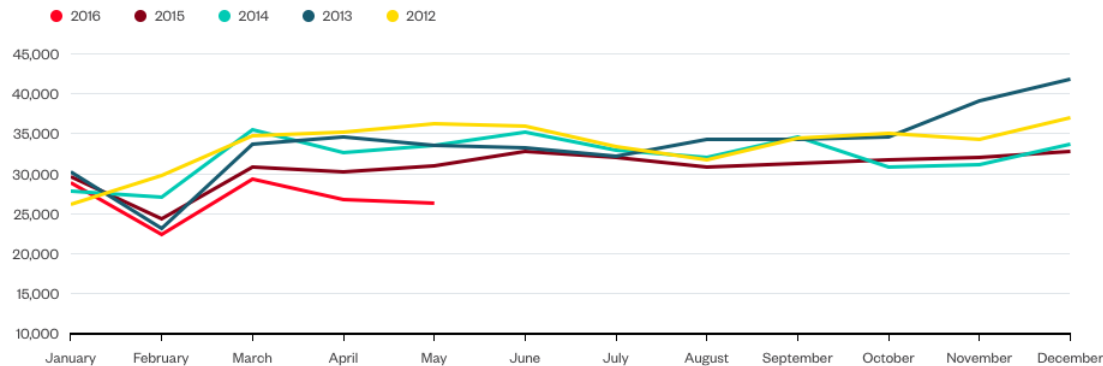
In June<sup>15</sup>, Bloomberg reported that China’s efforts to curb air pollution and eliminate so-called ‘zombie’ companies had seen coal output capacity fall by 280 million tons this year, equivalent to about 7.5 percent of production in 2015. Bloomberg quoted a [Citigroup research note](#), that China’s coal production may decline 9 percent this year, offsetting a demand drop of 3.4 percent.

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<sup>15</sup> <http://www.bloomberg.com/news/articles/2016-06-26/china-signals-coal-capacity-cut-equal-to-7-5-of-output-in-2015>

## Deep in the Pit

China's coal production this year has been running well below previous levels



Source: Bloomberg

Note: Measured in 10,000 metric ton units. 45,000 equals 450M tons.

IEEFA reported in June<sup>16</sup> that the rate of coal production decline was “staggering”, at **9.7% year over year (yoy) in the first six months** of 2016, compared with 2% yoy decline in 2015. Continuing decline at this rate in the second half of 2016, coupled with continuing U.S. coal production decline, would see the global coal industry record its third consecutive decline in production. Such data suggests that Chinese and global coal production might have peaked in 2013. China’s coal consumption declined 2.9% yoy in 2014, with a further decline of 3.7% yoy in 2015, which accelerated in the first two months of 2016.

Other commentators and analysts support the view that China’s coal demand is in structural decline. In XXXX<sup>17</sup>, coal industry consultancy Wood Mackenzie conceded that the thermal ‘coal bubble had burst’. Publishing in Nature Geoscience<sup>18</sup>, Nicholas Stern and colleagues at Tsinghua University in Beijing argued that Chinese coal consumption peaked in 2014 and the country has entered ‘the era of post-coal growth.’ They argued that the decline of domestic coal consumption was a permanent rather than a temporary feature of China’s development and may be an important ‘turning point in international efforts to mitigate the emissions of climate-altering greenhouse gases.

As IEEFA note<sup>19</sup>, Seemingly supporting this view, the thermal coal price has been falling in the seaborne market, but also in domestic Chinese markets, for the last five years. In the six months to June 2016 the domestic Chinese thermal coal price was again down 14.5% year-on-year. This collapsing fuel cost has meant the profitability of Chinese coal-fired power plants was at record highs in the six months to December 2015, notwithstanding collapsing utilisation rates. However, the result in 2015 was a record high 70GW of new coal-fired power plant build. The Central China government has attempted to curtail

<sup>16</sup> <http://ieefa.org/sign-continuing-shift-china-coal-production-9-7-first-half-2016-%E2%80%A8/>

<sup>17</sup> <http://endcoal.org/2016/05/coalwire-135-may-26-2016/>

<sup>18</sup> *(Guardian, Nature Geoscience)*

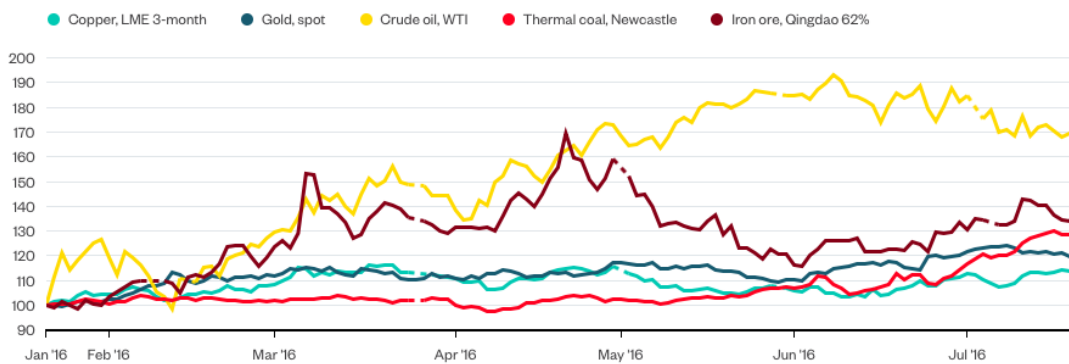
<sup>19</sup> [http://ieefa.org/wp-content/uploads/2016/09/China-Shenhua-Energy-Company\\_Key-Details-From-2016-Interim-Results\\_Sept-2016.pdf](http://ieefa.org/wp-content/uploads/2016/09/China-Shenhua-Energy-Company_Key-Details-From-2016-Interim-Results_Sept-2016.pdf)

such build by putting a moratorium on many new coal fired power plants, and cutting the price of coal fired electricity at the start of 2016. Coal fired power wholesale tariffs fell 11.2% yoy in the June 2016 half to Rmb301/kWh (\$45/MWh).

More recently, thermal coal prices have rallied internationally, reflecting a bounce in China's coal imports and the rapid curtailment of export country supply, particularly in Indonesia. Many commentators expect this rally to be short-lived, however, as China corrects an expectedly sharp contraction in domestic supply. Recent announcements have seen a call for domestic production to be boosted again. Indeed, IEEFA's central forecast is that China becomes an opportunistic net exporter of thermal coal by the end of this decade.

### Back in Black

Coal has been catching up to sexier commodities with a 24 percent surge over the past two months



Source: Bloomberg

Note: Rebased. Jan. 20, 2016=100.

### 1.3.2 India

India has been faced with the opposite issue on supply: domestic production has been stimulated. Bloomberg reported in July<sup>20</sup>, that the bounce-back international prices was seeing domestic customers shun imports in favor of local supplies, favoring Coal India Ltd, the world's biggest producer. The state-owned company's production rose 3.5 percent to 125.65 million metric tons, in the three months ended June 30. The miner, which controls more than 80 percent of the nation's coal production, had seen resulting falls in inventories.

Nevertheless, India has moved to tackle some of the potential growth in coal demand, IEEFA argued<sup>21</sup>, pointing, for example, to a record 6.93 gigawatts (GW) of new renewable energy projects commissioned across India in 2015/16, and a target for 10.5GW of solar in 2016/17, three times that commissioned in 2015/16. India is looking to rationalize and modernize its coal fired power fleet in the face of increasing

<sup>20</sup> <http://www.bloomberg.com/news/articles/2016-07-15/coal-india-sees-rising-import-costs-helping-to-trim-stockpiles>

<sup>21</sup> <http://ieefa.org/coal-decline-steepens-2016/>

water stress and particulate pollution. In May 2016, India announced plans to close 37GW of coal-fired power capacity that had reached the end of its useful life, and where upgrades were not commercially viable. India has a publicly stated goal to cease thermal coal imports by 2017-1. For IEEFA, that means Adani's Carmichael mine project in the Galilee Basin has no future.'

Further<sup>22</sup>, the Power Ministry has announced that it has scaled back its projected thermal power capacity growth forecast by 50GW, reducing the target from 289GW to 239GW by 2022. India's current thermal power capacity is 211GW. S&P Global Platts forecast a reduction in India's reliance on coal-fired power generation from an estimated 69 percent share in 2020 to 60 percent by 2030, down from a peak of 75 percent in 2015. IEEFA see the 60 percent milestone being reached as early as 2025.

#### **1.4. Tracking Thermal Coal power plants in more detail: Way too many in the construction phase**

There is therefore positive news from a climate and carbon perspective.

But as illustrated by the Bloomberg New Energy Finance outlook in Chapter 2, forecasters still expect longer-term demand for thermal coal to remain too high in a carbon context.

One of the key inputs to thermal coal demand forecasts is expectations for new power plant build. This is where the trend is still concerning in terms of power plants under construction right now.

##### **1.4.1 Data from CoalSwarm Global Coal Plant Tracker**

In line with the positive trends discussed above, CoalSwarm's Global Coal Plant Tracker<sup>23</sup> which follows power plant developments, shows that the amount of coal power capacity under development worldwide saw a dramatic drop in the first half of 2016, mainly due to shifting policies in Asia. For example, in April China announced sweeping restrictions to halt planned coal-fired power plants in 13 provinces. And in June, India's Ministry of Power issued an assessment stating that no further power plants would be needed in the next three years, and that 'any thermal power plant that has yet to begin construction should back off.'

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<sup>22</sup> <http://www.bloomberg.com/news/articles/2016-07-11/india-seeks-to-modernize-coal-plants-by-halting-renovations>

<sup>23</sup> [Global Coal Plant Tracker](#)

In a recent study,<sup>24</sup> Greenpeace noted that full implementation of China’s new policy to rein in over-capacity could see 110GW (160 coal-fired units)<sup>25</sup> of coal-fired power suspended, and up to 70GW (669 units) of existing capacity retired by 2020.

It is certainly good news that the total pre-construction pipeline in China and India dropped by a notable 155GW so far this year up to July. This pipeline comprises power plants which have been announced, permitted and our under construction.

However, this pipeline still stands at 584GW, which is totally unacceptable in a 2°C context without massive deployment of CCS. Furthermore, the capacity of power plants under construction has actually risen by 12GW in China, to 205GW<sup>26</sup>. India has seen a fall in power plants under construction, to 65GW.

### **Global Coal Plant Tracker – Plant Capacity Comparison 1/16 vs 7/16 (MW)**

Country	Pre-permit		Announced + Pre-permit +			Shelved	Cancelled 2010-2016
	Announced	development	Permitted	Permitted	Construction		
China (1/16)	247,160	217,294	54,960	519,414	193,179	61,735	164,495
China (7/16)	231,992	147,520	26,340	405,852	205,144	112,675	203,595
India (1/16)	64,630	95,595	58,244	218,469	72,200	85,065	305,272
India (7/16)	56,130	78,385	43,700	178,215	64,669	111,345	319,637

Source: CoalSwarm

**Note a full run down of all Asia can be found in Appendix 1.**

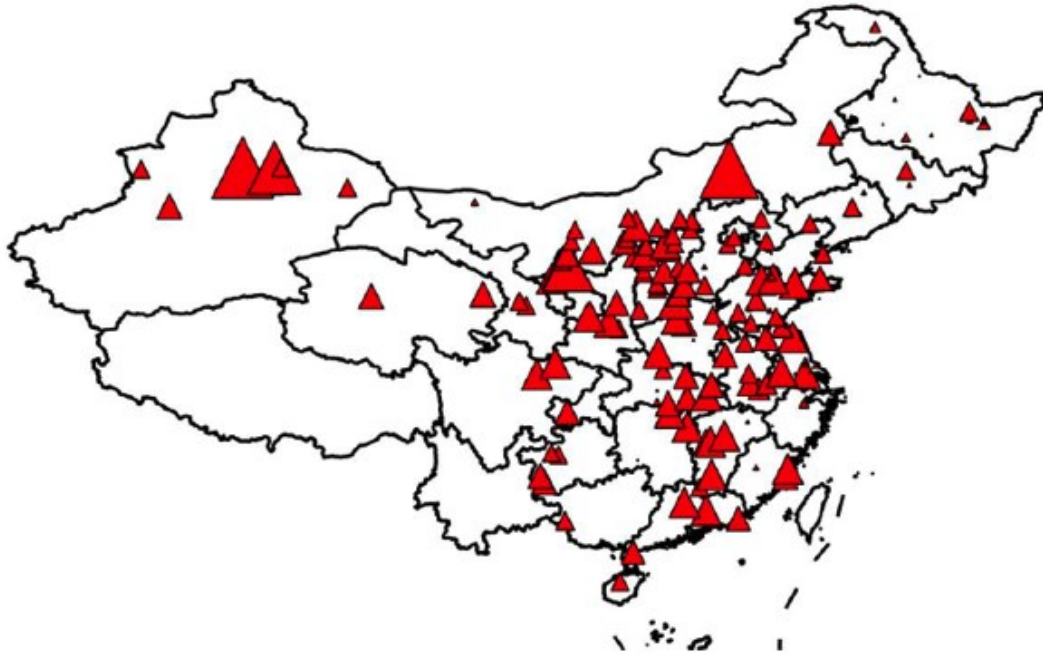
#### **1.4.2 China**

In China, the problem is both that coal power plant construction rose in the first six months of 2016, and the recent decline in the pre-construction pipeline follows a surge in 2015. The CoalSwarm Tracker found a “dramatic increase in permits” issued after the transfer of authority for permitting from the national to the provincial level after September 2014. As they noted, the risk is of growing over-capacity and future asset writedowns, as a result of the country’s economic rebalancing, declining energy intensity, and ramp-up in renewables.

<sup>24</sup> <http://www.greenpeace.org/eastasia/Global/eastasia/publications/reports/climate-energy/2016/Burning%20Money,%20How%20China%20could%20squander%20over%201%20trillion%20yuan%20on%20unneeded%20coal-fired%20capacity,%20Greenpeace.pdf>

<sup>25</sup> CoalSwarm’s Global Coal Plant Tracker estimates the effect to be 78GW in the context of their database – see above table

<sup>26</sup> A further 6GW has just been recently announced



*New coal-fired power plants being permitted in January-December 2015*

Source: Greenpeace <sup>27</sup>

Greenpeace noted the country had a further 160GW (295 units) of capacity that could still gain permits despite the new controls, with at least 30GW (55 projects) of new permits already issued in 2016. Further permitting was possible because not all provinces were covered by the suspension, and because projects were exempted if these were linked to western coal bases and long-distance transmission lines. These exemptions could still allow another seven years of one coal-fired power plant per week entering operation. Only one such year of additions would offset the present rate of retirements. By 2020, China could have 1,200GW of coal-fired power plants in operation and under construction, resulting in overcapacity of at least 400GW. This would represent wasted capital expenditure of approximately 1.4 trillion RMB (200 billion \$), according to Greenpeace. Nearly one quarter of this redundant capacity, 110GW, could still be avoided by fully suspending permits to all new conventional coal-fired projects, avoiding wasted capital expenditure of 300 billion yuan. Resolving the remaining overcapacity would

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<sup>27</sup> <http://www.greenpeace.org/eastasia/Global/eastasia/publications/reports/climate-energy/2016/Burning%20Money,%20How%20China%20could%20squander%20over%201%20trillion%20yuan%20on%20unnecessary%20coal-fired%20capacity,%20Greenpeace.pdf>

require either halting more than 100 projects under construction, or retiring hundreds of coal-fired units well before the end of their expected operating life.

However, China may be poised to take action to curtail coal power investment. The country's next five-year plan is due to be released soon, and may announce an extended moratorium on new coal power plants through 2018, according to the Australian Financial Review, with expectations that such a moratorium would be then be further extended. This will be taken up in section 5.

### 1.4.3 India

#### Collision Course – The Incompatibility of India's Coal and Renewable Strategies

CoalSwarm's Global Coal Plant Tracker<sup>28</sup> shows that India currently has 65 gigawatts (GW) of coal capacity under construction, and an additional 178GW proposed, for a total of 243GW of coal plants under development. If that full pipeline were fully executed, it would more than double India's current coal power capacity of 197GW. Such a coal development pipeline might either derail India's renewable energy ambitions, or else potentially lead to stranded coal plant investments. The CoalSwarm data shows that India's operating and under construction coal plants alone are enough to exceed the country's projected electricity demand through 2022. That is before accounting for pre-construction projects, or for India's proposals for 100GW of solar power and 60GW of wind power by 2022.

There are certainly forces working to keep constraints on further development short term. A threat of over-capacity is already indicated by a drop in average coal plant utilization rates, from 79 percent in 2007 to 64 percent in 2015. As in China, there are signs that policymakers in India are becoming alive to the threat of stranded investments. The Ministry of Power has concluded that slowing demand growth means India does not need any additional power plants over the next three years, beyond those already under construction, and those renewable projects which the government has committed to, reported the Economic Times. In an indication of this shift, India's largest electricity generator, NTPC, is tweaking its expansion plan to become the biggest renewable energy company in the next 10 years. The state-owned company's Rs 5 lakh core capital expenditure plan will be skewed towards adding renewable energy capacity, rather than more thermal units.

IEEFA<sup>29</sup> reports similar developments, noting, for example, that the nation's coal and power minister, Piyush Goyal, has asked regulators to stop approving repair and maintenance of plants older than 25 years. In addition, the chairman of the Central Electricity Authority, S.D. Dubey, has announced plans to close up to 37GW of antiquated, heavily polluting subcritical coal plants, or 20 percent of India's current coal-fired power fleet, and 12 percent of the total system capacity of 303GW.

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<sup>28</sup> <http://endcoal.org/2016/07/new-coalwarm-report-collision-course-the-incompatibility-of-indias-coal-and-renewable-strategies/>

<sup>29</sup> <http://www.bloomberg.com/news/articles/2016-07-11/india-seeks-to-modernize-coal-plants-by-halting-renovations>  
<http://ieefa.org/ieefa-asia-note-cancellation-4-ultra-mega-power-plants-underscores-indias-commitment-transition%E2%80%A8%E2%80%A8/>



IEEFA adds<sup>30</sup> that the Indian Ministry of Environment and Forests has stated that it will only allow the construction of so-called Ultra Mega Power Plants (UMPP), burning imported coal, to proceed if the project developers sign what are ultimately impractical memorandums of understanding with coal suppliers. The Modi government has expressed its commitment time and again to a policy of ending coal imports. Additional problems plague India's ambitious UMPP program. First, the cost of generated electricity may be too high. IEEFA estimates that the proposed Cheyyur UMPP would produce electricity at around Rs 5.93/kWh, compared with average wholesale power prices of around Rs 3.00-4.00, and solar generation bids of Rs 4.40-4.80. With both capital cost and operating costs projected to rise over time, electricity from UMPPs will become costlier with each delay in bidding. Second, in June 2016, the Indian Power Ministry proposed scrapping plans for four coal-fired Ultra Mega Power Plants, in Chhattisgarh, Karnataka, Maharashtra and Odisha. in the first such cancellation notice since a UMPP development policy was first proposed in 2005/06. Third, power companies have limited finance to build new thermal power projects. The leverage of the top six power players in India has risen from 1.5x in 2010/11 to 2.7x in 2015/16. Moreover, the Indian Banking system is under stress, with the Reserve Bank of India estimating that India's Gross Non Performing Assets may increase to 8.5 percent by March 2017, up from 4.6 percent in March, 2015. And fourth is the problem of over-capacity. India's coal-fired power plants operated at an average Plant Load Factor of 58% in 2015/16. IEEFA research indicates that India's coal-fired power plants would operate at an average PLF of only 56.7 in 2021/22, assuming it achieves its planned 175 gigawatts of renewable power, retirement of 37GW of old, inefficient and polluting plants, and that the full 65GW of currently under-construction coal fired power capacity comes on stream.

#### **1.4.4 The challenge remains**

Short term the outlook for new construction of new coal power plants shows them as mostly unnecessary in China and India. Commentators have warned that despite an emerging realization of over-capacity and shifting policy priorities, fossil fuel investments continue. Such investment indicated complacency among fossil fuel companies, according to Nicholas Stern, in a submission to the Task Force on Climate-related Financial Disclosures. Stern warned that fossil fuel assets could be hit by 'mass scrapping and stranding.' While businesses might argue that governments were not seriously committed to the new Paris Agreement on climate change, it would be a mistake to pin their entire strategy on this being so, Stern stated, as reported in the Financial Times.

Meanwhile, some G7 Countries are still providing billions of dollars in financing for coal plants, according to analysts at the Natural Resources Defense Council. Japan remains the worst offender, according to the NRDC, providing \$22 billion in coal financing from 2007 to 2015. Germany came second, providing \$9 billion during the same period. Japan was considering nearly \$10 billion in future coal projects, according to the NRDC's Han Chen.

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<sup>30</sup> <http://ieefa.org/blogs-indias-commitment-ultra-mega-power-plants/>



Longer term, as we now show in Sections 2, 3 and 4 there is no chance of meeting a full decarbonization pathway for the power sector in the face of the outstanding coal plant pipeline, even if we only consider power plants under construction now, and disregard the much larger pipeline of others so far only announced or permitted.

## Section 2: Assessing the outlook for Asian coal using BNEF's New Energy Outlook

This analysis is taken from the Bloomberg New Energy Finance 'New Energy Outlook' (NEO), BNEF's annual long-term global forecast for the future of energy focused on the electricity system<sup>31</sup>.

### 2.1 Summary: The outlook for thermal coal in Asia according to Bloomberg New Energy Finances' NEO

As a mainstream energy outlook but from a deep knowledge of renewables, we have been able to source Bloomberg New Energy Finances' New Energy Outlook (NEO) looking at Asia overall and China and India within that

The Asia-Pacific region will drive global power demand growth over the next 25 years, requiring over 4TW of new capacity additions – more than the rest of the world combined. Renewables will provide the bulk of this new capacity, with both solar and wind technologies becoming largely competitive with fossil-fired generation on a levelised cost basis from 2020, and in all major markets by 2040.

As solar and wind LCOEs decline, coal and gas LCOEs remain relatively flat as higher penetrations of renewables eat into the run-hours of conventional plants. This conclusion holds even with the availability of CCS or high-efficiency coal technology, as neither will dispatch ahead of (or close to) zero marginal cost renewables. Lower realized load factors for coal plants already apparent in China point to the creation of stranded assets, if this trend continues.

Nevertheless, to meet expected demand, a significant level of new coal capacity will still be needed in Asia, particularly in India. The NEO forecast suggests that India will add 258GW of new coal capacity over the next 25 years (almost 1GW per month), with coal-fired power generation in the country trebling by 2040. For the Asia-Pacific region as a whole, gross coal capacity additions are almost 700GW over the period 2016-40, or 0.5GW per week. Coal's share of the generation mix falls from 60% in 2015 to 42% in 2040, but in absolute terms it rises by a third to 8,400TWh/yr. over the same period. This translates into an additional 725Mt of coal consumption per year by 2040, the vast majority of which (650Mt) is in India.

Largely, as a result of this growth in Asian coal consumption, by 2040 global power sector carbon emissions will be five times higher than the level consistent with a 2°C pathway.

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<sup>31</sup> Focused on the power system, NEO combines the expertise of over 65 in-house country and technology-level specialists in 11 countries to provide a unique assessment of how the power market will evolve. See <http://www.bloomberg.com/company/new-energy-outlook/> for more information.

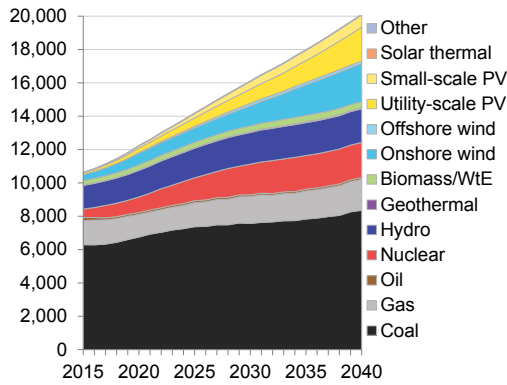
## 2.2. BNEF's NEO analysis

- *NEO considers a range of factors, such as the cost of wind and solar technology, battery storage, electricity demand, electric vehicles, consumer dynamics, and the price of coal, gas and oil among others.*
- *In the near term, our market projections are based on policy drivers and Bloomberg New Energy Finance's proprietary project database that provides a detailed understanding of planned new build, retrofits and retirements, by country and sector.*
- *In the medium to long term, the forecast is driven by the cost of building different power generation technologies to meet projected peak and average demand in each country. The modelling then preferentially deploys least-cost technology options that change over time in line with shifting capital, operating and financing costs. The latter, in turn, are influenced by manufacturing and deployment experience, fuel and carbon prices and changing risk profiles.*
- *The analysis assumes that, in general, renewables globally see no new subsidy support beyond 2020, however it does expect the continuation of strategic industries such as offshore wind and nuclear which may not otherwise be competitive.*
- *It assumes that carbon prices continue to exist where they are already in place or where there is some confidence in their emergence, such as China. In particular, the forecast also does not explicitly include the US Clean Power Plan or country pledges under the Paris Agreement. This means it is better used as a benchmark for policy action to be compared against, rather than a prediction, assuming policy targets are achieved.*
- *Furthermore, as NEO considers technologies based on their competitive economics, the deployment of CCS at scale does not feature in the forecast.*

## 2.3 Power generation mix

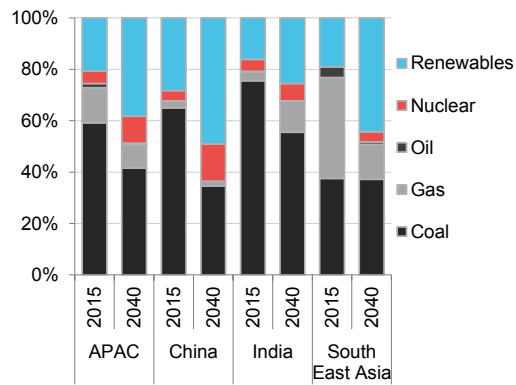
The power generation mix across the APAC region swings significantly away from coal over the next 25 years, despite growth of coal generation in absolute terms. Power demand almost doubles, but the majority of this new demand is met with nuclear, wind and solar power.

**Figure 1: Asia-Pacific power generation, 2015-40 (TWh/yr)**



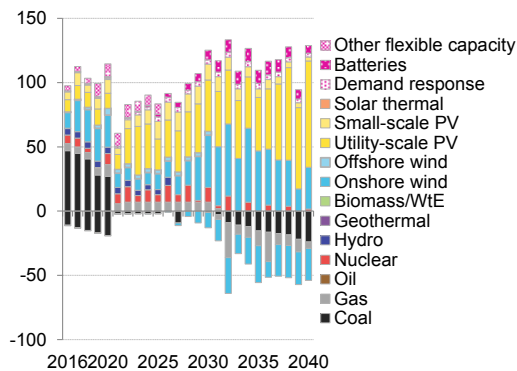
Source: Bloomberg New Energy Finance

**Figure 2: Power generation mix, 2015 vs 2040 by sub-region (%)**



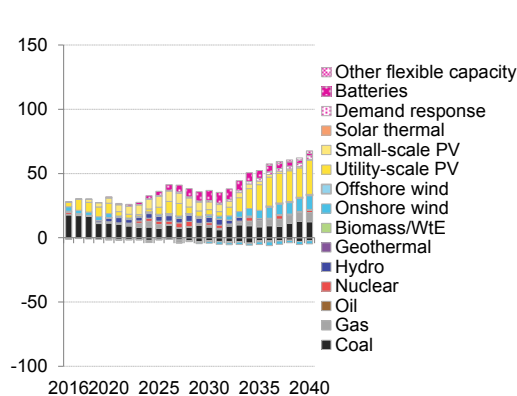
Source: Bloomberg New Energy Finance

**Figure 3: China gross annual capacity additions and retirements (GW)**



Source: Bloomberg New Energy Finance

**Figure 4: India gross annual capacity additions and retirements (GW)**

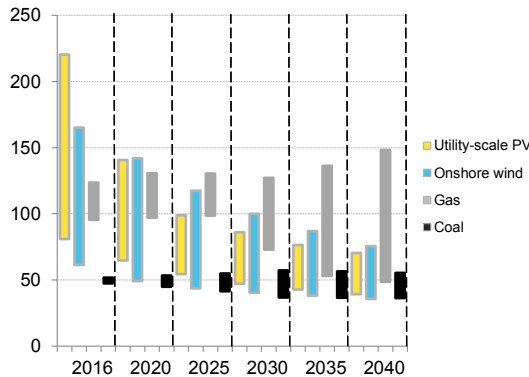


Source: Bloomberg New Energy Finance

## 2.4 Costs

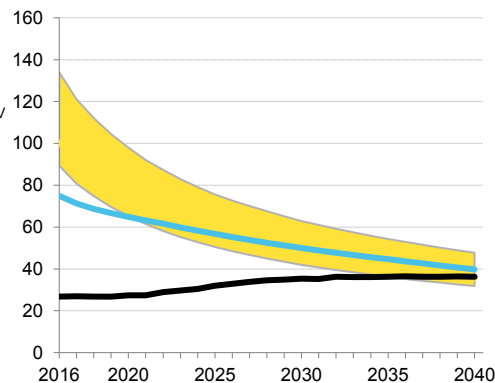
The growth in renewables is driven by continuous declines in the cost of solar and wind energy, which become increasingly competitive with new-build coal and gas generation on a levelised basis. In addition, new-build wind and solar start to compete with existing fossil plant in the later parts of the forecast period, when annualized all-in cost of these technologies match the running costs of coal and gas.

**Figure 5: Asia-Pacific LCOE based on, 2015-realised load factors, by technology, 2016-40 (\$/MWh, 2015-real)**



Source: Bloomberg New Energy Finance

**Figure 6: China solar PV and onshore wind LCOE vs. coal marginal cost of generation (\$/MWh, 2015 real)**

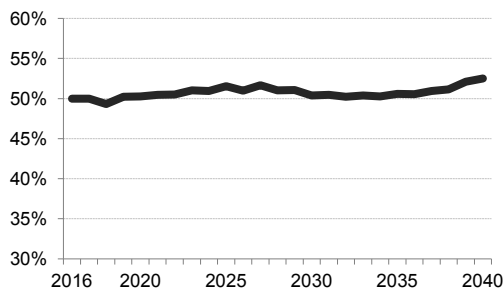


Source: Bloomberg New Energy Finance

## 2.5 Capacity factors

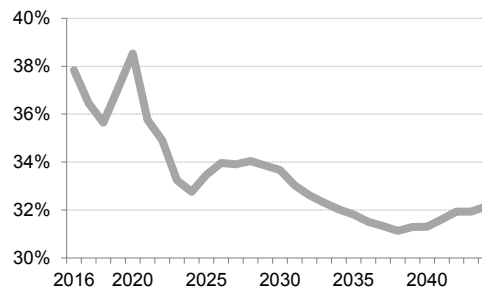
As the levelised cost of electricity (LCOE) for solar and wind technologies is expected to decline, the LCOE for coal and gas generation remains relatively stable, with gas increasing slightly in real terms. One reason for this is because of fuel and carbon prices (discussed below) rise over time, however also important are current low and declining capacity factors, as (near) zero short-run marginal cost renewables continue to eat into the running hours for coal and gas plants. This means traditional 'baseload' capacity becomes increasingly scarce.

**Figure 7: Coal global average capacity factor**



Source: Bloomberg New Energy Finance

**Figure 8: Gas global average capacity factor**

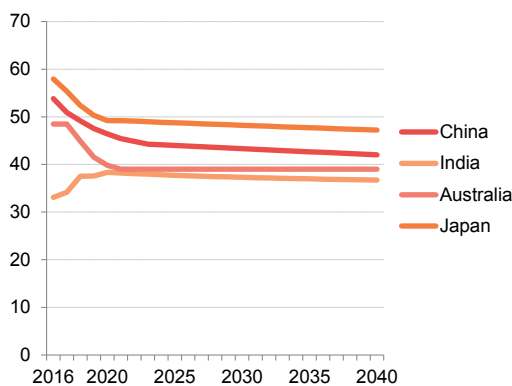


Source: Bloomberg New Energy Finance

## 2.6 Carbon and coal prices

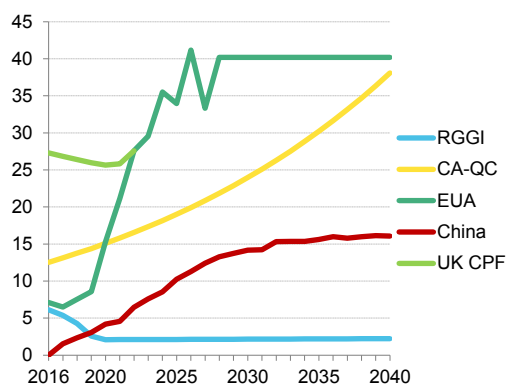
The forecast assumes thermal coal prices in the APAC region converge within a range of \$40-50/t (6,000kcal/kg) in real terms by 2020 and remain flat to 2040 in line with the expected marginal cost of production in each country. In addition to the price of fossil fuels, the NEO analysis assumes that fossil generators in several regions pay a price for their carbon emissions. The only country in the APAC region assumed to have a carbon price is China, where levels increase gradually to around \$15/t in real terms by 2030. This is below the expected CO<sub>2</sub> price in Europe and California, where prices rise to around \$40/t in real terms by 2040.

**Figure 9: Asia-Pacific coal price assumptions (\$/t, 2015-real)**



Source: Bloomberg New Energy Finance

**Figure 10: Carbon price assumption by region (\$/t, 2015-real)**

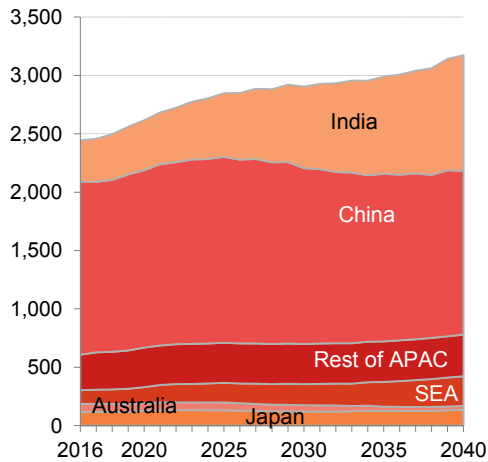


Source: Bloomberg New Energy Finance

## 2.7 Coal Demand

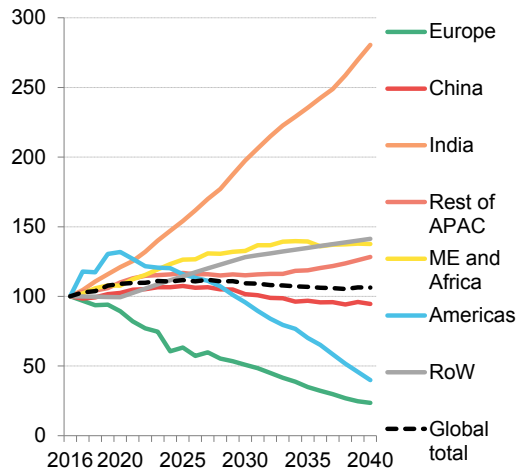
Power sector coal demand across the APAC region increases over the next 25 years, but on a country level that growth varies significantly. India sees the bulk of the growth with consumption expected to almost treble by 2040. Demand from China peaks and then declines, with moderate growth across the rest of the region.

**Figure 11: Projected power sector thermal coal consumption for APAC region (Mt/yr)**



Source: Bloomberg New Energy Finance

**Figure 12: Projected power sector thermal coal consumption by region, rebased to 100**



Source: Bloomberg New Energy Finance

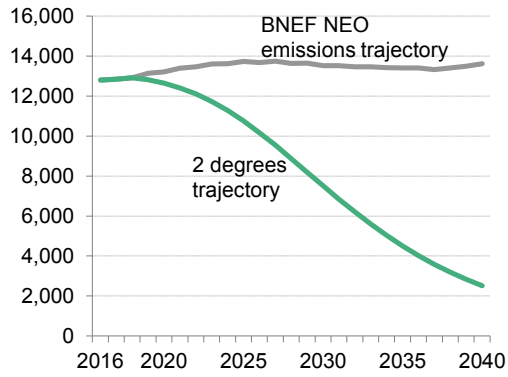
## 2.8 Carbon budget

Continued growth in coal consumption across the Asia-Pacific region, and in particular India, means power sector greenhouse gas emissions rise all the way to 2040. The 'carbon budget' for the power sector calculated by the IPCC dictates that total global power sector emissions must fall to around 2,000Mt CO<sub>2</sub>eq per year by 2040. However, based on the economics of competing energy technologies, the NEO forecast sees power sector emissions at around 14,000Mt CO<sub>2</sub>eq in 2040, completely blowing the power sector carbon budget.

Specifically for Asia, the chart below compares the NEO coal consumption forecast for China, India and South-East Asia, with the IEA's 450 scenario (i.e., consistent with a 2°C pathway, which does include some CCS as discussed in Section 3) for non-OECD Asia power sector coal consumption.<sup>32</sup> The difference between the two trajectories is stark, and reinforces the view that current expectations for thermal coal consumption are incompatible with a 2°C world.

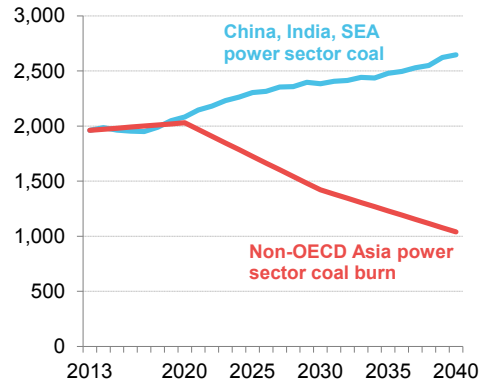
<sup>32</sup> The IEA's 450 scenario is not directly comparable with BNEF's NEO forecast as a number of underlying assumptions around available technologies, such as CCS, differ in the IEA's analysis. The countries included in the IEA's regional aggregation are also greater than just China, India and SEA, but the overall trend shown in is correct.

**Figure 13: NEO global power sector emissions projection vs. indicative 2°C trajectory (Mt CO<sub>2</sub>e/yr.)**



Source: Bloomberg New Energy Finance

**Figure 14: NEO projection for coal consumption across China, India and SEA vs. IEA's 450 scenario for non-OECD Asia power sector coal burn (Mt/yr.)**



Source: Bloomberg New Energy Finance, IEA

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## Section 3: Looking at the 2°C carbon budget and the role CCS is expected to play.

### 3.1. Summary

The IEA carbon budget interpolated from the 2016 ETP for both the Chinese and Indian power sectors calls for a near complete decarbonization by 2050, with an accelerating profile for reductions from 2030 onwards. IEA scenarios for achieving this decarbonization include significant amounts of carbon capture and storage (CCS) technology retrofitted to existing power plants. The IEA assumes that 2.8 GtCO<sub>2</sub> of cumulative emissions come from CCS plants up to 2050. That would rise to 21GtCO<sub>2</sub>, if these were all USC plants not eventually retrofitted with CCS.

For CCS to have any chance of success, there must be government-led strategies. These would first assess and develop storage potential. Second, they would price and fund transport networks based on the location of heavy industry and power. And third, they would subsidize actual projects. There is no evidence of this at present. Governments must lay out real policies targeting real opportunities.

The positive case for Chinese coal is laid out by an IEA paper<sup>33</sup> which cites 310GW of plants that could potentially be retrofitted. Nevertheless, trusting CCS before it is proven at scale is risky: the Chinese government first needs to lay out a comprehensive plan, for instance. It is important therefore also to move ahead with already proven and scaled zero carbon options, where these exist at a price at least as competitive as CCS. This opportunity indeed exists in the power sector, unlike in the cement and steel industries, where CCS has little alternative.

The output of Integrated Assessment Models can be counterproductive in this CCS policy context, as some models assume that without CCS the power sector simply cannot be decarbonized. We believe this is a dangerous outcome, and that it is more productive instead to analyze how decarbonization can be achieved. The falling relative cost of renewable energy shows one emerging, viable alternative. Similarly, scaling energy storage in a flexible smart grid is important, and starting to emerge. These issues are looked at in a policy context in Section 5.

We note that the question of “equity” in carbon budgets is receiving more attention<sup>34</sup>. India particularly is concerned that carbon budgets are set too low for their development needs. The implications are that either the OECD reduces its carbon budget further, or financing flows are used to further help the ramp up of low carbon energy

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<sup>33</sup> Ready for CCS retrofit: The potential for equipping China’s existing coal fleet with carbon capture and storage.

<sup>34</sup> <https://climateequityreference.org>



### **3.2. Carbon Capture and Storage (CCS) plays a crucial and often controversial role in 2°C scenarios where the power sector is decarbonized by 2050.**

- In the push towards a decarbonized power sector, IEA scenarios assume significant amounts of CCS in the power sector and Industrial sector. We will explore IEA assumptions in this section with specific reference to thermal coal in Asia.
- It is important to understand how CCS affects the Integrated Assessment Models (IAM) used to determining 2°C pathways.
- IAMs such as those used by the IEA use assumptions about relative costs of and availability of different low carbon technologies. In particular, if the model does not contain the option of large amounts of low carbon outcomes (renewables, nuclear) in the power sector, then without CCS the power sector fails to deliver very sharp reductions in emissions and can lead to results where other sectors in the economy are forced into very severe emissions reductions. It is noteworthy the IEA already assumes 40% of all emission reductions come from efficiency measures.
- Therefore, varying assumptions about CCS deployment is all about the viability of what can replace it at what cost to reach 2°C, even when the very viability of CCS is in question. Indeed, as discussed in Section 5, the political economy is just as central to any solution in terms of incumbents and power structures.
- CCS has a long way to go before reaching any scale at a reasonable cost could be assumed. It would seem very reasonable to look for 2°C scenarios without much, if any, CCS assumed at least in the power sector where alternatives are available and continue to evolve and can still lead to deep reductions, if not total elimination of emissions, by 2050. As time goes on it would seem reasonable to expect CCS estimates in models to fall unless action emerges.
- In the end, a combination of CCS where it is most relevant, and indeed demonstrated first alongside renewable scale up, seems the most efficient way.

These issues are briefly examined through the lens of the Martin School paper and then more thoroughly through the analysis of the IEA assumptions.

### **3.3. The Oxford Martin School – 2°C capital stock reached by 2017 – the role of CCS in Integrated Assessment Models**

The Oxford Martin School<sup>35</sup> paper (cite) illustrates the complexity of CCS assumptions in their paper “The ‘2°C capital stock’ for electricity generation: Committed cumulative carbon emissions from the electricity generation sector and the transition to a green economy “ . It is based on extensive analysis of possible outcomes using the >1000 different scenarios of the several hundred IAMs and configurations used for the IPCC Assessment Reports. Because of the way these models work they end up with the following conundrum: that assuming CCS works, the power sector should not build any unabated fossil-fueled electricity generation capacity after 2017 (consistent with the findings of much of this paper). But if it doesn’t work, there are models and scenarios that allow for additions to the polluting generation

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<sup>35</sup> <http://www.oxfordmartin.ox.ac.uk/publications/view/2119>

capital stock until 2029 before they stop building new plants and still stay below 2°C warming by the end of this century helped by negative emissions assumptions:

*'This paper shows that even under the very optimistic assumption that other sectors reduce emissions in line with a 2°C target, no new emitting electricity infrastructure can be built after 2017 for this target to be met, unless other electricity infrastructure is retired early or retrofitted with CCS.*

*... IPCC scenarios that assume more carbon capture tend to involve greater near-term emissions (precisely because the capture technologies operate in the future). This implies a lower available near-term power sector budgets, which moves the date of the 2°C capital stock (with assumed CCS in the future) earlier in time. Carbon capture deployment is particularly prevalent in the 430-530-ppm groupings.*

*In scenarios in which no CCS is deployed new power plants must be net zero several years later (2019-2029). This is explained by the fact that a 430-530-ppm consistent pathway without CCS (which primarily affects the electricity sector) requires stronger and faster decarbonisation in the non-power sectors. As a consequence, there is a larger share of cumulative carbon budget available for the power sector, which hence has more time before reaching the 2°C capital stock.*

*Scenarios that assume that most of the electricity sector emissions will be captured in later decades of the century allow for a slower decarbonisation of other sectors and hence leave less generation budget to the electricity sector today. '*

In some models this leads to a conclusion that if CCS is unavailable, the power sector gets a larger share of the carbon budget and can keep building stations without CCS until 2029. In effect, as we draw out below and in Appendix 3, this is a result of the structure of the model that forces the conclusions in this direction. Other models could look for a different pathway and, as explored in Section 5, policy could further intervene.

In terms of options, The Oxford Martin School sets out the following:

*'Our findings raise several fundamental questions ... but they also raise immediate and significant implications for the electricity sector. Logically, achieving the necessary transformation of the global power sector is going to require some combination of the following four options:*

- 1) new power assets are 100% zero carbon as soon as possible;*
- 2) existing fossil assets are retrofitted with carbon capture;*
- 3) existing fossil assets are stranded early, replaced by zero carbon assets; and*
- 4) CDR (CCS with Biomass) technologies are used to hold temperatures below 2°C.*

*The most cost-effective combination of these four options will depend strongly upon the rates of decline in the costs of the relevant technologies, including nuclear, renewables including hydro, carbon capture, associated grid balancing technologies (including storage) and negative emission technologies... ’*

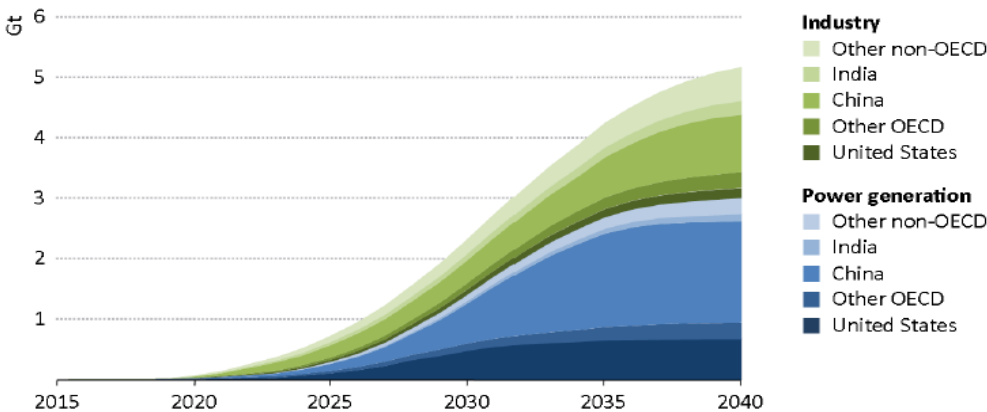
These issues are further set out by the IPCC methodology explanation in Appendix 3.

Exploring deep decarbonization options that look to scaling up renewables with storage in a smart grid is a viable, more realistic approach to IAM modeling.

### 3.4. CCS in IEA 2°C Carbon Budget

CCS plays a crucial role in IEA assumptions as shown in the 2016 ETP:

Figure 34 CO<sub>2</sub> captured in the 450 Scenario by sector and region



Note: Includes capture of CO<sub>2</sub> emissions from metallurgical coal. Industry includes the following sectors: steel, cement (energy- and process-related), chemicals and paper production; oil refining; coal-to-liquids, gas-to-liquids and natural gas processing. Source: IEA, *World Energy Outlook Special Report: Energy and Climate Change*, Figure 4.4

We now look to show Asian coal specifically in IEA CCS assumptions in the context of an overall carbon budget for thermal coal.

### 3.5. Driving a carbon budget for China and India thermal coal from the IEA<sup>36</sup>

#### Carbon budget methodology

The carbon budget for coal power in China, and India is determined from publicly-available model outputs from the IEA's Energy Technology Perspectives (ETP) 2°C scenario (2DS). The ETP model outputs

<sup>36</sup> Analysis by ETA/CTI

provide the fuel input for coal power and heat generation in PJ, gross electricity capacity from coal in GW and gross electricity generation from coal in TWh. The heat rate is determined by dividing BTU by kWh. We assume a BTU content per kWh of 3,412<sup>37</sup>. We assume a coal content of 95 kt/PJ and a carbon capture and storage (CCS) rate of 85% (i.e., 15% of emissions from CCS-equipped plants is released into the atmosphere)<sup>38</sup>. Linear interpolations are used where no annual data is provided.

### **Interpolated Carbon Budget From The IEA 2016 ETP**

<b>2 Degree Carbon Budget: Thermal Coal Only (MtCO<sub>2</sub>)</b>											
Country	Technology	2013	2015	2020	2025	2030	2035	2040	2045	2050	2015-2050
China	Unabated	4,188	4,149	4,050	3,748	3,007	1,786	518	14	0	<b>78,061</b>
China	Abated	0	0	0	7	32	62	113	158	144	<b>2,293</b>
China	Total	4,188	4,149	4,050	3,755	3,039	1,849	631	172	144	<b>80,356</b>
India	Unabated	887	1,014	1,330	1,319	1,244	769	147	1	1	<b>27,097</b>
India	Abated	0	0	0	1	6	16	23	34	45	<b>532</b>
India	Total	887	1,014	1,330	1,320	1,250	785	170	35	46	<b>27,630</b>
China + India	Unabated	5,075	5,460	5,380	5,067	4,251	2,555	665	15	1	<b>105,158</b>
China + India	Abated	0	0	0	8	38	78	136	192	189	<b>2,825</b>
China + India	Total	5,075	5,460	5,380	5,075	4,289	2,633	801	207	190	<b>107,983</b>

Source IEA ETP 2016/CTI/ETA Analysis

### **3.5.1 Potential emissions from coal plants should CCS technology fail to be retrofitted onto coal plants**

The IEA 2DS projects that 2.8GtCO<sub>2</sub> of cumulative emissions will be emitted from coal plants equipped with CCS by 2050 in China and India. While the IEA does not explicitly state its projections on the number of plants retrofitted with CCS compared to the number of plants that are built with CCS, it is certain that at least some of these emissions will be from coal plants retrofitted with CCS. If these plants are not retrofitted with CCS, the resultant cumulative emissions are substantial.

Given that a coal plant equipped with CCS is estimated to have an emissions factor of about 100 gCO<sub>2</sub>/kWh<sup>39</sup> and the most efficient coal plant type (USC) has an emissions factor of about 740 gCO<sub>2</sub>/kWh, the emissions of any plant that is not retrofitted with CCS is at least a factor of 7.4 higher than the emissions level with CCS. Applying this factor to the IEA's 2DS projection for cumulative emissions from CCS equipped plants to 2050 implies that there is a risk that up to 21GtCO<sub>2</sub> of emissions

<sup>37</sup> From US EIA. Available: <http://www.eia.gov/tools/faqs/faq.cfm?id=107&t=3>

<sup>38</sup> Both based on IEA ETP assumptions. For more information: <https://www.iea.org/etp/etpmodel/assumptions/>

<sup>39</sup> The IPCC states that the emissions intensity of a new pulverised coal plant equipped with CCS is between 92–145 gCO<sub>2</sub>/kWh, with a representative value of 112 gCO<sub>2</sub>/kWh, while the emissions intensity of a new IGCC plant is between 65–152 gCO<sub>2</sub>/kWh, with a representative value of 108 gCO<sub>2</sub>/kWh. Considering these representative values, this study assumes an emissions intensity of 100 gCO<sub>2</sub>/kWh. Source: Intergovernmental Panel on Climate Change, 2005, *IPCC Special Report on Carbon Dioxide Capture and Storage*.

could be generated if CCS technology is not successfully retrofitted onto coal plants. This figure represents 20% of the total carbon budget to 2050 for coal-fired plants in China and India.

### 3.6. Assessing CCS - What is the risk?

Firstly the positive case for CCS is set out by the IEA and Asian Development Bank

#### 3.6.1. OECD/IEA 2016 Ready for CCS retrofit (prepared in conjunction with the Chinese Energy Council)<sup>40</sup>. The potential for equipping China's existing coal fleet with carbon capture and storage

*'Executive summary*

*Retrofitting carbon capture and storage (CCS) on existing coal-fired power stations in People's Republic of China (hereafter referred to as 'China') represents a major opportunity, with significant benefits for emission reductions. In total, some 310 gigawatts (GW) of existing coal-fired power capacity meet a number of basic criteria for being suitable for a retrofit. This number is likely to increase, as new efficient plants are being commissioned during the next several years. Regardless of how much retrofitting will finally be required in a low-emissions pathway, this analysis indicates that there is ample potential available....*

*The costs of retrofitting are likely to vary significantly: the additional costs of power generation after retrofitting are estimated to vary between \$34 and 129 (United States dollars)/MWh. Some 100GW of existing capacity are estimated to generate additional power generation costs of less than \$50/MWh, indicating that a significant retrofit opportunity exists within a reasonable cost range.....*

*Retrofitting can represent a significant opportunity for emission reductions in China, but it will require establishing the right drivers. This has several implications for strategy and policy in the Chinese context. Three particular areas merit further work and policy consideration from the Chinese government and industry:*

- *Including CCS in Chinese climate policy, or retaining the option of future CCS retrofits, makes it imperative to continue work to analyse CO<sub>2</sub> storage opportunities and to develop actual project-level storage sites.*
- *Government and industry should continue their efforts in technology innovation and cost reduction, to further bring down costs of CCS in general and retrofitting in particular.*
- *Finally, given ongoing permitting of new coal-fired power stations, promoting CCS-readiness of new power stations can be an effective tool. Advancing CCS-readiness merits further attention by Chinese policy-makers in order to ensure that future retrofitting opportunities are maximised. In this regard, attention to the location of new plants is likely to be of particular importance.*

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<sup>40</sup> <https://www.iea.org/publications/insights/insightpublications/ready-for-ccs-retrofit-.html>

Further, the Asian Development Bank also looked at the potential for CCS in the [Roadmap for Carbon Capture and Storage Demonstration and Deployment in the People's Republic of China](#)<sup>41</sup>

*CCS demonstration and deployment is essential for cost-effective climate change mitigation;*

*The PRC can benefit from international experiences;*

*Unique low-cost CCS demonstration opportunities exist in the PRC;*

*CCS demonstration faces formidable challenges in the absence of targeted support;*

*Current low oil prices may have temporarily reduced incentives for CO<sub>2</sub>; and*

*A phased approach to CCS demonstration and deployment is needed.*

What emerges from this is:

1. The logistical challenge for transport and storage. It seems very likely that governments will need to plan and implement and potentially fund the development of the infrastructure needed for CCS.
2. The cost range showing wide uncertainties and significant costs.

Further discussion on the issues holding back widespread deployment of CCS is found below.

### **3.6.2 Carbon pricing levels will not be sufficient unless escalate dramatically**<sup>42</sup>

To make CCS attractive, investors will need sufficient assurance of financial returns. Carbon pricing supports the financial case for CCS, especially if there is a long-term price signal.

In the jurisdictions considered in this paper (China and India) carbon pricing has been implemented to a limited extent, with the seven pilot emissions trading systems (ETSs) in China. These ETSs price carbon between \$1-6/tCO<sub>2</sub>, with a weighted average price of \$3/tCO<sub>2</sub>.<sup>43</sup>

In contrast to this relatively modest carbon price, the IEA World Energy Outlook 2015 450 Scenario assumes carbon prices of \$10/tCO<sub>2</sub>, \$75/tCO<sub>2</sub> and \$125/tCO<sub>2</sub> in 2020, 2030 and 2040 respectively. The IEA's WEO 450S and ETP 2DS scenarios are, generally speaking, consistent, and we therefore assume

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<sup>41</sup> <https://www.adb.org/publications/roadmap-carbon-capture-and-storage-demonstration-and-deployment-prc>

<sup>42</sup> Analysis from ETA/Ecofys

<sup>43</sup> Source: World Bank and Ecofys, 2016, *Carbon Pricing Watch*.

<http://documents.worldbank.org/curated/en/418161467996715909/Carbon-pricing-watch-2016-an-advance-brief-from-the-state-and-trends-of-carbon-pricing-2016-report-to-be-released-late-2016>

that the carbon price level of both scenarios are identical. These price levels can be viewed as the carbon prices needed to support the CCS deployment rates that have been projected by the IEA.

In order for the current weighted average carbon price in China to reach the levels assumed by the IEA, the compound annual growth rates (CAGR) are 37%, 22% and 5% for the periods from 2016 to 2020, between 2020–2030 and 2030–2040 respectively. Such sustained annual growth rates in carbon prices, particularly from 2016–2030 have not been witnessed and are rarely seen in other types of markets. Without increased urgency in reducing GHG emissions, it is unlikely that carbon prices will increase to the levels needed to support the CCS deployment rates projected by the IEA.

### Recent Carbon Prices

Name	US\$/tCO <sub>2</sub>
Alberta SGER	15
Québec CaT	13
Switzerland ETS	9
Beijing pilot ETS	6
Chongqing pilot ETS	2
Guangdong pilot ETS	2
Hubei pilot ETS	4
Shanghai pilot ETS	1
Shenzhen pilot ETS	6
Tianjin pilot ETS	4
EU ETS	6
Saitama ETS	31
Tokyo CaT	31
Korea ETS	16
Kazakhstan ETS	0
New Zealand ETS	8
RGGI	6
California CaT	13
BC carbon tax	23
Switzerland carbon tax	9
Denmark carbon tax	26
Estonia carbon tax	2
Finland carbon tax (Liquid fuels)	66
Finland carbon tax (Other fossil fuels)	62
France carbon tax	25
Ireland carbon tax	23
Iceland carbon tax	9
Japan carbon tax	3
Latvia carbon tax	4
Mexico carbon tax (Upper)	3
Mexico carbon tax (Lower)	0.3
Norway carbon tax (Upper)	53
Norway carbon tax (Lower)	4
Poland carbon tax	0.1
Portugal carbon tax	8
Sweden carbon tax	137
Slovenia carbon tax	20
UK carbon price floor	26



### 3.6.2.1 Other arguments on CCS

- While the technologies needed to separate, capture, transport and store CO<sub>2</sub> may be viable separately, it is important to demonstrate that these technologies can be integrated on a commercial scale.
  - There is only one large-scale CCS power plant in operation (Boundary dam), which started in 2014. While the plant has a capture capacity of up to 1 MtCO<sub>2</sub>/year, in the first year of operation, the plant has only captured about 40% of its capacity. This has been attributed to lower than expected load hours due to mechanical issues<sup>44</sup>.
  - In China, there are 4 large-scale CCS projects for coal-fired power stations that are in the planning phase, but the final investment decisions have not yet been taken<sup>45</sup>.
  - No large-scale plants have been proposed for India or other ASEAN countries.
- Experts expect that it is unlikely that CCS will be commercially available in China before 2030 due to the low carbon pricing level, delayed demonstration projects and a lack of public acceptance in potential storage regions<sup>46</sup>. It is likely that for India, commercial availability will come even later than 2030, as there are no plans to build coal plants equipped with CCS or retrofit CCS to coal plants in these countries.
- However, by 2030, the IEA ETP 2DS projects that in China and India, 44 MtCO<sub>2</sub> will be emitted by coal plants equipped with CCS (meaning that emissions of at least a factor of 6.4<sup>47</sup> times this amount or 240 MtCO<sub>2</sub> are being captured annually).
  - In contrast, the total annual capture capacity of the 4 plants that are in the planning phase in China is 6 MtCO<sub>2</sub>. Assuming that these CCS plants all come online by 2020 as indicated by the CCS Institute, to reach the levels of CO<sub>2</sub> capture by coal plants equipped with CCS assumed by the IEA under the 2DS, a CAGR of almost 45% is required.
- Furthermore, considering the thought exercise scenarios presented in the next section on the resultant emissions from all existing and those under construction operating under a BAU scenario (50% load factor) the cumulative carbon budget for emissions from coal fired power plants in China and India is exceeded from 2022 onwards. This means that from 2022 onwards, to remain on the trajectory to limit warming to 2°C, emissions from coal fired power stations will need to be curbed either through retiring coal plants or applying CCS.
  - By 2030, the cumulative carbon budget is exceeded by 2 GtCO<sub>2</sub>
  - By 2040, the cumulative carbon budget is exceeded by 21 GtCO<sub>2</sub>
  - By 2050, the cumulative carbon budget is exceeded by 53 GtCO<sub>2</sub>
  - An even larger CAGR of CCS will be required to constrain emissions from coal-fired power plants under these BAU scenarios.

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<sup>44</sup> <http://www.powermag.com/saskpower-admits-to-problems-at-first-full-scale-carbon-capture-project-at-boundary-dam-plant/> and <http://www.globalccsinstitute.com/projects/boundary-dam-carbon-capture-and-storage-project>

<sup>45</sup> <http://www.globalccsinstitute.com/projects/large-scale-ccs-projects>

<sup>46</sup> Source: Viebahn, P., Vallentin, D., Holler, S. (2015) Prospects of carbon capture and storage (CCS) in China's power sector – an integrated assessment, *Applied Energy* 157 (2015) 229 – 244.

<sup>47</sup> The emissions factor for CCS is about 100g CO<sub>2</sub>/kWh while the emissions factor for USC (the most efficient plant) is about 740g CO<sub>2</sub>/kWh. This means that at least 640g CO<sub>2</sub>/kWh is captured or 6.4\* emissions from CCS plants.



Having noted all this, it is still possible for governments with industry to move ahead in the most promising regions and applications to roll out CCS properly planned. But it needs to get into development soon to be believable and take the risk out of expecting it 'one day'.

**Indeed, in terms of risk management, it would be much lower risk for governments to seriously launch and begin to implement CCS strategies before they are assumed to be available for a 2°C transition. Rather, it would be lower risk to push harder for available and proven zero carbon power sector options (CCS will be needed in the Industrial sector certainly as there are no alternatives there). Crucially, for reliability considerations, a smart flexible grid with energy storage will be a key requisite, but many of the required technologies are known and demonstrated at present.**

### **3.6.3 Cost competitive and low carbon options are here now.**

Wind, solar and nuclear are all proven at scale. This issue is cost as outlined in Section 2 by BNEF

A recent study by Carbon Tracker looked at trends in costs:

*End of the load for coal and gas?, compares the power-generation costs of four new-build coal, gas, wind and solar plants. The paper applies a Levelized Cost of Electricity (LCOE)<sup>48</sup> sensitivity analysis across three scenarios: the 2016 reference case scenario, an updated 2016 scenario and a 2020 2°C pathway setting, where investment decisions take into account decarbonisation trends.*

*The LCOE study shows that reduced load factors and shorter lifetimes for coal and gas plants in a world that is decarbonizing steadily, significantly undermine plant economics. Few models to date have factored in this kind of dynamic when calculating future LCOE. Meanwhile, the combination of lower cost capital with cheaper technology for solar and wind improves the relative competitive position of renewables.*

*"This analysis explains why renewables are already the cheapest option in a number of markets. This trend is only likely to spread as the growth of renewables undermines the economics of fossil fuels," said Paul Dowling co-author of the report.*

*The analysis compares the technical specifications of coal and gas plants with what is being achieved on average in plants currently operating and then with projects that may occur in 2020 and beyond. For example, typical plant utilisation rates used by industry in reference case scenarios are around 80% for coal and 60% for gas. But we know from available 2013 data that global average plant capacity factors were much lower at 59% and 38% respectively thereby making the plants less competitive than had been thought.*

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<sup>48</sup> The levelized cost of electricity is a way to compare different methods of electricity generation using average total cost to build and operate a power plant divided by its total lifetime energy output

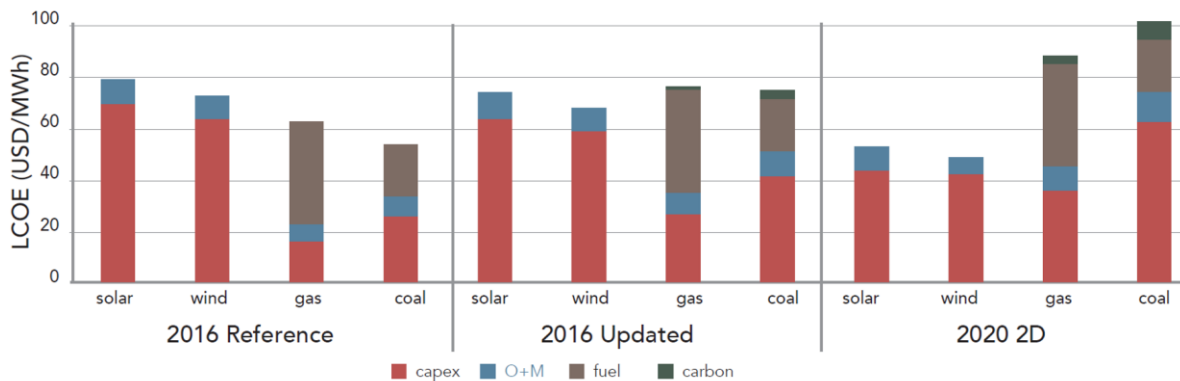
By 2020 falling utilization rates under a 2°C scenario finds plant capacity factors for coal and gas drop to an average of 42% for coal and 31% for gas, thereby leading to an increase in costs of \$8/MWh for gas plants and \$21/MWh for coal. By contrast, if solar and wind could deliver capacity factors of 20% and 40% respectively, they would cut their LCOEs by \$6/MWh for solar and \$17/MWh for wind.

Who is developing renewable power plants is an important factor to consider – developers and management funds with lower costs of capital are entering the market, bringing down LCOEs for more capital-intensive renewables. Factoring in the higher deployment of renewables and learning curves for technologies indicated by Bloomberg New Energy Finance further reduces the capital costs of clean power plants.

The study finds that the direction of travel forged by the implementation of Nationally Determined Contributions post-2020 will see renewables on average more cost-competitive even if fossil fuel prices fall and carbon prices are modest at around \$10/t CO<sub>2</sub> or lower.

The chart below shows the transition of relative average global costs from 2016 reference numbers through updated 2016 operational indicators to a post-2020 low carbon world.

### Comparison of LCOE Results Across All Scenarios



Source: CTI Analysis

“Markets are having to deal with integrating variable renewables on a growing scale. Rather than continue debating whether this energy transition is already occurring, it is time to focus on developing the opportunities in energy storage and demand management that can smooth the process,” said senior analyst and co-author Matt Gray.

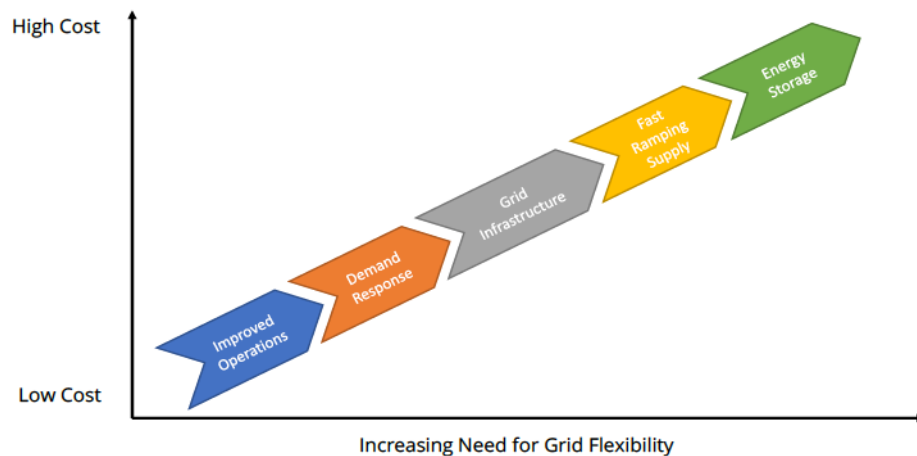
The report and release can be found here <http://www.carbontracker.org/report/the-end-of-the-load-for-coal-and-gas/>

### 3.6.3.1 Ancillary service costs – the key?

One thing of note is that LCOEs do not directly show 'ancillary' costs. These for renewables could be the smart flexible grid with storage, and for fossil fuels CCS might start to fall into that category. Given LCOEs for the underlying projects look to favor renewables, then much in pure cost terms might come down to the cost of CCS vs. the flexible smart grid!

Indeed, there has been much work done on the 'flexibility' of systems and how they can be more easily adapted at fairly low cost to increasing renewables. Energy Innovation published a paper *GRID FLEXIBILITY: METHODS FOR MODERNIZING THE POWER GRID* by Sonia Aggarwal and Robbie Orvis, MARCH 2016<sup>49</sup> that outlines the following approaches:

Figure 1: Flexibility Resource Supply Curve<sup>5</sup>



<sup>5</sup> Graphic adapted from: Paul Denholm et al., "The Role of Energy Storage with Renewable Electricity Generation" (National Renewable Energy Laboratory, January 2010).

At some point storage is going to be important to help address intermittency. That might be after 25-30% renewable penetration or higher in systems with far more variable resources. It is possible fossil fuel fleets – gas and even coal – could play a role in this. More importantly, energy storage solutions need to scale up and costs fall dramatically.

Energy storage looks like solar PV 20 years ago – just emerging and starting to scale. It was government incentives to drive scale, plus a massive push from the Chinese manufacturing sector that caused a huge and ongoing fall in costs. As discussed in Section 5, this is a pathway that could readily apply to storage, potentially at lower cost than CCS.

<sup>49</sup> <http://energyinnovation.org/wp-content/uploads/2016/05/Grid-Flexibility-report.pdf>

## Section 4. Asian thermal coal plants and emissions: High Efficiency Low Emission plants (HELE) cannot meet 2°C

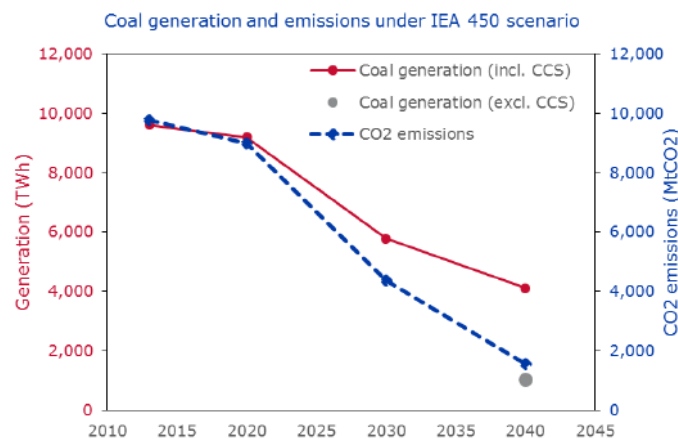
As already discussed in Section 1, power plants are the key source of demand for thermal coal and are hence a lead indicator of demand in terms of those under development and planned. This section looks at raw data for planned thermal coal power stations, as compiled in CoalSwarm’s Global Coal Power Plant Tracker, found at EndCoal.org and relates potential outcomes to the IEA carbon budget outlined in section 3.

To set the scene, CoalSwarm’s Global Coal Plant Tracker states in its most recent global study, increasing the number of coal-fired power plants could undermine the global goal to cap temperature increases since pre-industrial times to 2°C

*‘Even with no further building of coal plants, emissions from current coal plants will still be 150 percent higher than what is consistent with scenarios limiting warming to 2 degrees Celsius -- meaning that most operating and new coal-fired plants will have to be phased out well before the end of their planned lifetime,’ it said.*

Ecofys has used this analysis as a basis for looking at the impact of High Efficiency Low Emission (HELE) coal stations on global carbon budgets in April 2016.

***‘This report shows that HELE coal-fired electricity generation is incompatible with the goal to keep temperature rise under 2°C. The global carbon budget and the time remaining to reduce greenhouse gas emissions simply do not allow for replacement of retired coal plants with new more efficient coal plants, let alone capacity extensions. The 1,400GW of currently planned coal capacity is not compatible with limiting warming to 2°C; if all planned capacity were HELE coal-fired electricity generation plants, the 2°C goal would still not be within reach.’***



**Figure 4** Unabated coal-fired electricity generation (grey marker), coal electricity generation including CCS (red line) and CO<sub>2</sub> emissions (blue line) under the IEA 450 scenario<sup>18</sup>, which includes plants fitted with CCS.

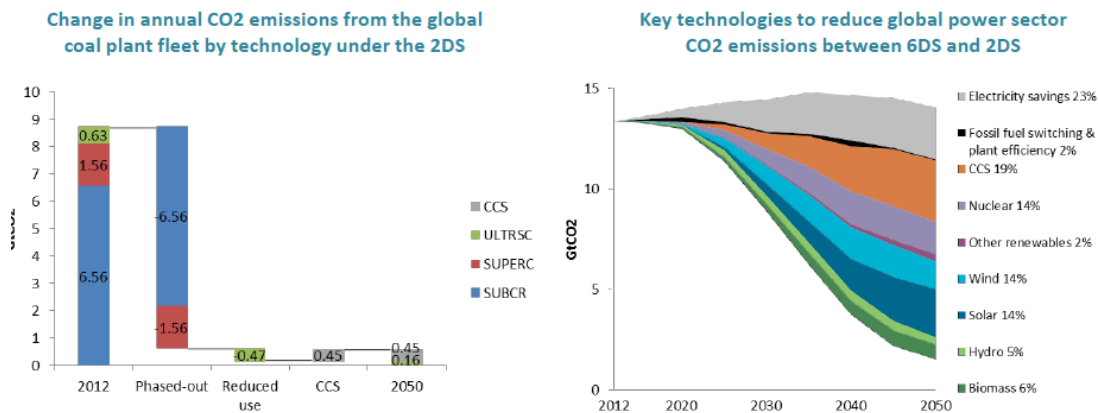
*In summary, the assumptions that are explicitly stated or can be inferred from the WEO are reasonable and consistent with the definition of the 450S. While little insights can be gained on the deployment of HELE, it is clear that CCS- rather than HELE-technology is critical for the power sector in order to constrain warming to 2°C in the IEA 450 scenario.'*

Further, IEA analysis has shown that to meet the 2DS, coal power can only be used if it is equipped with CCS.

## The long-term role of unabated efficient coal plants



### Efficiency gains cannot come at the expense of 'lock-in'



Source: ETP 2015

***While efficient plants offer potential to make significant emissions reductions, over the long term only the addition of CCS – combined with a phase-out of inefficient plants – can deliver the cuts needed for a 2 degree pathway***

#### 4.1. Deepening the analysis to focus on thermal coal in China and India

##### 4.1.1. Summary

There are presently some 1020 planned new thermal coal plants in China and India, whether pre-permitted, permitted or already under construction, corresponding to 566GW of potential capacity. Of this total, some 521 plants are under construction, with 270GW of capacity. China dominates, with 389 plants and 205GW under construction. India is presently building 132 plants, with 65GW capacity<sup>50</sup>.

Our analysis uses these growth forecasts, and applies accepted emissions intensities and assumes a load factor of 50%, which is above China's recent 46%, but below BNEF's forecast rate in India. We add

<sup>50</sup> Data is based on CoalSwarm, [www.EndCoal.org](http://www.EndCoal.org)

existing emissions, and a Business As Usual retirement schedule in China (18GW pa rising to 20GW), and compare the resulting emissions growth with China and India's annual and cumulative carbon budgets, interpolated from the IEA ETP 2016.

China dominates the overshoot. We make some generous assumptions: only plants under construction proceed; retirements run at 18GWpa of the subcritical fleet each year up to 2040, then 20GWpa of supercritical are retired up to 2050; and all remaining subcritical plants are converted to USC by 2040. Nevertheless, the annual budget is exceeded in China by 2019 when emissions are still running at around 4.6 GtCO<sub>2</sub> a year. Looking at the cumulative budget each year, then that also is exceeded by 2019. The total carbon budget of 80 GtCO<sub>2</sub> is exceeded by 2036. This clearly points to the need for even faster retirements and/ or lower load factors of subcritical and eventually supercritical plants.

In India, the annual carbon budget rises until 2020 when it starts to decline. If we were to assume that only those power plants under construction today proceeded, and that all subcritical were replaced by USC, then the carbon budget could last until the 2030s, but by the end of that decade would be exhausted. But that's with no new plants agreed after the current. However, India has suggested that OECD countries should bear a larger burden of the carbon budget from an equity stand point, given OECD historical emissions and India's need to grow.

**So even using the most efficient power plants and replacing older ones with those over time does not meet the carbon budget.**

#### 4.1.2 Key Assumptions

The carbon budget was outlined in Section 3. When looking at the impact of HELE power stations on the carbon budget, a starting point for existing emissions has to be established.

- CTI/ETA have taken the actual IEA carbon budget for 2015 which is based on interpolations from ETP data and we believe would be close to actual emissions in that year (2013 is the base used in ETP for emissions and the last year that actual sectorial emissions were published).
- We then have to make some assumptions about what we might call 'BAU' sub critical plant retirements. This is most relevant to China and we have concentrated on that profile. To start, we assume that from the existing plants, 82% of the coal generation is from subcritical plants and 18% is from supercritical plants according to Global Coal Plant Tracker. Obviously as a policy, retiring plants (or running down their load factors over time) and not replacing them is the key way to get to the 2°C pathway. But we want to start with a reasonable BAU baseline. The simple assumption Ecofys/ETA have taken in looking at HELE emissions is:
  - BAU Retirements China: sub critical 2015-39 18GW per annum
  - This is supported by Appendix 4.1 which looks at the age structure of Chinese coal plants.
- However, it is an important 'thought experiment' to see what happens if the existing subcritical power plants in China after BAU retirements are then 'converted' (retired and replaced) into USC plants. Can that save the carbon budget? We assume a smooth conversion 2021-2040 as



feasible. Beyond 2040, all sub-critical plants have been either retired or converted into USC plants. Retirements of the existing supercritical plant fleet are therefore assumed at a rate of 20GWpa over 2040 – 2050.

- Further it's important to break out from total planned power plants (pre-permitted, permitted and under construction) to focus on the under construction category on its own – cancelling 'the construction' category is hard, whereas 'all permitted' is easier to do.

#### **4.2 CoalSwarm Global Coal Plant Tracker (see Appendix 4.2 for methodology)**

The first place to start is with CoalSwarm's data on planned thermal coal plants. This incorporates estimates for recent announcements, particularly China's April 'moratorium' on permits.

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### Total: Pre-permit development, permitted and construction plants

All plant types	China	India	China + India
Number of plants	695	325	1,020
MW capacity	379,004	186,754	565,758
Total annual emissions (MtCO <sub>2</sub> )	1,341	674	2,015
TWh produced	1,660	818	2,478

Ultra Super Critical	China	India	China + India
Number of plants	217	2	219
MW capacity	178,464	1,320	179,784
Total annual emissions (MtCO <sub>2</sub> )	620	5	625
TWh produced	782	6	787

Super Critical	China	India	China + India
Number of plants	229	191	420
MW capacity	104,620	135,795	240,415
Total annual emissions (MtCO <sub>2</sub> )	375	488	864
TWh produced	458	595	1,053

Sub Critical	China	India	China + India
Number of plants	66	81	147
MW capacity	19,120	28,926	48,046
Total annual emissions (MtCO <sub>2</sub> )	70	106	176
TWh produced	84	127	210

Unknown	China	India	China + India
Number of plants	179	48	227
MW capacity	75,400	20,150	95,550
Total annual emissions (MtCO <sub>2</sub> )	273	73	346
TWh produced	330	88	419





## Construction

All plant types	China	India	China + India
Number of plants	389	132	521
MW capacity	205,144	64,669	269,813
Total annual emissions (MtCO <sub>2</sub> )	724	234	958
TWh produced	899	283	1,182

Ultra Super Critical	China	India	China + India
Number of plants	132	0	132
MW capacity	105,504	0	105,504
Total annual emissions (MtCO <sub>2</sub> )	366	0	366
TWh produced	462	0	462

Super Critical	China	India	China + India
Number of plants	144	66	210
MW capacity	63,180	44,865	108,045
Total annual emissions (MtCO <sub>2</sub> )	226	161	388
TWh produced	277	197	473

Sub Critical	China	India	China + India
Number of plants	39	53	92
MW capacity	9,960	16,061	26,021
Total annual emissions (MtCO <sub>2</sub> )	37	59	95
TWh produced	44	70	114

Unknown	China	India	China + India
Number of plants	72	10	82
MW capacity	25,900	3,180	29,080
Total annual emissions (MtCO <sub>2</sub> )	93	12	105
TWh produced	113	14	127



## Permitted

All plant types	China	India	China + India
Number of plants	48	73	121
MW capacity	26,340	43,700	70,040
Total annual emissions (MtCO <sub>2</sub> )	94	157	251
TWh produced	115	191	307

Ultra Super Critical	China	India	China + India
Number of plants	17	2	19
MW capacity	14,620	1,320	15,940
Total annual emissions (MtCO <sub>2</sub> )	51	5	55
TWh produced	64	6	70

Super Critical	China	India	China + India
Number of plants	10	50	60
MW capacity	3,460	33,920	37,380
Total annual emissions (MtCO <sub>2</sub> )	12	122	134
TWh produced	15	149	164

Sub Critical	China	India	China + India
Number of plants	9	11	20
MW capacity	2,860	3,955	6,815
Total annual emissions (MtCO <sub>2</sub> )	10	14	25
TWh produced	13	17	30

Unknown	China	India	China + India
Number of plants	12	10	22
MW capacity	5,400	4,505	9,905
Total annual emissions (MtCO <sub>2</sub> )	20	16	36
TWh produced	24	20	43



## Pre-permit development

All plant types	China	India	China + India
Number of plants	258	120	378
MW capacity	147,520	78,385	225,905
Total annual emissions (MtCO <sub>2</sub> )	523	283	806
TWh produced	646	343	989

Ultra Super Critical	China	India	China + India
Number of plants	68	0	68
MW capacity	58,340	0	58,340
Total annual emissions (MtCO <sub>2</sub> )	203	0	203
TWh produced	256	0	256

Super Critical	China	India	China + India
Number of plants	75	75	150
MW capacity	37,980	57,010	94,990
Total annual emissions (MtCO <sub>2</sub> )	137	205	342
TWh produced	166	250	416

Sub Critical	China	India	China + India
Number of plants	18	17	35
MW capacity	6,300	8,910	15,210
Total annual emissions (MtCO <sub>2</sub> )	23	33	56
TWh produced	28	39	67

Unknown	China	India	China + India
Number of plants	95	28	123
MW capacity	44,100	12,465	56,565
Total annual emissions (MtCO <sub>2</sub> )	160	45	205
TWh produced	193	55	248

### 4.3 Relating to the Carbon Budget<sup>51</sup>

The follow emissions' intensities are assumed in the scenarios considered below:<sup>52,53</sup>

- Subcritical coal plant: 880 gCO<sub>2</sub>/kWh
- Supercritical coal plant: 800 gCO<sub>2</sub>/kWh
- Ultra-supercritical coal plant: 740 gCO<sub>2</sub>/kWh

The emission intensities assumed for supercritical and ultra-supercritical plants provided by the IEA are at the lower end of the range. This assumption means that the emissions reductions achieved by replacement of sub-critical plants with USC plants are on the optimistic side.

A further key assumption is the capacity utilization or load factors. In this study, we assume that the plants are operating at a rate of 50%. Right now, China operates at 46%, according to IEEFA estimates cited in Section 1, and India would be at higher levels than 50%. But we have chosen the global average as set out by BNEF in Section 2 to illustrate in a realistic way a type of 'BAU' emissions profile. Arguably, this is conservative for India. BNEF have India up near 70%.

Retirements are also a crucial consideration, particularly in the huge Chinese fleet. In China, we consider two scenarios:

1. Retirement of 18GW of subcritical plants per annum starting in 2016.
2. Retirement of 18GW of subcritical plants per annum starting in 2016. From 2021, subcritical plants are retired at 18 GW per annum and the remainder of the subcritical capacity is assumed to be replaced by USC plants with a smooth trajectory to 2040. This means no sub critical fleet by 2039, after which we retire 20GW of Super Critical.

We assume all subcritical is replaced by USC in India.

In the table below we show three measures of the carbon budget

- 1) When annual emissions are exceeded
- 2) When Cumulative to date – each year – are exceeded
- 3) When the total budget up to 2050 is exceeded

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<sup>51</sup> Analysis provided by ETA/Ecofys

<sup>52</sup> Source: International Energy Agency, 2012, *High-Efficiency, Low-Emissions Coal-Fired Power Generation Technology Roadmap*.

<sup>53</sup> CO<sub>2</sub> emissions' intensities differ per coal type: increasing from bituminous, sub-bituminous to lignite, which is reflected in the ranges.

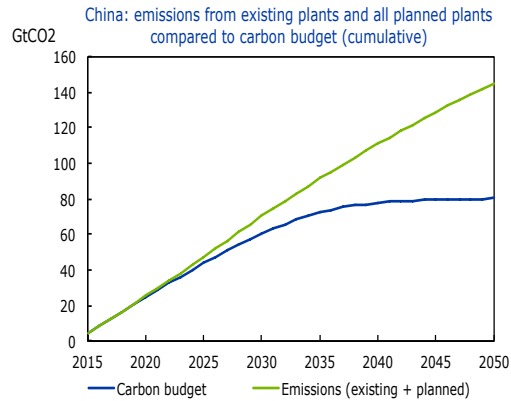
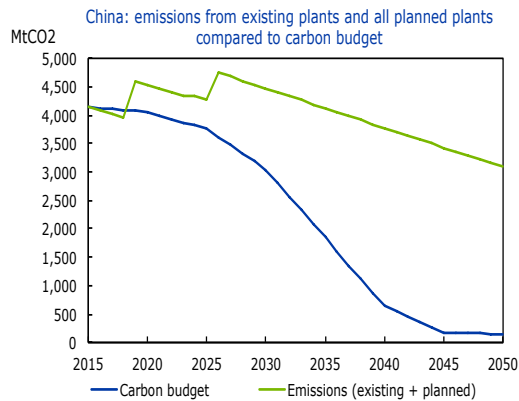
### High Efficiency Low Emissions do not rescue the carbon budget

Scenario	Year when emissions first exceed annual budget	Year when cumulative emissions exceed carbon budget to date	Year when cumulative emissions exceed total cumulative carbon budget to 2050	Annual emissions in 2050 (MtCO <sub>2</sub> )	TWh Produced in 2050
China all planned with retirements of existing plants	2019	2019	2033	3,069	3,702
China under construction with retirements of existing plants	2019	2019	2035	2,452	2,940
China all planned with existing plants retired or replaced by USC	2019	2019	2034	2,894	3,759
China under construction with existing plants retired or replaced by USC	2019	2019	2036	2,277	2,997
India all planned with replacement of existing plants with USC	2026	2031	2036	1,527	1,970
India under construction with replacement of existing plants with USC	2032	2039	2040	1,086	1,436

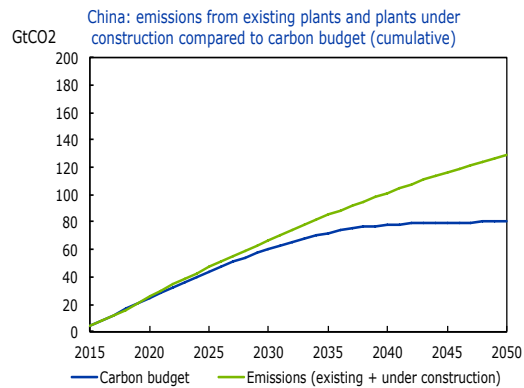
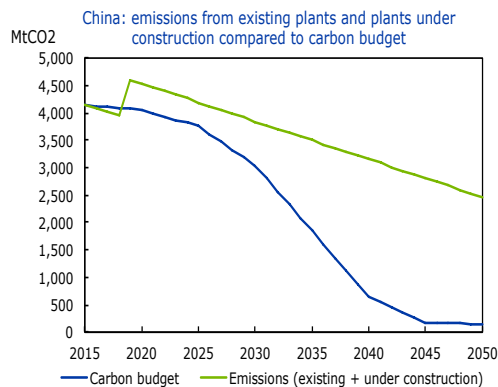
Source: CoalSwarm Ecofys/ETA Analysis

### 4.3.1 China

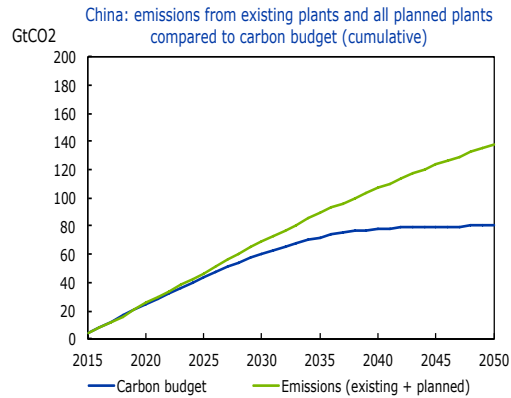
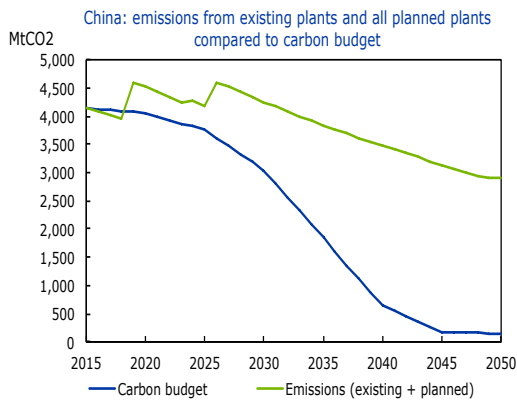
1) Existing plants, less retiring sub-critical plants at 18GWpa, plus all planned plants, break the annual emissions 2°C budget by 2019, and by 2019 the cumulative budget to date is broken. In 2050, annual emissions are still running at 3.1GtCO<sub>2</sub>.



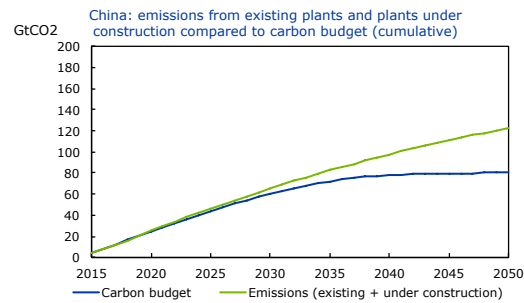
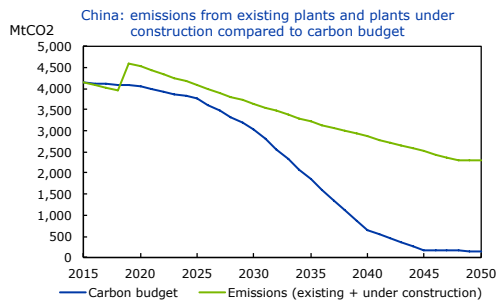
2) With under construction only, while not as large, it shows the same pattern. By 2050 Annual emissions are still running close to 2.5 GtCO<sub>2</sub>. Critically, even under this scenario, the annual and cumulative carbon budgets to date are still exceeded in 2019.



3) Taking existing plus all planned less retirements of existing sub-critical plants and then super critical after 2040, but at the same time convert the available sub critical existing plants to USC over 2021-40, the situation slightly improves. Existing subcritical plants are all either retired or replaced by USC plants by 2039 and existing super critical plants are all retired by 2049. Also there are obviously more TWh being produced as fewer plants are retired.

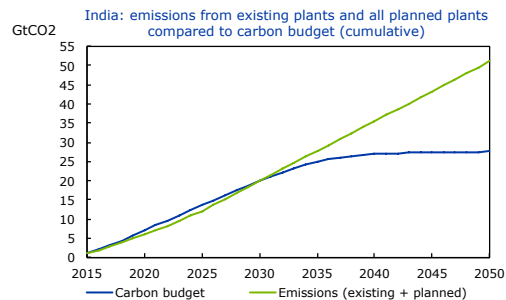
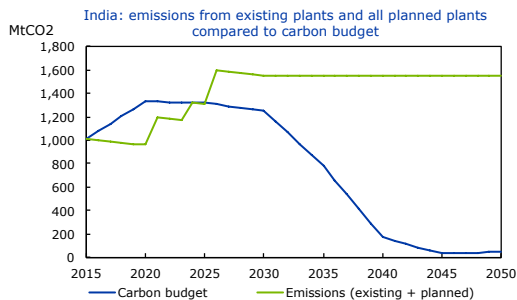


4) Again on an under construction only basis, the annual emissions are just below 2.3 GtCO<sub>2</sub>. Again, the annual and cumulative carbon budgets to date are exceeded in 2019.

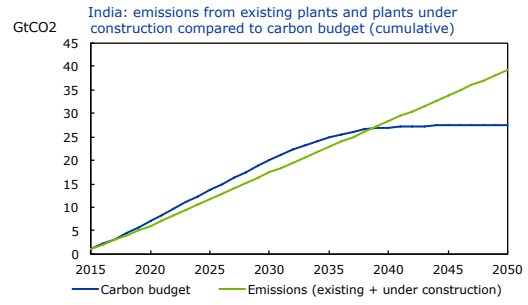
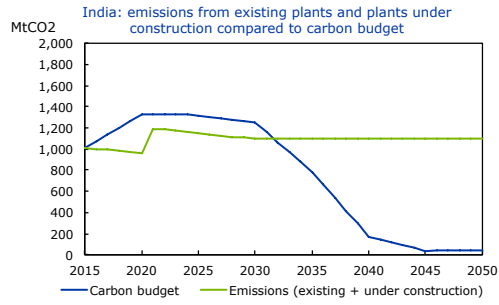


### 4.3.2 India

1) In India, existing plants with conversion of all plants to USC plants by 2030 plus all planned plants breaks the annual emissions 2°C budget closer to 2026 and the cumulative budget to date by 2029.



2) Looking at new Construction only it would only be in the 2030s that the carbon budget is exceeded



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## Section 5: Meeting 2°C - Potential New Policy Options and implications for Stranded Assets.<sup>54</sup>

### 5.1. Summary

The scientific and policy challenge for avoiding serious climate change is to limit global average warming to below 2°C. The analysis in previous sections indicates some hard choices in the energy sector, if the 2°C target is to be met, and the power sector to play a key role in decarbonizing, as is expected.

First, if CCS is to play a part, it must be deployed at scale with a full plan from government for situations where it is most suited. Second, renewable energy must take an increasing part of the energy mix, in a smart, flexible grid with storage. Third, if CCS is not deployed, then renewables and increased efficiency will have to carry the full load. This third scenario would also require much greater early retirement of coal power plants, with implications for asset stranding.

At present, there is no evidence of government planning to support CCS demonstration as a viable technology at scale and reasonable cost. An assumption of significant CCS deployment is therefore a leap of faith. It seems fair to expect IEA assumptions on CCS growth to decline over time, if no evidence of progress emerges.

If current power plant construction proceeds, and CCS fails to be deployed, then meeting the 2°C target will require some forceful policy interventions. First, older subcritical plants could be retired more quickly, something that would be resisted by incumbents and may be very inefficient economically. Incumbents would likely call for subsidies and higher electricity tariffs. Second, all existing coal power stations would face lower load factors over time, and then retirement. Again, managing the economics of this process would be important, with incumbents likely to call for subsidies and higher electricity tariffs. Third, unless other sectors and the economy were to take the strain, then decarbonizing the power sector needs near-zero emissions technologies – renewables and nuclear (if costs and public acceptance improve). Fourth, 24/7 reliability considerations would require a smart, flexible grid with energy storage at scale. Storage is already available, but at relatively high cost. To assume a lower cost scale-up is reasonable, given current and past trends, where a manufacturing focus in China could do for storage what it did for Solar PV. Fifth, a program of Electricity Market Reform will be imperative. For example, in many Asian countries there is no merit curve approach to dispatch low marginal cost renewables first. Instead, coal plants are often guaranteed running hours, even at specific tariffs. China has significant reforms in proposal but policymakers are still pursuing successful implementation.

To conclude, meeting the 2°C target will require governments to show they can implement and perhaps help fund a massive scale-up of CCS transport and storage infrastructure, both for industry (most likely needed) and power sectors, as well as putting more resources into deploying renewable power. If CCS fails then renewables must carry the full load.

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<sup>54</sup> Other than direct citations, this section reflects the views of Mark Fulton ETA

### **Potential Policy Action**

Given the effort required to meet the 2°C target, it is clear that a critical first policy step will be to extend or introduce moratoriums on new coal power permits and construction, and where feasible, to halt current construction. This first step would be consistent with electricity market reforms including adopting or enforcing least-cost merit order dispatch that favors renewables, and stopping the subsidizing of unneeded coal plants via electricity tariffs.

Implementing a full CCS rollout plan is an option particularly in China, with transport and storage funded where needed, and where applicable by government (potentially through carbon markets). Without such implementation, it is a high risk to assume that CCS will play an effective part in 2°C pathways.

In the longer term, effective emissions caps in the power sector will be key. These could be associated with consumption caps on coal, which are being implemented or looked at in a number of provinces already. Carbon markets could play a key role especially if a price over \$100 per tonne could be achieved in the future. Rigorous Performance Standards, which mandate emissions limits per unit of power generation, can ensure a 2°C pathway with or without CCS. Such standards overlap with carbon markets. Annual emissions targets by plant or fleet would fit with load factor management to deliver a 2°C result. Meanwhile, a major scale-up in renewable would require supporting for reliability, through the roll-out of smart grid technologies and storage.

Green financing initiatives are also very helpful in the funding of cleaner energy. The UNEP Inquiry into Design of a Sustainable Financial system sets out many of the opportunities and issues, as does the Climate Bonds Initiative.

For consistency of policy approach, subsidies on fossil fuel consumption and production should be removed. And it will be critical to help exiting workers transition towards new industries, to drive social acceptance.

### **5.2. The Asian Power market Policy context – focus on China and India**

Policy is a massive subject. There is no attempt to look at the full policy landscape but instead to pick out key aspects that come into play when trying to seriously mandate 2°C from a longer term perspective, with the focus on China and India. We assume, as does BNEF, that the pressure to reduce fiscal \$ incentives to renewable energy will be strong. However it is important to examine the fiscal \$ policy subsidies extended to coal in that context.

Regulatory structures will also be a key aspect to touch on. These range from stringent performance standards through to carbon markets and important aspects of electricity market structure as it affects renewables and energy storage.

### 5.1.1. The CCS option. Beware the risk – ‘actions speak louder than words’

As shown in Section 3 studies on potential CCS options have been looked at in China in particular.

Note that BNEF says in Section 2:

*‘Furthermore, as NEO considers technologies based on their competitive economics, the deployment of CCS at scale does not feature in the forecast.’*

Trusting to a scaled solution before it is planned and demonstrated is a risky approach. As discussed in 3.5, while technically feasible in the view of many engineers, it most likely only makes sense if governments provide the full transport and storage infrastructure. That would require for instance a 5-year plan in China that completely sets that out and lead to implementation. A lower risk policy approach would aim at 2°C and so force the deployment of renewable energy in a flexible smart grid including storage until CCS is actually contributing to the solution.

The issue of who pays for CCS is also complex. Arguably the fossil fuel industry should pay for its externalities. That must apply to the development of CCS in some degree. However, the industry simply may not have the cash flow to pay for all the transport and storage options – in some cases where Enhanced Oil Recovery is available that might be possible. So governments if serious will have to look at funding and taking on some of the liability of this infrastructure and carbon markets/prices could play a role. And for industrial applications that needs to be looked at. However, in that context of the power market, further enhancing the smart grid with storage may prove to be a cheaper and more realistic option and certainly goes with it.

***However, there is a real danger that the coal juggernaut continues forward on the basis of retrofitting what ever is built ‘one day’. If CCS doesn’t emerge either the climate gets stranded and or those coal plants do – a dangerous gamble with incumbent industries with political power likely to resist economic stranding. It seems fair to expect the IEA to start reducing its CCS assumptions over time as proven scalability fails to emerge.***

### 5.3. The carbon budget – full decarbonization without CCS.

If a carbon budget of near zero is set in line with the current IEA carbon budget as discussed in Section 3, but CCS is not available in the power sector as a proven at scale technology, then unlike the Integrated Assessment Models that assume this means the power sector requires a higher carbon budget as a result, planners can still track towards zero emissions by 2050 using other proven technologies that do exist technically now – notably solar/wind plus storage and nuclear (with all the caveats of public acceptance around that)..

Patently very few policy regions as yet support a full decarbonization of the power sector. It may well be that changing cost structures between fossil fuels and renewable energy are enough for markets to do this as the primary driver and indeed the view at CTI is that renewables as least cost with new

technology developments is the key driving force as discussed in 3.5.3. The recent CTI paper on LCOE trends cited in section 3 shows how this can emerge more consistently with 2°C. However, having policy support and frameworks that allow those cost forces to operate as efficiently as possible is crucial and the only sure way to find the pathway. This is particularly so in the face of incumbent industries with political power – as discussed below.

Further, the need for reliable 24/7 power is critical. The ‘flexible smart grid’ including storage has to be a reality for a massive scale up of renewable energy. At the energy access/poverty level, which is a crucial aspect, for demand and supply in Asia, mini grid and off grid solutions are an important consideration.

Finally, the political and social reality of repositioning away from coal has to be taken into account by policy to be acceptable, particularly in terms of the labor force in domestic supply.

#### **5.4. The Political Economy and Incumbents.**

In a mature and deregulated market for power least cost solutions would be adopted – much as in the US and EU today. However in Asian Emerging Markets there are many political and structural considerations that have a strong impact.

This can favor cleaner energy – incentives to deploy and scale up. But for years fossil fuel based power has been a critical development issue for emerging and developing economies. It appears cheap and is base load. So subsidies exist and the way the system is designed favors coal often.

This is a huge topic in its own right and can only be pointed to in this study. Our conclusion is that flexible clean energy with storage, and where better suited in distributed systems, can be a lower cost viable alternative, especially in a climate change context.

**Nevertheless, incumbent industries with strong political connections can resist change and the danger is they can dominate the development cycle. In particular CCS can be and is sometimes cited as a reason to go ahead with coal. This could prove to be a particularly dangerous assumption until it is proven.**

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## 5.5. Market approach through carbon markets.

### Setting a cap in some way has been the goal of global and regional climate policy for years now.

There has been action already around the idea of coal consumption caps. These cover all types of coal. As NRDC points out<sup>55</sup>

*Mandatory coal consumption caps have already been adopted in many of China's top coal-consuming provinces. For example, Beijing, Tianjin, Hebei, and Shandong have committed to reducing their coal consumption by 83 million tons by 2017, compared to 2012 levels. Shanghai, Zhejiang, Jiangsu, and Guangdong will announce their 2017 coal reduction targets soon."*

There is talk of an overall consumption cap for China just over 4bn tons a year in the next five-year plan. However, to practically implement there they have to be associated with more granular policies that will deliver these as NRDC also points out<sup>56</sup>.

Arguably the best pure market solution is to impose an overall emissions cap and specifically in the power sector and possibly at the regional level, which are consistent with that and then through carbon markets, price emissions and trade them. Section 3.5.2 looked at Carbon prices in this context and concluded they would have to escalate in China dramatically. Alternatively a tax could be imposed. **All this requires strong political will.** Most CCS scenarios assume a Carbon price that both incentives CCS and can form part of funding

- Extending and strengthening carbon markets – escalating floor prices or taxes are the most transparent signals.
- As discussed in 3.5.2 in IEA 450 scenarios the carbon price has to escalate to \$125
- Energy Innovation also provide policy models<sup>57</sup> – based on Chinese government data – that look at the impact of varying assumptions on carbon prices for instance.
- The Environmental Defence Fund has been looking at Carbon markets in both China and India<sup>58</sup>
- 

## 5.6. A full regulatory response to the 2°C challenge. – Performance Standards and Load factors are a potential tool in the power sector.

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<sup>55</sup> <https://www.nrdc.org/sites/default/files/paris-climate-conference-China-IB.pdf>

<sup>56</sup> <https://www.nrdc.org/experts/barbara-finamore/how-capping-coal-can-help-china-peak-its-co2-emissions-2025-and-contribute>

<sup>57</sup> <http://energyinnovation.org>

<sup>58</sup> <https://www.scientificamerican.com/article/china-will-start-the-world-s-largest-carbon-trading-market/>  
<https://www.iea.org/publications/insights/insightpublications/emissions-trading-in-the-peoples-republic-of-china-a-simulation-for-the-power-sector.html>  
<http://www.edf.org/sites/default/files/india-case-study-may2015.pdf>

A simple policy would be a set of performance standards that simply delivered the 2°C pathway at a plant or fleet level. In effect this is a carbon cap applied down more at a granular level and not 'tradable'. The US EPA point the way with their New Performance Standards and Existing Performance Standards, which allow for many technologies in a US context – although these are far from a 2°C pathway. China's centralized planning systems approach to retiring old power stations for more efficient ones and placing a moratorium on new permits are another version of a performance standard in effect.

**The idea of Load factors also plays a key role here.** As set out in Section 2, BNEF shows how load or capacity utilization factors have fallen. It is possible that following the construction of new coal plants in the next few years for economic short term growth considerations, regulators could attempt to economically strand them on an agreed emissions pathway by restricting hours run on an annual basis. This of course would be a dangerous approach, as the push back from incumbents would be against this restriction once built. Indeed tariffs can be changed to in effect subsidize plants as load declines. As IEEFA points out, in the first part of this year tariffs have actually been reduced in China to send a signal against this.

Further, the potential for the retrofitting of CCS could be used as an argument to build now and take the risk. Again full government commitment to a CCS roll out would be the only sure answer to this and does show complementarity to a carbon price as well

This has elements of fossil fuels as the back up as a storage option – again sub optimal compared to a full renewable storage approach. But this is far better thought of in terms of existing plants, which ultimately have to have their load factors reduced and be retired at some point.

Arguably Performance Standards and carbon markets overlap with some complementarity but some might argue it's an 'either/or' between them in terms of efficiency. In terms of ensuring that the 2°C goal is met then that overlap might be acceptable

Therefore, either through regulators or a central planning process, longer term the following could be used to reach a 2°C pathway in the lowest cost most efficient way stranding the least amount of assets in the system:

- Institute a robust carbon market set of policies that lead to a price consistent with a 2°C scenario and OR
- No new thermal coal stations to start construction until CCS is proven at scale (New Performance Standard = plant with CCS emissions)
- Existing coal stations in particular in China to run down capacity load factors in line with a 2°C pathway (Existing Performance Standard matches a 2°C pathway in terms of annual emissions) – need to manage potential stranding of assets over time
- To be able to meet reliability, a flexible smart grid with scale up in energy storage should be encouraged

## 5.7. Complementary Policy Measures – developing green financing, subsidies and energy efficiency

While full-blown performance standards can stand alone they are complementary to:

- Removing all existing subsidies (in effect negative carbon prices) to thermal coal production and generation of electricity from thermal coal is obviously associated with any serious attempt to properly price fossil fuels (see Section 6)
- Greatly increase investment in end-use energy efficiency. Indeed this remains one of the most cost efficient approaches to carbon mitigation, reducing the need for energy.

Importantly, the development of “green” financing to help the deployment of renewable energy is increasingly a focus of policy and markets in both India and China. Again this is a very large topic but The UNEP Inquiry into Design of a Sustainable Financial System<sup>59</sup> explores many of the important features. The Peoples Bank of China has set out its ideas around this<sup>60</sup>. Green bonds are increasingly gathering pace as a financing vehicle as tracked and discussed by the Climate Bonds Initiative.<sup>61</sup>

## 5.8. Electricity Market Reform - the key context and place to start now

Short term, the first place to start is by looking at the current regulatory frameworks of existing electricity markets. This is where a number of issues that favor coal over cleaner power can be found in Asia that are not present in many OECD countries. Most important is the ‘merit order curve’ – the rules that determine which fuel source in the electricity system runs first and so gets prioritized. In China and India that tends to be coal, whereas in OECD it would be the cheapest marginal cost of supply: renewables.

Certainly China has a set of policies that appear to promote the priority of renewable energy in the dispatch system But mostly they do not seem to be effective. These issues are discussed in great detail by the **Regulatory Assistance Project** – RAP<sup>62</sup>. The flowing discussion on Energy Post<sup>63</sup> sets out the issues. Note the conclusion; it will be hard to change the incumbency:

*‘China and India are building huge amounts of solar and wind power, but a lot of this capacity is wasted as it cannot be integrated into the grid. In China the problems stem mostly from rigid planning processes and compensation systems. In India, the stumbling block is state-owned distribution operators that have an incentive not to increase access to electricity. In both countries, reforms are contemplated but will be difficult to achieve.*

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<sup>59</sup> <http://unepinquiry.org/publication/inquiry-global-report-the-financial-system-we-need/>

<sup>60</sup> <http://www.pbc.gov.cn/english/130721/3133045/index.html>

<sup>61</sup> <https://www.climatebonds.net>

<sup>62</sup> [http://www.raonline.org/knowledge-center/issues-in-china-power-sector-reform-generator-dispatch/?\\_sf\\_s=generator+dispatch+reform+china&sf\\_paged=3](http://www.raonline.org/knowledge-center/issues-in-china-power-sector-reform-generator-dispatch/?_sf_s=generator+dispatch+reform+china&sf_paged=3)

<sup>63</sup> Max Dupuy and Ranjit Bharvikar of the Regulatory Assistance Project (RAP).





*In recent years, China and India have greatly expanded renewable energy capacity... However, despite this surging investment in renewables, both countries face major difficulties in integrating these new resources into the grid. Wind energy curtailment in China averaged 15 percent in 2015, with rates surpassing 30 percent in regions rich in wind resources. Detailed estimates of curtailment in India are more difficult to come by, but wind generators in Tamil Nadu, the state with the highest share of wind energy, have complained to regulators about curtailment despite the regulatory provision of mandatory dispatch.*

*Around the world, every country seeking to boost renewable energy is facing the challenge of finding ways to increase system flexibility. However, China and India are struggling with some particularly deeply entrenched rigidities and inefficiencies – including their approaches to system operations. Although these two countries are very different, some common threads run through their power sectors. In both countries, even when grid conditions and weather would allow use of additional renewable energy—typically at near-zero marginal cost—relatively expensive and polluting coal-fired power plants are often operated instead. Meanwhile, within each country’s fleet of coal-fired power plants, grid operators often dispatch relatively inefficient power plants over more efficient counterparts. In short, the ‘merit order’ ranking of available resources according to marginal cost is largely absent in both countries. Unclear rules and compensation for ancillary services also hamper flexibility in both countries. The upshot is that system operators in both countries are missing opportunities to take advantage of available renewable resources to reduce system costs and emissions.*

*Coal-fired generators in China are resistant to any reform perceived as threatening allocated operating hours*

### **China: overcapacity and battles over generator operating hours**

*In China, the problems stem, in part, from an official annual planning process that assigns generators a targeted number of operating hours for the year. The system operators within the grid companies tend to manage generator unit commitment and dispatch to enable each coal-fired generator to reach its targeted hours. In the context of overall [generation overcapacity](#), system operators often curtail renewables in order to give operating hours to coal fired generators.*

*There have been several provincial-level attempts at reform in recent years, but the way generators are compensated has been a major obstacle to change. Most generators earn a set per kWh price, and are only paid when feeding energy into the grid. There is no peak pricing for these generators and no capacity payment. Coal-fired generators—which still account for more than 60 percent of total installed capacity and constitute a powerful interest group—are resistant to any reform perceived as threatening allocated operating hours.*

*The all-in kWh price has also acted as a barrier to investment in gas-fired generation, which*





*should otherwise have an economic role as peaking capacity and for providing additional flexibility to the system in support of renewables. In other words, a gas-fired generator operating in a limited number of hours would not earn enough to cover capital costs. (In 2015, the government launched provincial pilots to address the problem by offering gas-fired generators capacity payments in addition to a per-kWh price.) Compensation issues also complicate the provision of ancillary services. In China, generators are typically required to provide ancillary services, but these services are not well defined and generators are only partially remunerated for them, if at all.*

***India: overcapacity but millions still lack access to electricity***

*Unlike China, where investment floods into new power system resources, India has long suffered from an overall shortage of generation capacity. The official peak demand (approximately 145GW) and installed capacity (around 290GW) create an opposite impression—i.e. that of a surplus. Coal-based thermal generation capacity operates at remarkably low capacity utilization factors of approximately 60 percent. Yet, 300 to 400 million people still don't have access to electricity and those who do, receive unreliable service. These seemingly contradictory sets of facts are a result of the dysfunctional operations of the distribution companies. Most Indian distribution companies are wholly owned by the respective state governments and prefer not to increase electricity access or improve reliability, as their ability to increase tariffs to recover the incremental costs is limited. In addition, limited inter-state trading of generation resources—a legacy of the vertically integrated state-government utilities—has created a major barrier to the growth of renewable energy. Some regions regularly experience strong surges of wind or solar output, but then curtail that clean, low-cost energy due to a lack of inter-state trading and the flexibility that trading enables. Like China, one source of inflexibility is insufficient emphasis on a merit-order approach to system operations.*

*Generators declare their availability to their buyers and the relevant system operators (intra-state or inter-state). Buyers—typically, state government-owned distribution companies—provide the 'merit order' to system operators. The system operator acts as a kind of 'traffic cop' and, typically, complies with distribution company instructions. The basis for establishing this 'merit order' varies from state-to-state. Sometimes it is based on the long-term all-in power purchase agreement cost and other times it is on the latest variable cost. Although there are not much data available in the public domain, there is indirect evidence that the merit order does not reflect short-term marginal costs. Another parallel with China is the treatment of ancillary services. In India, there is no formal recognition of 'ancillary services' as a distinct service to be provided. 'Flexibility' attributes are neither recognized nor valued appropriately. Maintaining the stability of the grid is achieved in a completely decentralized manner. Generators adjust their production in response to the frequency of the grid (stable frequency is 50 Hz in India) and the administratively set incentives and penalties linked to the deviation from the frequency—the 'deviation settlement mechanism.' This approach is inefficient and unnecessarily costly.*

### **Windows for reform**

*Over the past twelve months, Chinese policymakers have signaled their intent to grapple with dispatch reform. In September of last year, China's President Xi, in a joint statement with U.S. President Obama, [made a commitment to 'green dispatch'](#) as a headline reform pledge ahead of the Paris talks. (The two presidents [reaffirmed](#) these commitments in their March 2016 meeting.) This, together with the announcement from China's State Council and Communist Party Central Committee of a new round of [power sector reform](#), indicates the dramatic elevation of a once-obscure issue to the top level of Chinese policymaking. Now, however, the challenge is to break through opposition and translate the concept of green dispatch into a concrete—and politically workable—set of practices on the ground.*

*Reform of system operational practices will be an important part of the picture, but because of political considerations and the power of special interests, achieving it will be difficult*

*In India, the 2003 Electricity Act established—for the first time—the principles of more efficient grid operation in law. Since then, several reforms have been implemented to promote inter-state grid operation. However, the unexpectedly rapid growth of renewable energy has highlighted the fundamental limitations of these reforms.*

*Consequently, in 2015, the central government's NITI Aayog issued the [Report on India's Renewable Electricity Roadmap 2030](#), which discusses a broad set of opportunities for improving system flexibility and integrating renewables—including improved regional and inter-regional dispatch, ancillary services, faster markets, etc. Policymakers are studying several of these recommendations.*

*It is important not to overstate the parallels between the two countries. But, even so, the two countries are similar in their need to increase flexibility in their power systems in order to integrate high penetration rates of renewable energy. In both countries, reform of system operational practices will be an important part of the picture, but because of political considerations and the power of special interests, achieving it will be difficult. Until now, these issues have had low profiles in both places, but they will become increasingly important as installed renewable energy capacity continues to grow.'*

The issue of 'flexibility' as discussed in 3.5.3.1 is a key one as it goes to the heart of relative costs

## 5.9. Focus on China

A more detailed look at the evolution of regulations in the Chinese electricity sector can be found in RAPs paper Issues in China Power Sector Reform: Generator Dispatch Discussion Paper, July 2016.

*'Generator dispatch has been a major obstacle to meeting China's clean energy, air quality, and economic goals. In most provinces, grid companies dispatch power plants to enable each generator to achieve its annually allocated number of operating hours. This is very different from the rest of the world. In many other countries, system operators typically seek to minimize short-run costs, ideally including the social cost of emissions, based on a 'merit order' approach.<sup>2</sup> No other major country has annual planning of generator hours.*

*There are four main reasons why dispatch reform is crucial to meeting China's power sector goals. The current approach to dispatch:*

- Is a major reason for current high levels of curtailment of wind, solar, and hydroelectric energy and is an obstacle to integrating higher penetrations of wind and solar energy onto the grid;*
- Results in more frequent use of less efficient coal-fired power plants, even when more efficient ones are available, resulting in excessive fuel use and higher emissions;*
- Distorts investment decisions, contributing to over-investment in (typically coal-fired) baseload power plants and under-investment in peaking capacity and more flexible power plants (particularly natural gas);*
- Lowers efficiency of emission control equipment, causing more air pollution, especially nitrogen oxides (NOx), a precursor to ambient ozone and fine particulates (PM2.5).*

*In short, the provision of electricity services in China is both more expensive and environmentally damaging than it would be with merit order dispatch.*

*Recent policy pronouncements regarding electricity reforms represent a major step forward in improving dispatch. However, there are still a number of important questions that have yet to be addressed. ....*

*We highlight issues in four areas that need to be addressed as China transitions toward more efficient dispatch: (1) generator compensation, (2) dispatch order determination, (3) reconciliation of 'planned,' 'priority,' and 'market' generation, and (4) the political economy of cross-provincial exchange. We argue that, regardless of how rapidly wholesale markets are developed and what form they take, in the near term China's policymakers should seek to move toward a merit order approach to dispatch in all provinces'*

And

*'... a less-discussed policy, issued by China's National Energy Administration in June, may ultimately be more important for dealing with these challenges. This document, with the innocuous name [Power Sector Planning Regulation](#) (Chinese), sets out a broad framework for a transition of the Chinese power sector away from a model in which meeting rapid demand growth is the prime consideration—and toward a model based on careful consideration of complex trade-offs and multiple targets, including China's goals for renewable energy, environmental quality, affordability, and reliability.....*

*Overall, the new regulation is a very useful blueprint for a new planning process in China. However, the road to successful implementation may be quite long. The next items on the work agenda will include building adequate institutional capacity, establishing suitable analytical approaches, and ensuring adequate oversight and transparency.'*

### 5.9.1. Potential China Policy Responses

As discussed a 5year plan starting at in 2020 to roll out CCS deployment is a real option.

To reach 2°C before it is available, or even without CCS, restrictions on construction and planning would have to be very stringent. Load factors would have to be managed down. China's planning system is capable of delivering a performance standard approach, which could look to the following options:

- Continue to develop and strengthen carbon markets in line with Paris Agreement
- Extend and strengthen the current new permit and construction moratorium past 2018 in the next FYP until CCS is launched at scale
- Cancel plants under construction now wherever reasonable – prioritize reducing air pollution and water impacts
- Prioritize existing policies to allow renewable energy to run first – not, as often is the case, as coal does at present - through a merit order approach along with other key changes outlined by RAP above
- Look at further reducing capacity load factors in thermal coal stations to mirror a 2°C pathway. Managing the economics of this in terms of a run off in the fleet will be complex, needing careful planning
- Encourage the production and deployment of energy storage dramatically as per renewables in the last five years
- Look to help workers transition from coal production to newer industries. Renewable energy and storage industries are one avenue.

For instance, Greenpeace recently produced these recommendations:

- Extend ban on new permits and construction starts to cover all provinces, and all conventional coal power projects.



- Cancel projects that started construction in 2015 or later in areas with coal power overcapacity, and in water over withdrawal areas.
- Substantially reduce investments in retrofitting of older coal-fired power plants and retire this capacity instead.
- Strictly implement priority grid access for renewable energy. Increase transparency of information about the power system to improve planning and enable the public to scrutinize reasons for high rates of ‘wasted wind and solar’.
- Pay particular attention to stopping new projects and reducing existing capacity in the most water-stressed areas of the country. ‘

**Indeed, the debate in Chinese policy making circles is concentrated on whether any new power plants are needed beyond what is already under construction. This is reflected in the article below. However as our Global Plant Tracker analysis shows, even this level of current development still leaves the carbon budget stranded.**

***‘Future electricity supply -***

*If the 13th Five-Year Plan (2016-2020) period only sees the completion of coal-fired power projects already under construction, or being prepared for construction, with the assumption that no additional coal-fired generation capacity is built, China will have 980GW of coal-fired power capacity in 2020, higher than the total EU installed electricity capacity in 2014 of [977GW for 28 member states combined](#).*

*If average hours of utilisation per year are 4,900, that gives 4.8 trillion kWh of electricity supply per year. Under the economic slowdown, moderate recovery and strong recovery scenarios, energy demand in 2020 will be 4.8 billion, 5 billion and 5.2 billion [tonnes-of-coal equivalent](#) respectively. If the [goal of drawing 15% of the energy](#) supply from non-fossil sources is achieved, that means the non-fossil supply of electricity will be 2.4 trillion, 2.5 trillion and 2.6 trillion kWh per year respectively.*

*Meanwhile if natural gas electricity generation reaches 0.3 trillion kWh per year by 2020, then China’s total electricity supply under the three scenarios will be 7.5 trillion, 7.6 trillion and 7.7 trillion kWh per year respectively. This is more than adequate to meet the predicted demand of 6.6 trillion, 7.2 trillion and 7.5 trillion kWh under the three scenarios.*

*This means it would actually be possible to halt construction on some coal-fired power projects already under preliminary construction.*

*Similarly, if only projects already under construction are completed during up to 2021, and no new coal-fired power is brought online during the 14th (2021-2025) and 15th (2026-2030) Five-Year Plans, and we again assume that 9GW of inefficient coal-fired power is shut down annually, installed coal-fired power capacity in 2030 will be 900GW.*

*If hours of utilisation increase to 5,300 hours per year, a benchmark commonly used by the Chinese power sector for when coal-fired power capacity is [fully utilised](#), that provides 4.8 trillion kWh of electricity per year. Assume 20% of energy is drawn from non-fossil fuel sources and natural gas generation stands at 0.5 trillion kWh per year, and supply will be adequate to meet demand under the sustained slowdown and moderate recovery scenarios, and the shortfall in the strong recovery scenario is only 0.3 trillion kWh – 3% of total demand.*

### **Strict coal power controls**

*The above analysis shows that strict controls on coal-fired power – even zero expansion – still allows for China to meet rising demand for electricity.*

*So whether it is to control local air pollution and greenhouse gas emissions or to avoid wasted investment and surplus generation capacity, existing state policy on controlling coal-fired power should be strictly enforced with tough limits on new capacity during the 13th FYP.*

*The small 2030 shortfall under the ‘strong recovery’ scenario could easily be met by increasing efficiency of electricity use and increasing non-fossil fuel sources of power.*

*Even if at the time there is a need for new coal-fired capacity to make up that 0.3 trillion kWh gap the decision can wait a decade – coal-fired plants can be built in two to three years, by which time the construction costs, electricity prices, reliability and practicality of natural gas and non-fossil fuel sources [i.e. wind, solar and nuclear] of electricity may have improved. In economic, environmental and efficiency terms, it is better to make that investment decision in 10 years’ time.*

*Zou Ji is deputy director of China’s National Centre for Climate Change Strategy. Fu Sha is a research assistant of China’s National Centre for Climate Change Strategy.*

*This article first appeared in [China Dialogue](#).*

## **5.10. Focus on India**

Right now policy is very much ‘all of the above’ and, as described by IEEFA in Section 1, there is no doubt that renewables are part of that.

To expect India to adopt a full performance standard at present looks hard. The key is to prove up the economics of off-grid solutions that put together solar and storage, in particular, instead of a massive coalfired central grid rollout.

This was discussed in detail in the CTI Publication *Coal-fired energy for all? Examining coal's role in the energy development of India and sub-Saharan Africa*<sup>64</sup>(November 2014).

*'Focusing on India and sub-Saharan Africa, we examine solutions to make electricity more accessible, reliable, and affordable - particularly in respect of the role claimed for coal. Key takeaways are as follows:*

*-For initial stages of energy access (i.e. general lighting), off-grid interventions (e.g. solar lanterns) can provide energy access at 4-20% of the cost of grid extension*

*-In a scenario of universal electricity access by 2030, the IEA estimates 3/5 of households gaining access will do so via mini/ off-grid solutions - in which coal plays little role*

*-Business model innovations such as pay-as-you-go financing and local manufacturing are essential*

*-High economic losses from unreliable grid-based power supplies make businesses a key early adopter of solar PV and other distributed generation - particularly with payback periods now at 4-6 years in many areas*

*-Declining battery costs are set to improve the economics of hybrid PV/diesel/battery systems by enabling greater reliance on solar output and less reliance on diesel*

*-India and Africa can achieve high (~80%) renewable electricity futures with minimal long-term impact on system costs or potentially savings – but up front capital costs are a challenge. '*

*'Of particular note in terms of batteries and storage...*

*'Declining battery costs will enable hybrid systems to use more solar and less diesel: Including battery storage in hybrid PV/diesel systems enables a greater portion of load to be met through solar power, reducing reliance on costly diesel generation. Current battery prices, however, often constrain the amount of storage capacity that it is economical for hybrid diesel/PV systems to employ. For example, in the case of a 300 kW system, each MWh charged via battery typically adds \$200/MWh or more in cost - making battery costs 30% or more of the LCOE of such a system. As a result, assuming a diesel price of \$1/liter, the LCOE of PV/diesel-battery hybrid systems ranges from roughly \$270/MWh (for a 1 MW system) to over \$450/MWh (for a 300 kW system). Though generally still less expensive than diesel generation, the difference has heretofore been too small to motivate widespread adoption. Projected declines in battery costs, however, are set to make the economics of PV/diesel-battery hybrid systems more attractive. For example, the Tesla Motors 'Gigafactory' is currently sourcing lithium-ion batteries from Panasonic at a price (\$168/MWh) that is 40% less than the per-MWh price of batteries in most*

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<sup>64</sup> <http://www.carbontracker.org>



*hybrid storage systems; moreover, based on material costs, the long-term competitive price for lithium-ion batteries may be as low as \$100/MWh. Other battery chemistries have similarly attractive long-term economics. Battery costs at \$100/MWh could reduce the LCOE of a 300 kW hybrid system by 20% or more - resulting in greater savings relative to diesel generation, faster paybacks of up-front investment, and broader adoption.'*

### **5.10.1. Potential India Policy Response**

Similarly to China, India could:

- Institute a new permit and construction moratorium .
- Look at cancelling under construction now, wherever possible
- Allow renewable energy to run first through a merit order approach
- Look at further reducing capacity load factors in existing thermal coal stations to mirror a 2°C pathway
- Encourage the production and deployment of energy storage dramatically as per renewables in the last five years
- Develop and strengthen carbon markets
- Remove subsidies for fossil fuel production and consumption
- Look to help workers transition from coal production to newer industries. Renewable energy and storage is one new avenue

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## Section 6: Subsidies focus

Prepared by Shelagh Whitley ODI

### 6.1. Government Support To Coal In Asia

There are a number of overall categories of subsidies that we look at below

- **Support through public finance for fossil fuels (domestic and international)**
- **Support through SOEs**
- **Links between production and consumption subsidies**
- **Failure to price externalities**

One further area that is crucial but is much harder pinpoint in numeric terms is:

- Providing Infrastructure – Rail and Ports

The provision of infrastructure including public funding for the construction of the electricity grid and the rail network and ports reduces costs for importing fuel and transmitting power; data is often hard to find. But it this type of subsidy provides a crucial initial support for development and is mostly state sponsored.

This data is a compilation of publicly available information on production subsidies. However, limited transparency and wide variations in data availability pose major obstacles to the identification and estimation of fossil fuel subsidies. In practice, the ways in which subsidies are financed and recorded in government budgets vary across countries and can change over time (OECD, 2015).

Although most existing fossil fuel subsidy inventories do not cover public finance and investment by state-owned enterprises, the OECD has stated that it would seek to expand its own inventory to include risk transfers, concessional loans, injections of funds (as equity) into state-owned enterprises and market price support, and it is currently undertaking research to that end (OECD, 2012, 2015; Lucas, 2015). As with our own research, there are likely to be barriers to this work due to data limitations and calculation complexity, as government budgets are often not transparent about transfers to state-owned enterprises, or about the proportions of public finance which are based directly on public resources (as opposed to that raised on capital markets) or dependent on the institutions' government-linked credit rating.

In addition to excluding fossil fuel consumption subsidies, the data has limited coverage of a sub-set of the following stages of fossil fuel production, for these reasons:

- Transport and distribution (through international shipping). Although approximately 42% of all of sea-borne freight by mass is used for moving oil, gas, coal and petroleum products (UNCTAD, 2014), and international shipping is exempt from all taxes on fuels, the distributed nature of the industry makes it

challenging to identify subsidies to these activities. Nonetheless, there is some evidence of public finance for international shipping of fossil fuels (for example, China ExIm Bank (Chexim) financing oil tankers), and this could be an area for further research in the context of fossil fuel production subsidy inventories (Trade Finance, 2013).

- Distribution (of fossil fuel-based electricity). This often takes place through grid systems that are also distributing non-fossil based electricity (nuclear, wind, solar, etc.). Where a grid is primarily fossil fuel-based, any support to distribution is discussed in the relevant country studies. However, we did not undertake the pro-rata calculations that would be needed to include this support (which at times may be significant) in the overall estimates of production subsidies.
- Decommissioning (of power plants, refineries, pipelines and offshore rigs). There is currently relatively limited government support to these activities. However, this may increase in the future in the context of regulations linked to addressing climate change.
- Plant construction, operation and distribution for petrochemicals. This use of fossil fuels has a much smaller impact than burning them to provide energy services, therefore coverage of these activities is limited.

## 6.2 CHINA

### 6.2.1 Support through direct spending and tax breaks

Direct spending and tax breaks supporting the extraction and production of coal averaged \$2.7 billion per year in 2013 and 2014, however, many production subsidies have not been quantified due to a lack of publicly available data, and it is possible that not all production subsidies have been identified.

Subsidies to coal production in China include the following measures:

- The Chinese government offers subsidies for some categories of comparatively lower-emission coal-fired power plants generating and equipment upgrades. Subsidies are available for denitrification, desulfurization, and dust removal.
- Tax exemptions are available for changes in land use for the production of coal
- Preferential import tax rates are available for equipment used in fossil fuel project development
- Preferential loan rates are offered for fossil fuel project developments
- Public support is provided for coal enterprise management, and pensions payments

### 6.2.2 Support through public finance for fossil fuels (domestic and international)

China's public finance to coal mining and coal fired power averaged at least \$8.3 billion per year in 2013 and 2014. For example, Chinese banks provide low interest rate loans to coal production both in China and abroad. In particular, China is a top provider of export finance to fossil fuel projects, including in

India, Latin America and Africa. In 2013, the China Development Bank (CDB) had \$26 billion in outstanding loans to coal. One recent study estimated that the total lifetime social cost of coal-fired power plants supported by Chinese public finance institutions could range from \$117 billion to \$892 billion<sup>65</sup>

Just two Chinese policy banks now provide as much international development finance as the next six largest multilateral lenders—combined. However, this financing carries great social and environmental risks. China’s plan for One Belt One Road (OBOR) financing is to concentrate on infrastructure, especially power generation, natural resource extraction, and heavy industry, which could lock in high carbon dioxide levels for decades to come if this means funding and subsidizing high-carbon infrastructure throughout Asia. OBOR financing could drive up coal consumption in recipient countries even while China curbs coal use at home.

### **6.2.3 Support through SOEs**

China’s state-owned enterprise investment in coal averaged at least \$11.1 billion per annum in 2013 and 2014. This may be a significant underestimate given limited public availability of data on China’s SOE investment in coal

China’s energy sector is dominated by SOEs<sup>66</sup>. In the coal sector, Shenhua Coal, the world’s largest coal company, plays a leading role along with the China National Coal Group Corporation and the Datong Coal Mining group.

Information on the commercial viability and effectiveness of these SOEs is limited, though much of the industry is understood to be running losses. Much more transparency and discussion is needed to evaluate whether investments of these SOEs in fossil fuel projects are commercial, or potentially stranded assets with high carbon emissions for years to come. The fall in load factors in power plants points in this direction. As energy sector organizations fall on hard times, demands may increase to provide subsidies to mask the losses of SOEs. In the electricity sector, subsidies for coal generation obscure the real cost of coal electricity and prevent a level playing field for renewable generators.

### **6.2.4 Links between production and consumption subsidies**

For decades, China’s subsidies to energy production were meant to satisfy demand and ensure low energy costs for domestic consumers. To a significant extent, subsidies to coal extraction and coal-fired generation were driven by parallel subsidies to electricity consumption in China. Such consumption subsidies include:

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<sup>65</sup> [https://www.bu.edu/pardeeschool/files/2016/05/Fueling-Growth.FINAL\\_.version.pdf](https://www.bu.edu/pardeeschool/files/2016/05/Fueling-Growth.FINAL_.version.pdf)

<sup>66</sup> <https://www.odi.org/sites/odi.org.uk/files/odi>

- As discussed elsewhere in this paper, ‘Must-run’ power contracts (and generation dispatch practices) that favor coal-fired power over renewables, as well as cross-subsidies between electric consumer classes that keep electricity prices for residential consumers low;
- Credit support in the form of low interest rates and favorable repayment terms;
- Subsidies for ‘clean’ coal use of households
- Winter coal use for heating purposes

### **6.2.5. Failure to price externalities**

If the ‘true cost’ of coal in terms of health and environmental impacts is included in the definition of a subsidy, the scale of subsidies in China has a much greater order of magnitude. The International Monetary Fund’s analysis showed that global energy subsidies in 2015 amounted to \$5.3 trillion, of which China accounted for \$2.3 trillion mostly costs associated with air pollution and GHG emissions.

## **6.3 INDIA**

### **6.3.1 Support through direct spending and tax breaks**

In terms of producer subsidies (through direct spending and tax breaks), the Indian government provides various types of budgetary support (through Ministry of Finance) by making allocations to be dispersed to energy sector actors by line Ministries (Ministry of Coal (MoC) and Ministry of Power (MoP)) The Ministries provide capital outlays, tax exemptions/rebates to the state-owned enterprises under their ambit. MoC provide subsidies to Coal India (CIL) and its subsidiaries, while from what has been identified, MoP provides subsidies to diesel and gas based fuel generators. The estimated value of subsidies to coal production was \$99 million on average in 2014 and 2013, however, many fossil fuel production subsidies have not been quantified due to a lack of publicly available data, and it is possible that not all subsidies have been identified.

### **6.3.2 Support through public finance**

In addition to direct spending by government agencies, the government owns the majority of India’s banks, resulting in a large number of institutions in India providing public finance as defined in this report. We identified coal financing at 8 of India’s largest public finance institutions and state-owned banks – for coal projects including mining, transportation and/or combustion. On average per year in 2013 and 2014 support provided through Indian public finance institutions and state owned banks was \$2.3 billion. A number of multilateral development banks have provided loans to CIL at subsidised rates for the procurement of equipment and technical assistance under the Coal Sector Rehabilitation Project (CIL, 2015a). The Indian government also guarantees these loans. The subsidised loan to CIL is estimated have been approximately \$11 million and \$2 million in 2013–14 and 2014–15.

### **6.3.3 Support through SOEs**

Investment by SOEs in coal mining and coal-fired power was \$4.4 billion on average per year in 2013 and 2014. The Ministry of Coal (MoC) is responsible for overseeing the management of India's coal industry through a number of agencies and companies, including Coal India Limited (CIL), a 90 per cent state-owned enterprise. CIL oversees, and is largely responsible for, the production of coal, which fuels more than 70 per cent of India's power plants (CEA, 2015). India's electricity generation capacity is also dominated by enterprises owned by the central and regional (state-level) governments.

### **6.3.4 Links between production and consumption subsidies**

It should be noted that fossil fuel consumption subsidies in India are significant, and in many cases provide additional support to fossil fuel production. The accumulated losses of India's power distribution utilities equates to about 2.7 per cent of GDP, largely owing to the provision of free or underpriced power.

The government has begun to reform gas pricing and to deregulate downstream activities. This reform is part of a wider drive to remove or reduce consumer subsidies and move away from government fixing the retail prices for certain petroleum products (LPG, kerosene, diesel and gasoline). Although fossil fuel producers take on the burden of some of these costs, much of the cost of price fixing is covered by payments from government budgets.

In spite of the deregulation of petrol prices (in 2010) and diesel prices (in 2014) and the global fall in oil prices, costs to the government of price fixing still remained substantial at \$11 billion in 2014–15 (MoPNG, 2015b). Similar consumer subsidies of approximately \$12 billion in 2012–13 existed in the primarily fossil fuel based electricity sector. These subsidies may drive demand for further production of fossil fuels and electricity (the majority of which is fossil fuel-based).

### **6.3.5 Failure to price externalities**

If the 'true cost' of coal in terms of health and environmental impacts is included in the definition of a subsidy, the scale of subsidies in India has a greater order of magnitude. The International Monetary Fund's analysis showed that global energy subsidies in 2015 amounted to \$5.3 trillion, of which India accounted for \$277 billion mostly costs associated with the air pollution and GHG emissions.

## **6.4 OPPORTUNITIES TO PHASE OUT GOVERNMENT SUPPORT TO COAL**

The principles that apply worldwide, apply to Asia.

A significant proportion of the private sector receives some level of support, interventions and subsidies from the public sector. In general, governments use subsidies as part of wider processes of economic policy to support specific businesses, markets, sectors or regions and these are among the more common public policy instruments in current use, with political interests often determining who receives subsidies and at what scale. In the specific case of energy subsidies (a subset of which are for the production of fossil fuels) their use has been historically linked to supporting energy security, domestic energy production and affordable access to energy, which are expected to have wider positive effects for economic development.

In recent years, however, accounting for the full economic, social and environmental costs and benefits of fossil fuel subsidies, alongside those of alternative government interventions to achieve the same objectives, has favoured a move away from subsidies to fossil fuel production. These drivers are increasingly allowing governments to overcome persistent barriers to reform, which include: a dearth of information on the scope and scale of subsidies, the undue influence of special interests, and a lack of other effective means and institutional capacity to adopt more suitable policies (see Whitley and van der Burg, 2015 for a wider discussion of barriers to and key principles for subsidy reform).

A number of governments have begun to phase out subsidies to fossil fuel production. In Asia, for example, in its recent self-review as part of the peer review process under the G20 fossil fuel subsidies commitment, China formally recognized at least some production subsidies as inefficient and wasteful in the context of the 2009 G20 commitment to phase out fossil fuel subsidies, and slated them for elimination. These production subsidies identified by China for elimination include a land-use tax exemption that benefits coal-fired power plants.

There is an important series of inter-linked financial, economic, social and environmental, and political drivers that are rapidly transforming decisions around government support to fossil fuel production.

**Financial drivers:** The global energy sector has changed significantly since mid-2014, with changes in demand and supply leading oil, gas and coal prices falling dramatically. This has taken place alongside rapid increases in the cost competitiveness and uptake of alternatives including renewable technologies and electric vehicles. These changes are linked to wider economic and political trends, and have a significant impact on the investment climate for fossil fuel production.

**Economic drivers:** While many have suggested that the recent drops in fossil fuel prices is a once-in-a-generation opportunity to remove subsidies and introduce a carbon price, it is important to recognise that although falling prices can support the phase out of consumption subsidies<sup>67</sup>, they often lead to a parallel rise in demands for production subsidies. An emerging group of governments have sought to mitigate the impacts of price falls by reforming subsidies to fossil fuel production and focusing on economic and energy diversification. Other countries have used the revenue from oil and gas production to set up sovereign wealth funds to support economic diversification.

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<sup>67</sup> Falling oil and gas prices have facilitated fossil fuel consumer subsidy phase-out in around 30 countries in 2014 and 2015 (Merrill et al., 2015).

**Social and environmental drivers:** Although in most cases the inter-linked financial and economic rationales prevail as a primary driver of fossil fuel subsidy reform, increasingly broader environmental (including climate-related) issues are creating a direct motive for reform. This includes an increasing focus on the health and safety impacts of fossil fuel production, and a falling social licence to operate in the context of climate impacts (highlighted through the global divestment movement).

Government support plays a critical role in the economics of fossil fuel production. Due to falling prices, rising costs, improvements in efficiency, more stringent environmental regulations and greater competition from ever-cheaper alternatives, it may increasingly be that fossil fuel production is only sustained because of government subsidies. On the other hand, if policy were aligned with climate objectives, subsidies would not be focused on producing fossil fuels, but on facilitating the energy transition.

Yet, on a global scale, the level of support for incumbent fossil fuels dwarfs that provided to alternatives for energy services. These alternatives to fossil fuels include not only renewable energy, but also the complementary technologies that will increase the uptake of the latter and better balance energy supply and demand, through efficiency, interconnection, storage and electrification of vehicles and heating. The potential to transfer significant volumes of investment away from fossil fuels and towards alternative energy services and other public goods, is significant. The energy transition will only be accelerated through the removal of fossil fuel subsidies.

#### **6.4.2 Opportunities for international collaboration and support**

In 2009, the G20 and Asia-Pacific Economic Cooperation leaders agreed to phase out ‘inefficient fossil fuel subsidies in the medium term’. Implementation, however, has been slow and patchy, and focused on consumption subsidies.

While reform is ultimately undertaken at the national or sub-national level, international cooperation is already supporting national reform efforts in many ways, by identifying and estimating subsidies, providing support for country-level reform processes, coordinating reform efforts and drawing out lessons and advocacy.

There are, however, important opportunities for these existing activities to be scaled up, and for new efforts to be developed in order to: 1) improve the availability of comparable information on fossil fuel subsidies; 2) increase technical and financial support for national reform efforts (with a focus on complementary measures); and 3) widen and strengthen countries’ commitment to reform.

The primary channels for this scaled-up ambition and action at the international level are: 1) bodies for reporting, tracking and accountability; 2) financial and technical support which must be diverted away from providing subsidies and toward reform; 3) multilateral and bilateral agreements (including on trade); and 4) through regions and countries leading by example in reforming subsidies.

## 6.5 Recommendations

Recognising that subsidies for fossil fuel production: drive the world towards exceeding safe climate limits; enable increasingly risky and uneconomic activities by fossil fuel companies; place countries and companies at financial risk of stranded assets in a carbon-constrained world; strain treasuries; and divert public resources away from supporting low-carbon energy systems and universal energy access.

Governments, led by the G20, must: and including those in this study

- Adopt a 2020 deadline for the phase-out of fossil fuel subsidies with country-specified measurable outcomes.
- Increase transparency through a publicly disclosed, consistent reporting scheme for all national subsidies for fossil fuels, strengthening the OECD inventory and expanding it to include all countries (using their model for tracking agricultural subsidies).
- Increase transparency of reporting on investment in and finance for fossil fuels by state-owned enterprises and majority publicly owned financial institutions.
- Work closely within international institutions and processes, such as the G20 and APEC, the OECD, the UNFCCC and the Sustainable Development Goals to ensure that any existing incentives for fossil fuel production are eliminated, and to monitor reforms so that no new incentives are established.
- Transfer subsidies from fossil fuel production to support wider public goods, including the transition to low-carbon energy systems and universal energy access.

Phasing out fossil fuel subsidies is a critical and necessary step to limit the impacts of climate change, reduce air pollution and facilitate the transition to low-carbon energy systems. Removing public support for fossil fuels would rebalance our energy markets and force the industry to operate on a more level playing field with emerging options to provide the same energy services. Ending these subsidies will also free up scarce government resources for development needs and social goods.



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## Appendix 1 Global Coal Plant Tracker

Global Coal Plant Tracker - CoalSwarm - Comparison 1/16 vs 7/16 MW

	Announced	Pre-permit development	Permitted	Announced + Pre-permit + Permitted	Construction	Shelved	Cancelled 2010-2016
China (1/16)	247,160	217,294	54,960	519,414	193,179	61,735	164,495
China (7/16)	231,992	147,520	26,340	405,852	205,144	112,675	203,595
India (1/16)	64,630	95,595	58,244	218,469	72,200	85,065	305,272
India (7/16)	56,130	78,385	43,700	178,215	64,669	111,345	319,637
<b>OTER ASIA</b>							
Vietnam (1/16)	15,620	10,400	14,820	40,840	12,140	0	13,930
Vietnam (7/16)	13,900	14,200	2,520	30,620	15,789	0	28,350
Indonesia (1/16)	17,825	17,930	4,400	40,155	5,210	1,450	5,465
Indonesia (7/16)	24,965	12,735	1,930	39,630	8,215	9,220	7,795
Philippines (1/16)	1,872	4,952	750	7,574	4,448	600	1,450
Philippines (7/16)	2,472	6,824	750	10,046	3,780	600	1,650
Japan (1/16)	7,982	10,407	3,022	21,411	1,977	0	0
Japan (7/16)	3,212	13,521	2,312	19,045	3,059	0	0
Pakistan (1/16)	10,470	3,890	5,793	20,153	930	5,800	7,620
Pakistan (7/16)	8,305	4,700	5,403	18,408	2,880	4,810	8,610
Bangladesh (1/16)	9,277	4,810	0	14,087	0	0	283
Bangladesh (7/16)	4,860	8,185	0	13,045	0	3,647	283
Sri Lanka (1/16)	3,300	1,000	0	4,300	0	600	1,200
Sri Lanka (7/16)	1,800	500	500	2,800	0	0	1,800
Thailand (1/16)	3,425	3,940	0	7,365	0	4,000	500
Thailand (7/16)	4,425	3,000	0	7,425	600	4,600	500
South Korea (1/16)	2,000	7,542	1,000	10,542	10,234	0	3,840
South Korea (7/16)	2,000	5,340	3,080	10,420	9,254	0	3,840
Cambodia (1/16)	1,200	0	540	1,740	405	1,830	200
Cambodia (7/16)	3,200	0	540	3,740	405	0	200
Laos (1/16)	1,226	0	0	1,226	1,252	0	0
Laos (7/16)	1,326	0	0	1,326	0	0	0
Myanmar (1/16)	1,226	0	0	1,226	1,252	0	4,720
Myanmar (7/16)	1,326	0	0	1,326	0	0	4,720
Taiwan (1/16)	6,000	0	0	6,000	5,600	6,800	0
Taiwan (7/16)	0	0	0	0	5,600	12,800	0
Malaysia (1/16)	0	2,000	0	2,000	2,600	1,800	1,710
Malaysia (7/16)	0	2,000	0	2,000	1,600	1,800	1,710
North Korea (1/16)	0	0	0	0	300	0	0
North Korea (7/16)	0	0	0	0	300	0	0
Total (1/16)	312,581	274,415	85,285	672,281	239,527	80,015	203,430
Total (7/16)	292,698	206,840	42,875	542,413	256,626	141,905	260,470

### Appendix 3 Integrated Assessment Models – IPCC WG3 AR5 <sup>68</sup>

*‘All integrated models share some common traits. Most fundamentally, integrated models are simplified, stylized, numerical approaches to represent enormously complex physical and social systems. They take in a set of input assumptions and produce outputs such as energy system transitions, land-use transitions, economic effects of mitigation, and emissions trajectories. Important input assumptions include population growth, baseline economic growth, resources, technological change, and the mitigation policy environment*

*... Perfect-foresight models (e. g., intertemporal optimization models) optimize over time, so that all future decisions are taken into account in today’s decisions. In contrast, recursive-dynamic models make decisions at each point in time based only on the information in that time period. In general, perfect-foresight models would be likely to allocate emissions reductions more efficiently over time than recursive dynamic models, which should lead to lower aggregate costs*

*... Models can be categorized into two groups with respect to technological change. On one end of the spectrum, models with exogenous technological change take technology as an input that evolves independently of policy measures or investment decisions. These models provide no insight on how policies may induce advancements in technology. On the other end of the spectrum, models with endogenous technological change (also known as induced technological change) allow for some portion of technological change to be influenced by deployment rates or investments in research and development (RandD). Models featuring endogenous technological change are valuable for understanding how the pace of technological change might be influenced by mitigation policies.*

*... A question that is often raised about particular stabilization goals and transformation pathways is whether the goals or pathways are ‘feasible’ (see Section 6.1). Integrated models can be helpful in informing this question by providing information about key elements of transformation pathways that might go into assessments of feasibility, such as rates of deployment of energy technologies, rates of reductions in global and regional emissions, aggregate economic costs, financial flows among regions, and links to other policy objectives such as energy security or energy prices. However, beyond cases where physical laws might be violated to achieve a particular scenario (for example, a 2100 carbon budget is exceeded prior to 2100 with no option for negative emissions), these integrated models cannot determine feasibility in an absolute sense.*

*... The most critical set of technologies in the context of the timing of emission reductions is CDR technologies, which can be used to generate negative emissions (van Vuuren et al., 2007; Edenhofer et al., 2010; Azar et al., 2010, 2013; van Vuuren and Riahi, 2011; Tavoni and Socolow, 2013). In most model studies in the literature, negative emissions are generated via the use of biomass energy with carbon dioxide capture and storage (BECCS), and to a lesser extent, afforestation, though in principle other options could potentially result in negative emissions as well (see Section 6.9). CDR technologies have not*

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<sup>68</sup> [https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc\\_wg3\\_ar5\\_chapter6.pdf](https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter6.pdf)

been applied yet at large scale. The potential of afforestation is limited, and the use of BECCS is ultimately constrained by the potential for CCS and biomass supply (van Vuuren et al., 2013). CDR technologies have two key implications for transformation pathways. One is that by removing emissions from the atmosphere, CDR technologies can compensate for residual emissions from technologies and sectors with more expensive abatement. The second is that CDR technologies can create net negative emissions flows, which allow faster declines in concentrations in the second half of the century and thus facilitate higher near-term emissions, effectively expanding the potential scope for overshoot. In model comparison studies, many of the models that could not produce scenarios leading to concentrations of about 450 ppm CO<sub>2</sub>eq by 2100, particularly in combination with delayed or fragmented policy approaches, did not include CDR techniques (Clarke et al., 2009). The vast majority of scenarios with overshoot of greater than 0.4 W / m<sup>2</sup> (greater than 20 ppm CO<sub>2</sub>eq) deploy CDR technologies to an extent that net global CO<sub>2</sub> emissions become negative. Evidence is still mixed whether CDR technologies are essential for achieving very low GHG concentration goals (Rose et al., 2013). A limited number of studies have explored scenarios with net negative emissions as large as 20 GtCO<sub>2</sub> per year or more (lower panels Figure 6.7), which allow for very substantial delays in emission reductions. However, the majority of studies have explored futures with smaller, but often still quite substantial, contributions of CDR technologies. Technology portfolio assumptions other than CDR technologies (e. g., regarding renewables, CCS, efficiency, and nuclear power) can also have implications for emissions trajectories, although these are often less pronounced and may in fact shift mitigation earlier or later (Rogelj et al., 2012; Eom et al., 2014; Krey et al., 2014; Kriegler et al., 2014a; Riahi et al., 2014)

... A final observation is that the characteristics of emissions profiles discussed here are, in many cases, driven by the cost-effectiveness framing of the scenarios. A more comprehensive consideration of timing would also include, among other things, considerations of the tradeoff between the risks related to both transient and long-term climate change, the risks associated with deployment of specific technologies and expectation of the future developments of these technologies, short-term costs and transitional challenges, flexibility in achieving climate goals, and the linkages between emissions reductions and a wide range of other policy objectives (van Vuuren and Riahi, 2011; Krey et al., 2014; Riahi et al., 2014).

... The decarbonization of the energy supply will require a significant scaleup of low-carbon energy supplies, which may impose significant challenges (see Section 7.11.2). The deployment levels of low-carbon energy technologies are substantially higher than today in the vast majority of scenarios, even under baseline conditions, and particularly for the most stringent concentration categories. Scenarios based on an idealized implementation approach in which mitigation begins immediately across the world and with a full portfolio of supply options indicate a scaleup of anywhere from a modest increase to upwards of three times today's low-carbon energy by 2030 to bring concentrations to about 450 ppm CO<sub>2</sub>eq by 2100. A scaleup of anywhere from roughly a tripling to over seven times today's levels in 2050 is consistent with this same goal Figure 6.18, Section 7.11.4). The degree of scaleup depends critically on the degree of overshoot, which allows emissions reductions to be pushed into the future



*... A major advance in the literature since AR4 is the assessment of scenarios with limits on available technologies or variations in the cost and performance of key technologies. These scenarios are intended as a rough proxy for economic and various non-economic obstacles faced by technologies. Many low-carbon supply technologies, such as nuclear power, CO<sub>2</sub> storage, hydro, or wind power, face public acceptance issues and other barriers that may limit or slow down their deployment (see Section 7.9.4). In general, scenarios with limits on available technologies or variations in their cost and performance demonstrate the simple fact that reductions in the availability and / or performance or an increase in costs of one technology will necessarily result in increases in the use of other options. The more telling result of these scenarios is that limits on the technology portfolio available for mitigation can substantially increase the costs of meeting long-term goals. Indeed, many models cannot produce scenarios leading to 450 ppm CO<sub>2</sub>eq when particularly important technologies are removed from the portfolio.'*

## Appendix 4.1- The Age structure of Chinese Subcritical coal plants – source CoalSwarm.

**China Coal Fleet Age Structure 2015-2050, Currently Operating Plants Only (MW)**

Year	0 Yrs or Older	1-5 Yrs or Older	6-10 Yrs or Older	11-15 Yrs or Older	16-20 Yrs or Older	21-25 Yrs or Older	26 Yrs or Older
2015	82,242	39,767	12,695	3,930	1,400	300	250
2016	97,451	48,347	16,147	4,030	1,400	300	250
2017	108,655	58,750	20,834	5,030	1,500	350	250
2018	124,012	65,535	28,221	7,125	2,400	550	250
2019	134,844	72,875	34,063	8,875	2,930	750	250
2020	152,647	82,242	39,767	12,695	3,930	1,400	300
2021	166,543	97,451	48,347	16,147	4,030	1,400	300
2022	175,028	108,655	58,750	20,834	5,030	1,500	350
2023	193,655	124,012	65,535	28,221	7,125	2,400	550
2024	222,446	134,844	72,875	34,063	8,875	2,930	750
2025	268,448	152,647	82,242	39,767	12,695	3,930	1,400
2026	350,623	166,543	97,451	48,347	16,147	4,030	1,400
2027	427,323	175,028	108,655	58,750	20,834	5,030	1,500
2028	484,036	193,655	124,012	65,535	28,221	7,125	2,400
2029	548,289	222,446	134,844	72,875	34,063	8,875	2,930
2030	609,267	268,448	152,647	82,242	39,767	12,695	3,930
2031	674,548	350,623	166,543	97,451	48,347	16,147	4,030
2032	724,047	427,323	175,028	108,655	58,750	20,834	5,030
2033	776,724	484,036	193,655	124,012	65,535	28,221	7,125
2034	816,704	548,289	222,446	134,844	72,875	34,063	8,875
2035	872,964	609,267	268,448	152,647	82,242	39,767	12,695
2036	884,544	674,548	350,623	166,543	97,451	48,347	16,147
2037	884,544	724,047	427,323	175,028	108,655	58,750	20,834
2038	884,544	776,724	484,036	193,655	124,012	65,535	28,221
2039	884,544	816,704	548,289	222,446	134,844	72,875	34,063
2040	884,544	872,964	609,267	268,448	152,647	82,242	39,767
2041	884,544	884,544	674,548	350,623	166,543	97,451	48,347
2042	884,544	884,544	724,047	427,323	175,028	108,655	58,750
2043	884,544	884,544	776,724	484,036	193,655	124,012	65,535
2044	884,544	884,544	816,704	548,289	222,446	134,844	72,875
2045	884,544	884,544	872,964	609,267	268,448	152,647	82,242
2046	884,544	884,544	884,544	674,548	350,623	166,543	97,451
2047	884,544	884,544	884,544	724,047	427,323	175,028	108,655
2048	884,544	884,544	884,544	776,724	484,036	193,655	124,012
2049	884,544	884,544	884,544	816,704	548,289	222,446	134,844
2050	884,544	884,544	884,544	872,964	609,267	268,448	152,647

## Appendix 4.2 CoalSwarm Global Coal Plant Tracker Methodology

Data for this report was provided by the Global Coal Plant Tracker (GCPT), a database of existing and proposed coal-fired power plants of 30 MW or larger developed by CoalSwarm. Results of the GCPT were first released in July 2014 on EndCoal.org and are updated every six months.

The GCPT uses a two-level system for organizing information. Summary information is maintained in Google sheets, with a separate sheet for each country (outside India and China) and for each state or province (inside India and China). Each worksheet row tracks an individual coal plant unit. Details at the

individual project level are recorded on footnoted wiki pages. When information about a proposed power station changes, the changes are made to both the spreadsheet and wiki page.

For each update cycle, preliminary lists of plants in each country are gathered from public and private data sources including Platts UDI World Energy Power Plant database, Global Energy Observatory, CARMA, BankTrack's 'Dirty Deals' list, Wikipedia, Enipedia, SourceWatch, Industcards 'Power Plants Around the World Photo Gallery,' India Central Electricity Authority's 'Monthly Report on Broad Status of Thermal Power Projects in the Country,' National Integrated Resource Plans, reports by state-owned and private utilities, and national-level trackers by researchers and advocates (Germany: Deutsche Umwelthilfe; Japan: Kiko Network; Turkey: Greenpeace Kara Atlas; Vietnam: GreenID; US: Sierra Club). For each project in China, the English name is converted to Pinyin. For all countries, alternate names for projects are also tracked.

For each project location, a wiki page is created and maintained on the Center for Media and Democracy's SourceWatch wiki. Wiki pages provide a repository for in-depth information including project background, financing, environmental impacts, coal types and sources, public opposition, aerial photographs, videos, links to permits, plant location (longitude and latitude), and maps. Under standard wiki convention, each piece of information is linked to a published reference, such as a news article, company report, or government permit.

In order to ensure data integrity in the open-access wiki environment of SourceWatch, CoalSwarm researchers review all edits of project wiki pages by unknown editors, an infrequent occurrence.

For each proposed coal plant unit, one of the following status categories is assigned:

- **Announced:** Proposed plants that have been described in corporate or government plans but have not yet taken concrete steps, such as applying for permits or acquiring land.
- **Pre-permit development:** Plants that are seeking environmental approvals and pursuing other developmental steps such as securing land and water rights. In India, this means that a 'Terms of Reference' has been received from the Ministry of Environment and Forests (MoEF). In China, this means a feasibility study has been completed.
- **Permitted:** All necessary environmental approvals have been received but the project has not yet begun construction. In India, this means a project has received an 'Environmental Clearance' permit from the MoEF. In China, this means a plant has received a permit from the National Development and Reform Commission (NDRC), allowing for construction, or the equivalent approval at the provincial level.
- **Construction:** Site preparation and other development and construction activities are underway.
- **Shelved:** Projects where sufficient evidence is found to indicate that a project is no longer moving forward, but not enough to declare it definitively Cancelled. Projects where construction has been put on hold are also considered 'Shelved.' A project that shows no activity over a period of 2 years is categorized as 'Shelved': unless there is evidence to the contrary.
- **Cancelled:** In some cases a sponsor announces that it has cancelled a project. More often a project fails to advance and then quietly disappears from company documents. A project that was previously in an active category is moved to 'Cancelled' if it disappears from company documents, even if no announcement is made. In addition, a plant that shows no activity over a



period of 4 years is categorized as 'Cancelled,' unless there is evidence to the contrary. Projects that are switched to natural gas are considered 'Cancelled' as coal plants.

- **Operating:** The plant has been formally commissioned.
- **Deactivated:** Projects that are not currently operating but not permanently retired.
- **Retired:** Projects that have been permanently decommissioned or converted to another fuel.

Once wiki pages are created and summary data sets compiled, they are circulated for review to researchers and organizations familiar with local conditions, updates, and languages.

For CoalSwarm's July 2016 update, China data was modified based on analysis by Greenpeace East Asia of [China's April 2016 guidelines for reining in the country's overcapacity](#) in coal-fired power generation, discussed in the Greenpeace report '*Burning Money: How China could squander over one trillion yuan on unneeded coal-fired capacity*,' July 2016:

*The guidelines suspend new approval for coal-fired power projects in 13 provinces and slow down construction in 15 provinces with exception for district heating power plants and power exporting projects in the coal bases.*

*Provinces and regions should suspend new approvals: Heilongjiang, Shandong, Shanxi, Inner Mongolia, Jiangsu, Anhui, Fujian, Hubei, Henan, Ningxia, Gansu, Guangdong and Yunnan (13 provinces and regions).*

*Provinces and regions should halt or slow down new projects construction: Heilongjiang, Liaoning, Shandong, Shanxi, Inner Mongolia, Shaanxi, Ningxia, Gansu, Hubei, Henan, Jiangsu, Guangdong, Guangxi, Guizhou and Yunnan (15 provinces and regions).*

In addition to the exception for district heating power plants and power exporting projects in coal bases, the policy also allowed for an exception for projects in 'revolutionary areas and poor areas'.

Plants identified by Greenpeace as located within restricted provinces and not affected by one of the three exception criteria (district heating, power exporting, and revolutionary/poor) were reclassified by the Global Coal Plant Tracker as 'Shelved.'

For each coal plant unit, the tracker calculates carbon dioxide emissions based on the following:

- unit capacity;
- emission factor (pounds of carbon dioxide per million Btu) for each type of coal;
- heat rate for each combustion technology (Btu/kWh), adjusted for quality of coal;
- capacity factor based on the 2013 worldwide average of 59.3% ([IEA 'World Energy Outlook,' Annex A, November 2015](#)).

Further details can be found at CoalSwarm, ['Estimating carbon dioxide emissions from coal plants,'](#) SourceWatch, December 2015.





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