

The incompatibility of high-efficient coal technology with 2°C scenarios



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Summary

In December 2015, international governments in Paris pledged to limit global average temperature rise to well below 2°C above pre-industrial levels, and to pursue efforts to keep it under 1.5°C. In order to meet these commitments, the world needs to move towards a low-carbon economy. According to the International Panel on Climate Change's (IPCC) assessment of emissions scenarios, this implies that **by 2050 the global electricity sector needs to be decarbonised**. The deployment of high-efficient low-emission (HELE) coal-fired power plants is presented by the coal industry and some governments as a technology that is climate friendly, claiming that if combined with carbon capture and storage (CCS) – another, separate technology – it would ultimately lead to zero and even negative emissions. HELE technologies for coal-fired power generation could reduce emissions from over 1,000 gCO₂/kWh for current coal plants in operation, to 670 gCO₂/kWh for future most efficient coal plants – to be compared with 350-490 gCO₂/kWh for gas turbines or 0 gCO₂/kWh direct emissions for wind and solar power.

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 1,400 GW 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.

This conclusion was reached through an assessment of the IPCC scenarios presented in the Fifth Assessment Report, of the role of coal plants in the IEA World Energy Outlook 2015 scenarios, and of the data on coal plants currently planned and/or under construction.



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1 Introduction

To limit the long-term, global average temperature rise well below 2°C above pre-industrial levels, the world needs to move towards a low-carbon economy and a fully decarbonised power sector by 2050. At the international climate summit, COP21, in Paris in December 2015 the 2°C objective was tightened, as Parties committed 'to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change'¹. High-efficiency, low-emissions (HELE) coal-fired power generation has been proposed as one of the solutions to greenhouse gas mitigation. This report examines the role of HELE coal-fired electricity generation in 2°C compatible pathways.

What is high-efficiency, low-emissions (HELE) coal-fired electricity generation?

HELE coal-fired electricity generation is electricity produced from plants which have a higher conversion efficiency² and lower CO₂ emissions intensity than conventional subcritical coal-fired power plants³. Due to these features, the development and deployment of HELE technologies is promoted by the coal industry and some governments as one of the key steps towards CO₂ emissions mitigation in the energy sector⁴. There is a range of HELE technologies for power generation with various degrees of conversion efficiency and levels of emissions, known as supercritical (SC), ultra-supercritical (USC), advanced ultra-supercritical (A-USC) and integrated gasification combined cycle (IGCC) plants. The plant efficiency, CO₂ emissions intensity and coal consumption of these plants are displayed in Table 1.

In 2011, approximately 50% of new coal-fired power plants used HELE technologies, predominantly SC and USC pulverised coal combustion units⁵. USC coal combustion is currently the most efficient HELE technology, with some units reaching a conversion efficiency of 45%, and with an emission intensity of 740 gCO₂/kWh. Development of A-USC technology is expected to begin in the 2020s and could lower emissions to 670 gCO₂/kWh.

¹ Paris Agreement, <http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf>

² The energy conversion efficiency of a coal plant is the ratio of the (net) useful energy output (i.e. electricity) and the energy content (lower heating value) of the fuel input (i.e. coal).

³ Source: International Energy Agency, 2012, *High-Efficiency, Low-Emissions Coal-Fired Power Generation Technology Roadmap*.

⁴ Source: Ibid; World Coal Association, *High efficiency low emission coal*, available at: <https://www.worldcoal.org/reducing-co2-emissions/high-efficiency-low-emission-coal>

⁵ Source: International Energy Agency, 2012, *High-Efficiency, Low-Emissions Coal-Fired Power Generation Technology Roadmap*.

Table 1 Conversion efficiency, CO₂ emissions intensity and coal consumption values for coal technologies^{6,7}

Technology	Conversion efficiency ²	CO ₂ emissions intensity (gCO ₂ /kWh)	Coal consumption (g/kWh)
Subcritical	Up to 38%	≥880	≥380
Supercritical	Up to 42%	800–880	340–380
Ultra-supercritical	Up to 45%	740–800	320–340
A-USC/IGCC	45–50%	670–740	290–320

Some remarks need to be made with respect to HELE coal technology:

- 'High-efficiency' and 'low-emission' of HELE coal technology refers to the characteristics of conventional subcritical coal power plants. Other technologies have higher efficiencies (e.g. up to 60% for gas turbines), and lower direct CO₂ emission factors (e.g. 350-490 gCO₂/kWh for gas turbines, 0 gCO₂/kWh for wind and solar power)⁸.
- The indicators presented in Table 1 can be achieved when the coal plant operates under constant and high capacity factors. In real markets the plants have lower utilisation rates, and have to frequently ramp up and down, which deteriorates these performance indicators. In future electricity systems – with larger shares of variable renewable electricity – this situation will be predominant.
- The CO₂ emission factors presented in in Table 1 represent direct emissions at plant level (ranges a.o. reflect the different qualities of the coal input). Lifecycle emissions (including the emissions through the entire coal value chain: extraction, processing, transport, etc.) are about 40-70 gCO₂/kWh higher⁸.

Coal-fired electricity generation with carbon capture and storage (CCS) will reduce emissions intensity but also conversion efficiency.

Coal-fired electricity generation with carbon capture and storage (CCS) has also been proposed separately as a possible measure to reduce greenhouse gas emissions, and has a crucial role in 2°C scenarios from the International Panel on Climate Change (IPCC) and International Energy Agency (IEA). CCS is a process where CO₂ is separated from industrial and energy-related emissions, transported to a storage location and isolated from the atmosphere in the long term⁹.

⁶ Source: International Energy Agency, 2012, *High-Efficiency, Low-Emissions Coal-Fired Power Generation Technology Roadmap*.

⁷ CO₂ emissions intensities differ per coal type: increasing from bituminous, sub-bituminous to lignite, which is reflected in the ranges.

⁸ Source: Intergovernmental Panel on Climate Change, 2014, *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Annex III).

⁹ Intergovernmental Panel on Climate Change, 2005, *IPCC Special Report on Carbon Dioxide Capture and Storage*.

Coal plants fitted with CCS are assumed in this report to have an emissions intensity of about 100 gCO₂/kWh (which is believed to be a conservative estimate)¹⁰, which is less than 20% of the intensity of the most efficient HELE plant.

However just as for HELE coal technology real-life emission factors will be higher, and conversion efficiencies lower, as the process of capturing CO₂ consumes energy. Lifecycle emissions for CCS are 70-110 gCO₂/kWh higher than the range of 95-150 gCO₂/kWh reported in literature¹¹.

This report investigates the role of HELE coal-fired electricity generation in meeting the 2°C target.

Firstly, this report will present the 2°C scenarios considered by the Intergovernmental Panel on Climate Change (IPCC) and their implications for electricity sector emissions and coal-fired electricity generation.

Secondly, the scenarios of the International Energy Agency's (IEA) World Energy Outlook 2015 report are analysed. This part of the analysis focuses on the assumptions of the models, and how their outcomes compare to the IPCC 2°C scenarios.

Finally, the scenarios of IPCC and IEA are evaluated against the actual planned coal capacity. This part of the analysis considers the projected emissions, and whether these are in line with staying below the 2°C limit. It also considers two separate theoretical cases where the entire planned capacity are HELE plants or plants that are equipped with CCS.

¹⁰ The IPCC states that the emissions intensity of a new pulverised coal plant equipped with CCS is between 92–145 gCO₂/kWh, with a representative value of 112 gCO₂/kWh, while the emissions intensity of a new IGCC plant is between 65-152 gCO₂/kWh, with a representative value of 108 gCO₂/kWh. Considering these representative values, this study assumes an emissions intensity of 100 gCO₂/kWh. Source: Ibid.

¹¹ Intergovernmental Panel on Climate Change, 2014, *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Annex III).

2 The role of HELE coal-fired electricity generation in 2°C scenarios

2.1 Implications of 2°C scenarios on coal-fired electricity generation and electricity sector emissions

To be 2°C compatible, the electricity sector needs to be decarbonised by 2050.

In order to limit global warming to well below 2°C above pre-industrial levels, greenhouse gas emissions from all sectors need to be slashed over the next decades.

Figure 1 shows the IPCC’s Fifth Assessment Report (AR5) scenarios (see Box 1 for a description of these scenarios), with annual emissions from the electricity sector needing to be cut from current levels (13.4 GtCO₂ in 2013)¹² to approximately zero by 2050¹³. In this scenario, from 2050 onwards negative emissions from the electricity sector are needed, which could be delivered through for instance biomass energy with carbon capture and storage (BECCS), or through (more) carbon sequestration outside the electricity sector, for example through reforestation, air capture, and/or mineral carbonisation.

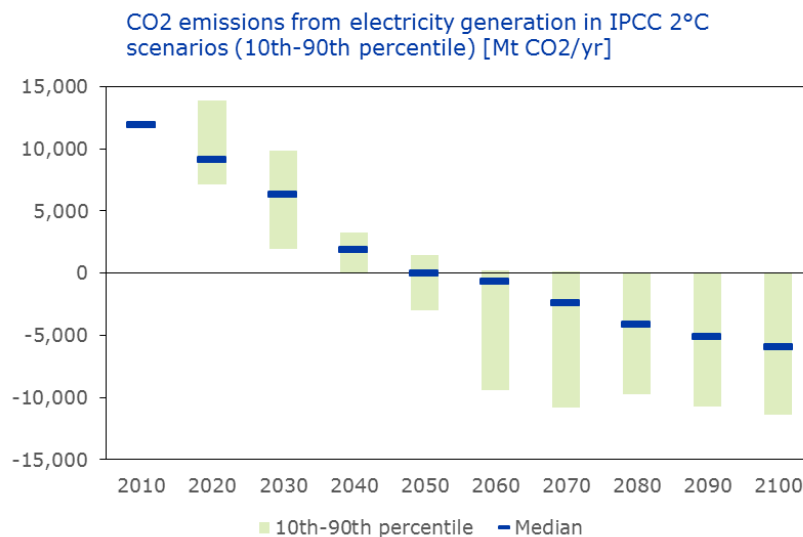


Figure 1 CO₂ emissions from electricity generation in 2°C scenarios included in the IPCC AR5 report. The green range indicates the 10th to 90th percentile, and the blue line indicates the median value¹³.

¹² Source: International Energy Agency, 2015, *World Energy Outlook*.

¹³ Source: Intergovernmental Panel on Climate Change, 2014, *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.

Box 1 IPCC scenarios¹³

The IPCC finds that emission pathways resulting in a maximum concentration of 430–480 ppmCO₂e by the end of the century, would give a 66% chance of confining the global temperature increase to below 2°C by 2100. In our research we assume 450 ppm scenarios to be consistent with 2°C compatible levels insofar as this 430-480 ppmCO₂e threshold is being met: emissions scenarios that were excluded in our research were those that either (1) failed to limit warming to below 2°C with an at least 66% chance; (2) deviate from central historical estimates of 2010 global emissions by more than 5%; (3) assumed extreme negative CO₂ emissions in the order of -20 GtCO₂/year by the end of the century; (4) involved a “deliberate” delay in mitigation action¹⁴.

These scenarios are produced using various software from different research teams. There is therefore a range in the quantification of numerical values, for example emissions. In this report, we present the median value and the 10th-90th percentile range, i.e. capturing the central 80% of projected values.

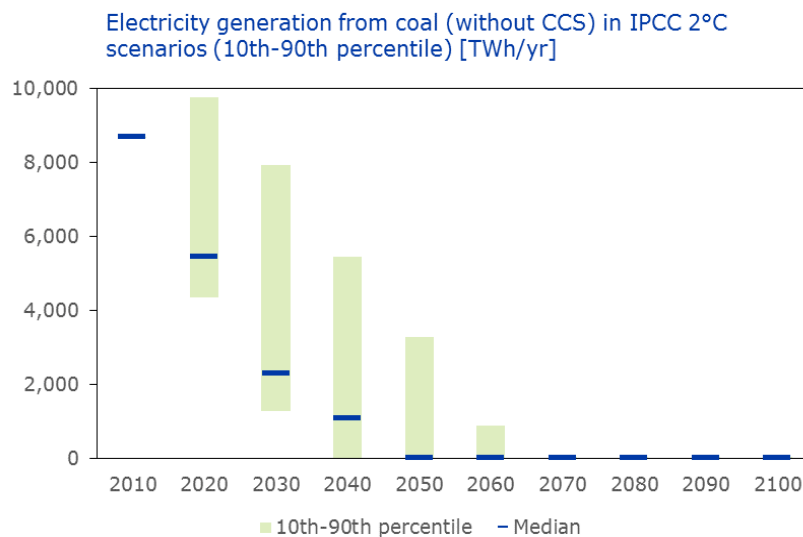


Figure 2 Electricity generation from coal (without CCS) in 2°C scenarios included in the IPCC AR5 report. The green range indicates the 10th to 90th percentile, and the blue line indicates the median value¹³.

¹⁴ Source: Climate Action Tracker, 2015, *The Coal Gap: planned coal-fired power plants inconsistent with 2°C and threaten achievement of INDCs*, available at: http://climateactiontracker.org/assets/publications/briefing_papers/CAT_Coal_Gap_Briefing_COP21.pdf

Unabated coal needs to be phased out by 2050.

Given the need to decarbonise the electricity sector by 2050, it is not surprising that electricity generation from unabated coal (i.e. coal-fired electricity generation without CCS) needs to be cut significantly. According to the median of the IPCC 2°C scenarios, unabated coal-fired electricity generation needs to be almost completely phased out by 2050 (see Figure 2)¹³.

Figure 3 shows that in 1.5°C scenarios¹⁵, the decline in unabated coal-fired electricity generation to 2050 is even more rapid. Being more stringent than the 2°C scenarios, a 1.5°C scenario will require that unabated coal-fired electricity generation to be phased out even sooner. The phase out rate of unabated coal-fired electricity generation increases in these scenarios from around 5% per year over 2010 – 2020 to 8% per year over 2030 – 2040 (compared to 4% and 5% respectively for the 2°C scenarios). Similarly to the 2°C scenarios, under the 1.5°C scenarios, almost all unabated coal-fired electricity generation needs to be phased out by 2050.

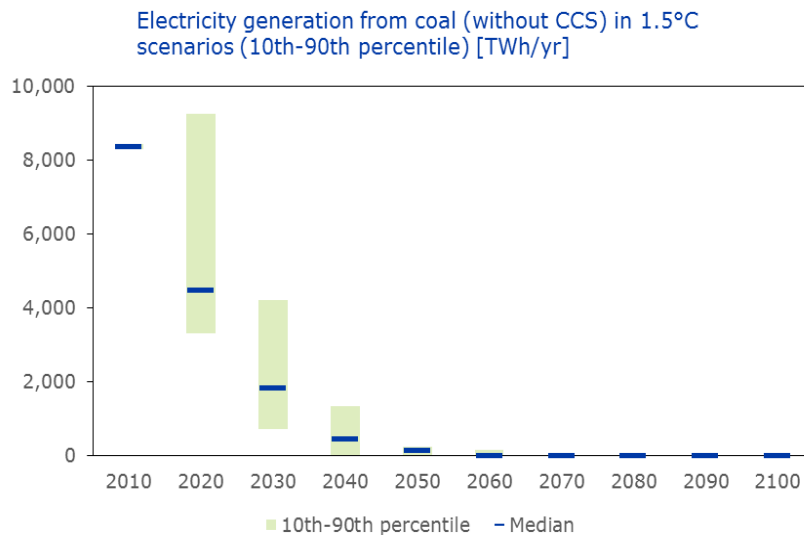


Figure 3 Electricity generation from coal (without CCS) in 1.5°C scenarios. The green range indicates the 10th to 90th percentile, and the blue line indicates the median value¹³.

¹⁵ Source: Rogelj, J., G. Luderer, R. C. Pietzcker, E. Kriegler, M. Schaeffer, V. Krey and K. Riahi (2015). "Energy system transformations for limiting end-of-century warming to below 1.5°C." *Nature Clim. Change* 5(6): 519-527.

2.2 Comparing IEA World Energy Outlook 2015 to IPCC 2°C scenarios

The IEA's 450 Scenario also shows that unabated coal-fired electricity generation must rapidly decline.

The International Energy Agency's (IEA) 2015 World Energy Outlook (WEO) presents three energy scenarios up to 2040 (see box 2). Of these, the 450 scenario (450S) is intended to be consistent with the 2°C limit (see Box 2 and Box 3). Total **CO₂-emissions from fossil fuels** in this scenario surpasses the percentile range of IPCC 2° degrees scenarios by 20% in 2040.

Box 2 WEO 2015 scenarios¹⁶

The 450 Scenario (450S) assumes a set of policies that bring about a trajectory of GHG emissions from the energy sector that is consistent with a 50% chance of limiting the long-term increase in average global temperatures to no more than the 2°C goal. In this scenario, the concentration of greenhouse gases in the atmosphere peaks by around the middle of this century at a level above 450 parts per million (ppm) – which is accepted to be the threshold for keeping global warming below 2°C – but not so high as to be likely to precipitate changes that make the 2°C objective ultimately unattainable. The concentration of greenhouse gases stabilises after 2100 at around 450 ppm. See box 3 for further details on the assumptions of this scenario.

The Current Policies Scenario (CPS) takes into consideration only those policies for which implementing measures had been formally adopted as of mid-2015 and makes the assumption that these policies persist unchanged. (Previously this was called the Reference Scenario).

The New Policies Scenario (NPS) incorporates the policies and measures that affect energy markets and that had been adopted as of mid-2015. It also takes account other relevant intentions that have been announced, even when the precise implementing measures have yet to be fully defined. This includes the energy-related components of the Intended Nationally Determined Contributions (INDCs) submitted by 1 October 2015. In this scenario the global mean temperature increase will be 2.7 to 3.6°C by the end of the century¹⁷.

With regards to coal, the 450S shows that **CO₂ emissions from coal-fired electricity generation** need to decrease by 84% between 2013 and 2040 to 1.5 GtCO₂ per annum (see Figure 4)¹⁶. This emissions trajectory – as such – is consistent with the median trajectory of the IPCC 2°C scenarios to 2040 for the electricity sector (see Figure 5). One of the scenario's key assumptions, however, is that policies and measures are in place to support CCS deployment: while unabated coal-fired electricity generation declines to approximately 1,000 TWh in 2040 – which is similar to the median value in the IPCC 2°C scenarios – the total coal-fired electricity generation in 2040 amounts to the much higher amount of 4,100 TWh: the 450S assumes that in the power sector CCS is deployed in China from around 2020, and in India from around 2025, that CCS is introduced to coal-fired power generation in

¹⁶ Source: International Energy Agency, 2015, *World Energy Outlook*.

¹⁷ <http://climateactiontracker.org/>

Japan, and that extended support to CCS is provided in the US and EU. As a result, three quarters of the total coal generated power (3,100 TWh) come from plants equipped with CCS.

The WEO report is not explicit on the number of HELE coal plants assumed in the 450S scenario. However, given the significant amount of CCS needed and the low emissions intensity of coal plants in the 450S scenario (see Box 3), it is clear that the deployment of HELE coal plants alone will not limit warming to 2°C.

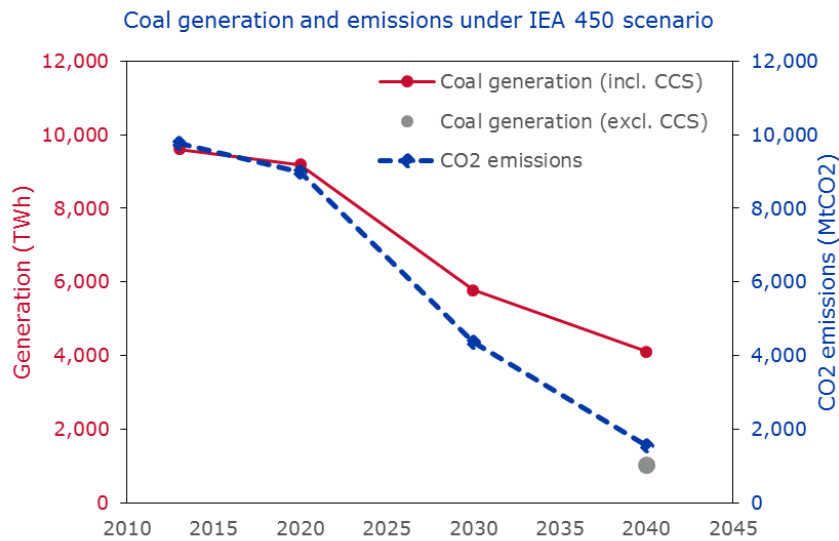


Figure 4 Unabated coal-fired electricity generation (grey marker), coal electricity generation including CCS (red line) and CO₂ emissions (blue line) under the IEA 450 scenario¹⁸, which includes plants fitted with CCS.

¹⁸ Source: International Energy Agency, 2015, *World Energy Outlook*; International Energy Agency, 2016, *Personal Communication*.

Box 3 IEA 450S assumptions on coal-fired electricity generation¹⁸

Coal-fired electricity generation capacity in the 450S declines from 2,000 to 1,250 GW over the period from 2020 – 2040. The WEO report does not explicitly state the number of existing plants which are retired in this scenario and the assumptions on new coal capacity are not clear. However, the type of coal plants in operation can be inferred from the emissions intensity trend. This decreases from 978 gCO₂/kWh in 2020, to 756 gCO₂/kWh in 2030 and 374 gCO₂/kWh¹⁹ in 2040. This trend shows that in the 450S, there is still a significant share of subcritical plants in 2020. However, by 2030 this share is smaller as the emissions intensity in this year is typical to that of USC plants (see Table 1); this could be attributed to a growing number of CCS plants in operation or deployment of HELE plants. By 2040, the low emissions intensity is indicative of the large scale deployment of CCS plants (both new-built and retrofit).

The conversion efficiency of coal plants in the 450S is stable at 36% in 2020–2030 and falls to 34% in 2040²⁰. This trend could be due to the large share of CCS in the 450S; CCS consumes energy and therefore reduces the overall conversion efficiency of a plant. But also the use of dry cooling technologies in water-stressed areas, or lower utilisation rates is mentioned by IEA as a possible cause (even though not explicitly reported in WEO 2015).

The capacity factor of coal plants in the 450S decreases from 53% in 2020 to 43% in 2030 and 37% in 2040²¹. This decline may be attributed to the deployment of renewable energy, as well as the costs of carbon pricing and CCS, which make coal-fired electricity generation more expensive and therefore uncompetitive with lower carbon generation.

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.

The IEA's Current Policies and New Policies scenarios are not consistent with 2°C compatible pathways.

The Current Policies Scenario (CPS) and New Policies Scenario (NPS) of the WEO 2015 report are both inconsistent with the 2°C limit. By 2040 the **CO₂ emissions** from coal-fired electricity generation in these scenarios is at least 8,000 MtCO₂/year higher than the median value of CO₂ emissions from electricity generation from all fossil fuel sources in the IPCC 2°C scenarios (see Figure 5).

¹⁹ Source: own calculation based on IEA WEO 2015 electricity generation and emissions data from coal power plants.

²⁰ Source: own calculation based on IEA WEO 2015 electricity generation and TPED in the power sector for coal.

²¹ Source: own calculation based on IEA WEO2015 electricity generation and installed capacity.

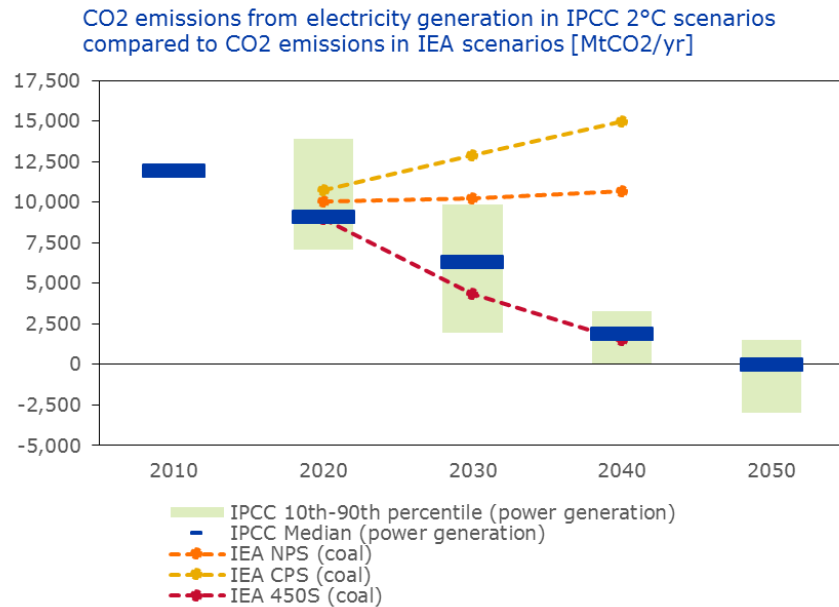


Figure 5 CO₂ emissions from electricity generation in IPCC 2°C scenarios compared to CO₂ emissions from coal-fired electricity generation in IEA scenarios [MtCO₂/year]. Both IEA and IPCC scenarios presented assume deployment of CCS ²².

The quantity of **electricity generated** from coal plants in the CPS and NPS scenarios over 2020 - 2040 is also higher than the range from the IPCC 2°C scenarios (see Figure 6). A source of inconsistency in this comparison is that the IPCC 2°C scenarios consider unabated electricity production, while the IEA scenarios include CCS. The WEO 2015 does not explicitly state the amount of coal-fired electricity generation from plants fitted with CCS over the full 2020 - 2040 period, but based on data for the 2040 end-point it is possible to conclude that neither CPS nor NPS scenarios are compatible with the 2°C goal:

- The WEO states for the New Policies Scenario that “by 2040, total generation from plants fitted with CCS reaches some 470 TWh, more than 90% from coal-fired plants” (hence about 420 TWh).
- Total coal-fired electricity generation in the CPS and NPS equals 16,500 and 11,900 TWh respectively, creating a gap with the unabated coal-fired power generation in the IPCC 2°C scenarios of respectively 15,500 and 10,800 TWh (median values, in 2040).
- Therefore, it is clear that after excluding CCS coal-fired electricity generation from the CPS and NPS, these two scenarios are fully inconsistent with the 2°C pathways.

²² Source: International Energy Agency, 2015, *World Energy Outlook*; International Energy Agency, 2016, *Personal Communication*; Intergovernmental Panel on Climate Change, 2014, *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.

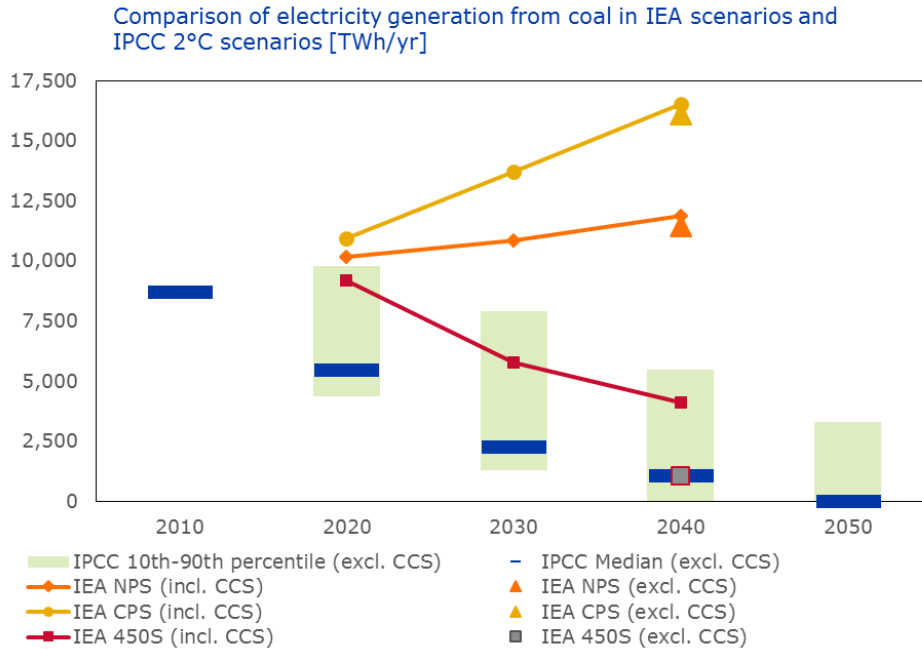


Figure 6 Comparison of electricity generation from coal in IEA scenarios and IPCC 2°C scenarios (10th – 90th percentile). IPCC data excludes CCS, while IEA data is presented including and excluding CCS. For the IEA NPS and CPS scenario, the generation excluding CCS assumes the upper limit of CCS equipped coal-fired electricity generation (420 TWh).

2.3 Planned coal capacity additions in the context of 2°C scenarios

The 1,400 GW of planned coal capacity is not compatible with limiting warming to 2°C.

According to the Global Coal Plant Tracker, 1,400 GW of new coal capacity is planned, partially as additional capacity and partially as replacement of retired plants²³. Of this total, 350 GW is already under construction, while 1050 GW is in other phases (planned, pre-permit, permitted). Assuming that all these planned coal plants are operational by **2030**²⁴, from this year onwards, it would be impossible to remain on an emissions pathway consistent with 2°C: the annual CO₂ emissions from the plants (6,100 MtCO₂^{25,26}) would only be slightly lower than the median annual emissions from the total

²³ Source: Global Plant Tracker, 2016, *Proposed Coal Plants by Country (MW) – January 2016*. Available at: <http://endcoal.org/wp-content/uploads/2016/01/Global-Coal-Plant-Tracker-December-2015-Countries-MW.pdf>.

²⁴ This is a realistic assumption as the typical construction time of a coal-fired power station is five years⁸, with 5-10 years of preparation.

²⁵ Source: Global Plant Tracker, 2015, *Proposed Coal Plants by Country: Annual CO₂ in Million Tonnes (December 2016)*. Available at: <http://endcoal.org/wp-content/uploads/2016/01/Global-Coal-Plant-Tracker-December-2015-Countries-Annual-CO2.pdf>.

²⁶ It is likely that not all planned capacity will actually be constructed. A study by Shearer et al. (2015) found that a growing number of planned coal plants are cancelled due to reasons including environmental concerns and competition with renewables. Source: Shearer C., N. Ghio, L. Myllyvirta., and T. Nace, 2015, "Boom and bust – Tracking the Global Coal Plant Pipeline", available at: <http://endcoal.org/wp-content/uploads/2015/05/BoomBustMarch16embargoV8.pdf>.

electricity sector (i.e. all fossil fuel sources) allowed under the IPCC 2°C scenarios (6,300 MtCO₂/year in 2030, see Figure 7). This means that, in order to operate the planned coal capacity and remain on track to keep warming to 2°C, almost all existing coal plants must be retired and very little unabated generation from natural gas is permitted by 2030.

Comparing the 1400 GW of coal capacity with the median value for electricity production from coal of 2,300 TWh according to the IPCC 2°C scenarios pathway (see Figure 2), one can conclude that these plants would only have a capacity factor of less than 20% (1,600 full load hours). Such a scenario is highly unrealistic due to the financial cost and the coal-gas fuel-switching which is anticipated in the low carbon transition. This therefore shows that the planned capacity is incompatible with the 2°C path towards 2030.

By **2040** this situation is even more striking: the planned coal capacity would produce emissions which are higher than the total emissions allowed from the entire electricity sector under the IPCC 2°C scenario (see Figure 7). This shows with extremely high certainty that the planned coal capacity is not consistent with a 2°C pathway beyond 2040.

Furthermore, the planned coal capacity is greater than the global coal capacity allowed under a 2°C pathway by 2040 (including CCS plants) according to the IEA 450S. In order to remain on the 2°C path, the planned coal capacity will either need to be rapidly phased out well before the 50 year technical lifetime of a coal plant²⁷, or possibly all plants to be retrofitted with CCS (this scenario is discussed in detail below). Alternatively, extensive BECCS will need to be deployed to capture the additional emissions. These actions would be very expensive and would require high carbon prices to secure finance, reaffirming the conclusion that the planned coal plant capacity is not consistent with 2°C compatible pathways.

If all planned capacity were HELE coal-fired electricity generation plants, the 2°C goal would still not be within reach.

The average emissions factor of the planned capacity (830 gCO₂/kWh)²⁸ indicates that not all of these plants are HELE coal-fired electricity generation. If we apply a theoretical case where all of the planned capacity were A-USC plants with an emissions intensity of 670 gCO₂/kWh, the resultant emissions from this planned capacity would be 5,000 MtCO₂. This is still 80% of the median annual electricity sector emissions (from all fossil fuel sources) in the **IPCC** 2°C scenarios in 2030 (see Figure 7).

²⁷ Source: International Energy Agency, 2015, *World Energy Outlook*.

²⁸ Source: own calculation based on the capacity factor of 59% assumed by the Global Coal Plant Tracker.

And from 2040 onwards, such an emission level would remain higher than the 10th–90th percentile electricity sector emissions range. Thus using the same arguments as those presented above, limiting warming to 2°C is not possible with the planned coal capacity, even if all plants would have HELE characteristics.

Figure 7 also considers the impact of HELE plants on the unabated coal-fired electricity generation forecast in the **IEA** scenarios. In 2030, if all unabated coal-fired electricity generation is produced from A-USC plants, the resulting emissions in the CPS and NPS scenarios are higher than the allowed median electricity sector emission level from all fossil fuel sources in the IPCC 2°C scenario. By 2040, the emissions level of the CPS and NPS scenarios are at least three times higher than the median electricity sector emission level in the IPCC 2°C scenarios.

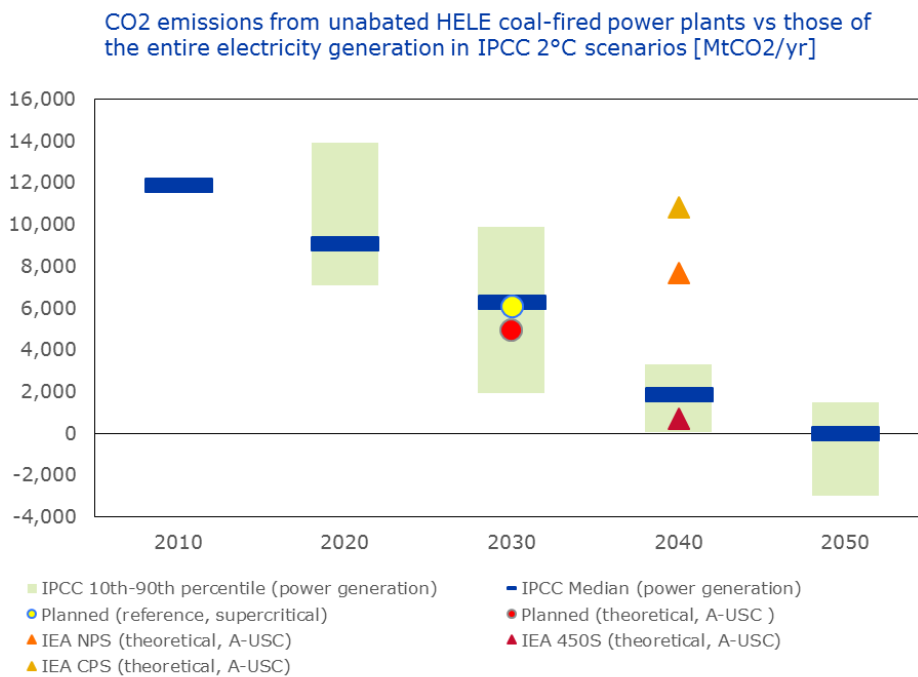


Figure 7 CO₂ emissions from unabated HELE coal-fired power plants (excluding CCS) compared to CO₂ emissions from the entire electricity generation in IPCC 2°C scenarios. 'Planned' refers to the 1400 GW identified in the Global Coal Plant Tracker. IEA NPS, CPS and 450S refer to the three IEA WEO 2015 scenarios (see box 2). For 'Reference, supercritical' it is assumed that all capacity additions are conventional supercritical power plants. For 'Theoretical, A-USC' it is assumed that all new capacity will use advanced ultra-supercritical technologies²⁹.

²⁹ Source: Own calculations; Global Coal Plant Tracker, 2016, *Proposed Coal Plants by Country (MW) – January 2016*, available at: <http://endcoal.org/wp-content/uploads/2016/01/Global-Coal-Plant-Tracker-December-2015-Countries-MW.pdf>; International Energy Agency, 2015, *World Energy Outlook*; International Energy Agency, 2016, *Personal Communication*; Intergovernmental Panel on Climate Change, 2014, *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.

Even if all planned capacity were equipped with CCS, there would be no guarantee that the 2°C goal will be met.

Equipping the planned capacity with CCS would theoretically make the plants feasible under a 2°C pathway to 2050. Emissions from CCS equipped plants would amount to 740 MtCO₂/year³⁰, which is within the emissions trajectory to 2050 needed to constrain warming to 2°C (see Figure 7). Under this scenario, 5,400 MtCO₂ from coal plants would be captured and stored each year. However, it is extremely unlikely that such extensive deployment of CCS will take place by 2030 - within less than 15 years – given that today there is only one large-scale CCS power plant in operation, capturing up to 1 MtCO₂/year³¹, the relative high cost and hence strong competition from other low-carbon technologies, as well as factors such as the changing dynamics on electricity markets, the development of storage sites and associated infrastructure, and regulatory and societal challenges.

Beyond 2050, negative emissions from the electricity sector are needed (see Figure 1). It is debatable whether 1,400 GW of coal CCS capacity is consistent with this long term negative emissions pathway.

³⁰ Assuming an emissions factor of 100 g/kWh.

³¹ Source: Global CCS Institute, *Large Scale CCS Projects*, available at: <http://www.globalccsinstitute.com/projects/large-scale-ccs-projects>.

3 Conclusions

To limit the long-term, global average temperature rise well below 2°C or even 1.5°C above pre-industrial levels, the world needs to move towards a low-carbon economy. The IPCC assessment of emissions scenarios shows that this implies that **by 2050 the electricity sector needs to be decarbonised**. The deployment of high-efficient low-emission (HELE) coal-fired power plants is presented by the coal industry and some governments as a technology that is climate-friendly - ultimately leading to zero and even negative emissions through the introduction of the separate technology of carbon capture and storage (CCS). HELE technologies for power generation include supercritical (SC), ultra-supercritical (USC), advanced ultra-supercritical (A-USC) and integrated gasification combined cycle (IGCC) plants. Specific emissions might drop from values above 1,000 gCO₂/kWh for current (old) plants, to 670 gCO₂/kWh for future plants with novel technologies – to be compared with 350-490 gCO₂/kWh for gas turbines or 0 gCO₂/kWh direct emissions for wind and solar power.

This report examines the role of HELE coal-fired electricity generation and concludes that it is incompatible with 2°C pathways. The global carbon budget and the remaining time 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. Their specific emissions are still too high to fit in a decarbonisation pathway.

This conclusion was reached through an assessment of the IPCC scenarios presented in the Fifth Assessment Report, of the role of coal plants in the IEA World Energy Outlook 2015 scenarios, and of the data on coal plants currently planned and/or under construction.

The IEA's 450 Scenario (450S) shows, like the IPCC 2°C scenarios, that the CO₂ emissions of coal-fired electricity generation must rapidly decline (by 84% over the 2013 - 2040 period). Total electricity sector emissions are above the IPCC range, however. The IEA's 450 Scenario forecasts that the widespread deployment of CCS, rather than HELE coal is critical to constraining warming to 2°C: it forecasts that three-quarters of coal-fired electricity generation will come from plants equipped with CCS by 2040. The other scenarios considered in the WEO (Current Policies (CPS) and New Policies (NPS) scenarios) are not consistent with 2°C scenarios.

Currently, about 1,400 GW of new coal capacity is planned to be constructed in the coming decades. This planned coal capacity is neither compatible with the IPCC 2°C scenarios nor the IEA 450S. From 2040 onwards, emissions from planned capacity would be higher than the emissions of the entire electricity sector in the IPCC 2°C scenarios. This conclusion holds, even if all the planned capacity were HELE coal plants.

Equipping all the planned capacity with CCS would be consistent with 2°C compatible pathways to 2050. However, beyond 2050, a negative emissions pathway is required from the electricity sector.

Throughout this report, optimistic values were used for conversion efficiencies and deployment rates. However, it is not realistic to assume that 1,400 GW of coal based CCS generation will be operational by 2030, and the high capture efficiency needed to reduce the emissions intensity to 100 gCO₂/kWh (which we consider to be a low estimate) may come at a high cost. Thus, 1,400 GW of planned coal capacity is unlikely to be compatible with a long term 2°C trajectory.

There are other facts that further deteriorate the case for coal-fired power plants, be it HELE or equipped with CCS: the development and deployment of these advanced technologies is not a given. Both technological, economical and societal barriers will most likely constrain the theoretical performance and deployment of these options. One example is the operation of coal plants in future energy markets: utilisation rates/load factors can be expected to be lower, and in combination with more frequent ramping up and down this will result in lower conversion efficiencies and higher specific emissions. Furthermore, lifecycle greenhouse gas emissions may be 40-110 gCO₂/kWh higher than direct emissions during the operation phase.

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