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Rapid phase out of coal essential, but not enough to hold warming below 2°C

Climate Action Tracker

Policy Brief

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Summary

- Limiting warming below 2°C requires rapid reductions of all greenhouse gas emissions, especially carbon dioxide emissions from fossil fuel combustion and industrial use.
- Fossil fuel and industrial CO₂ emissions need to be reduced to close to zero by 2050 to hold warming below 2°C with a high probability (85% or more).
- The electricity sector produces over 40% of global CO₂ emissions from fossil fuel combustion. Coal produces over 70% CO₂ of emissions from the electricity sector, although it produces only around 40% of the total electricity generation.
- The electricity sector can and needs to be decarbonised more rapidly than other sectors, however CO₂ emissions in this sector continue to increase rapidly, with coal use one of the main drivers. The most recent emissions data for 2013 confirm that CO2 emissions from coal are still rising at an extreme rate, continuing the trend set since year 2000.
- The International Energy Agency's latest projections (WEO 2013) with current policies estimate that CO2 emissions from coal use in the electricity sector will likely increase by close to 20% by 2020 and 35% by 2030. Under current policies, electricity production is expected to increase significantly and coal electricity production is likely to remain stable at about 40% of electricity generation from now until 2035.
- Under current policies warming is projected to be around 3.7°C by 2100. Completely removing coal from the electricity sector by 2050 would bring this back to around 3.2°C warming. In other words, phasing out coal emissions from the power sector alone would reduce warming by about half a degree and achieve 25% of the task of reducing warming from 3.7°C under current policies to below 2°C.
- Replacing coal with gas, as proposed by some, is clearly not an option it would only reduce warming by about 0.1°C after consideration of the effect of reducing sulphur

emissions, of which about half are co-emitted by coal plants and would be phased-out along with CO₂, irrespective of coal being replaced by gas or renewables.

- In terms of a carbon budget approach, in order to have a high probability of limiting warming below 2°C, a budget of less than 1000 gigatonnes of carbon dioxide remains after 2011. Under the current CAT policies scenario, as assumed here, 4,900 gigatonnes of carbon dioxide will be released to the atmosphere by 2100.
- Current policies in place around the world are projected to exceed the carbon dioxide budget by 3,900 GtCO₂ by 2100.
- Phasing out only coal emissions from the power sector by 2050 would reduce this exceedance by more than 1,400 GtCO₂, or 35%.
- The reduction in warming projected by 2100 achieved with a switch from coal to gas is only 25-45% of what is obtained with a switch to renewables.
- A strong political signal is needed now that the electric power sector needs to be decarbonised by 2050 and emissions from coal use need to be phased out rapidly. It is clear whilst a rapid coal phase out this is just one part of the mix of policy measures needed to limit warming below 2°C, but it is one of the most essential first steps given the momentum towards increasing coal investment in the industry and the real and escalating danger of a lock-in of new carbon-intensive energy sector infrastructure.

Decarbonisation of the power sector: the role of coal

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) found that in order to have a likely chance of keeping global warming below 2°C above preindustrial levels, global CO₂ emissions from the energy supply sector need to decline sharply over the coming decades. Reductions of 90% or more below 2010 levels by between 2040 and 2070 will be needed.¹

Limiting warming to below 2° C with a higher probability (85% or greater) requires faster emission reductions: CO₂ emissions from fossil fuel and industry sources would need to be zero by the 2040s, and certainly no later than 2070 (Figure 1). Negative CO₂ emissions would be required thereafter.

In round terms, CO₂ emissions from fossil fuel

and industry need to be zero by around 2050 to place the world on an emissions pathway that can limit warming below 2°C with high confidence (and keep within reach of bringing warming back to 1.5°C by 2100).

The electricity sector, consuming almost 40% of total primary energy demand in 2011 and with attractive low-carbon options to offer, plays an important role when it comes to decarbonising the future energy system.²

Rapid decarbonisation of the power sector is key in order to hold global warming below 2°C. However, all indications at present are that under present policy settings coal use will increase in the coming decades (Figures 2 & 3). Global electricity production from coal has risen from 4,400 TWh in 1990 to 9,100 TWh in 2011, and currently constitutes around 40% of global electricity production.³

According to the IEA's latest projections in



Figure 1: Total global CO₂ emissions from energy and industry 2005 – 2100 compatible with a 2°C pathway. Source: Own calculations based on IPCC database (10-90% range of AR5 WGIII emission scenarios that are not deliberately forced to reach 2020 emission levels comparable to those implied by the Cancun pledges and do hold warming below 2°C in >66% of climate-model runs) and scenarios that hold warming below 2°C in >66% and return to below 1.5°C by 2100 in >50% of climate-model runs.

¹ In many of the AR5 scenarios remaining below 2°C temperature increase, emissions from energy supply are projected to decline to below zero in the latter half of this century

² IEA (2013): WEO 2013

³ IEA (2013): WEO 2013

the WEO 2013's current policy scenario, i.e. the scenario, which takes into account only those policies and measures affecting energy markets that were formally enacted as of mid-2013, coal will continue its starring role as the main energy source in the global electricity mix until 2035, unless new policy measures are implemented.⁴ The "current policy scenario projects that the share of coal remains stable at 40% from now until 2035. Given that total electricity production is expected to increase significantly, coal



Figure 2: Re-carbonisation of electricity sector between 1990-2011



Figure 3: Past decade has seen strongest increase in CO₂ emissions from coal over last 50 years and faster than any other fossil-fuel source. Source: Le Quéré et al (2014) Global carbon budget 2014, Earth Syst. Sci. Data Discuss., 7, 521-610.

electricity production will too, together with CO2 emissions. The share of renewables of global electricity generation increases from 20% in 2010 to 27% in 2035. Gas is projected to remain stable with a share of around 23% throughout the period.

Given a limited emissions budget for the energy sector, it is necessary to look into different ways of how to decarbonise. One clear option is to eliminate the most polluting energy source: coal.

> It is in this context that CAT addresses the question of the impact of a phase-out of coal from the power sector. In this briefing, we explore scenarios where coal is phased out of global electricity generation by the middle of this century and replaced with renewable energy or gas power. We calculate the potential effect such a phase out would have on the global temperature increase in 2100.

Coal phase out scenarios: the power sector

Electricity generation based on coal is the most carbon-intensive of all electricity production. It is than тоге twice ลร emissions-intensive as gas production, and power clearly considerably more than renewable energybased electricity generation.

Using an estimate of 1,000 g CO₂/kWh,⁵ the 9,100 TWh electricity produced by coal-fired power plants in 2011 resulted in 9.1 gigatonnes of CO₂ emissions. Coal also emits a large amount of other non-GHG pollutants, causing severe environmental and health problems, especially in developing countries.

This assessment is built up around a reference scenario and two phase out scenarios. The first phase out scenario illustrates the effect on GHG emissions and global temperatures if coal is replaced with gas power plants; the second phase out scenario illustrates coal's replacement through zero-emissions renewable energy. These phase out scenarios represent the boundaries within which actual development could occur.

The reason why we include a gas replacement in the scenarios is that a fuel switch from coal to gas will, in the first instance, lead to massive reductions in GHG emissions. The emissions intensity of gas is significantly less than that of coal, at an estimated 500 g CO₂/kWh. Recently, some countries and regions have increased their focus on gas as a cleaner source of energy production. Due to technoloav improvements, shale gas can now be exploited in regions where it was previously not feasible.

In a world aiming to hold warming below 2°C, there is a very strong limit to the role that natural gas power plants can play, unless emissions from this technology are eliminated. Substitution of gas power sources into the electricity system, without emissions removal technology, will be unable to provide the emissions reductions in the electricity sector required to stay below 2°C in the long run. Instead, development of long-lived infrastructure may actually become a major obstacle for the full decarbonisation of the electricity sector.

However, it is important to explore the consequences of a gas substitution for coal on CO_2 emissions and the temperature increase in the long run.

The CAT scenarios

1. **"Current policies":** depicting the global GHG emission pathway to 2100, the total energy demand, the share of coal for global energy use and power generation, and the shares of other energy sources until

2100. We use the CAT current policy pathway as the reference emission scenario. For details on the electricity mix not present in the CAT scenario, we use the IEA's "current policy scenario" from the WEO 2013 (until 2035) as a starting point. For the period after 2035 we apply the average growth rates of the electricity mix in the IPCC AR5 RCP 8.5 scenarios to the "current policy scenario" until 2100.

- 2. "Gas Substitution": in which coal is entirely replaced with gas. In this scenario, we use the parameters of the reference scenario but phase out coal electricity production linearly from 2015 to 2050 and replace it with gas.
- 3. **"Renewable Energy Scenario"**: in which coal is entirely replaced with renewables. Here, we phase out coal production linearly from 2015 to 2050 and replace it entirely with renewable energy sources.

The first step was to calculate the amount of electricity generated by each energy carrier following the assumptions above until 2100. In a second step, we calculate the CO_2 emissions from the revised electricity mix by using the emission intensity rates of WEO 2013 for the period to 2035. Thereafter, we assume some slight improvements over time to reflect improvements in the power plants' efficiency.⁶

The gas substitution and renewable energy scenarios are only different to the current policies scenario in the direct CO₂ emissions from the combustion of coal and gas and in emissions of sulphur. A full overview of all emissions would also imply taking the lifecycle emissions of the power plants into account, as well as emissions from associated infrastructure like coal mining, expansion of the power grid and increased electricity

⁶ We assume that the efficiency of coal, oil and gas power plants will reach 41%, 34% and 48% in 2100, respectively.

storage capacity. We have not considered these second order effects here.

These scenarios do, however, consider the effect of reductions in air pollutants, notably sulphur emitted along with CO₂ from coalfired power plants. Reductions in sulphur emissions are particularly important, as reduced sulphur emissions will counteract the reduction of GHG forcing quite significantly.⁷ On a global net basis, aerosols formed from sulphur emissions exert a net cooling on the climate system, so that removal of these would imply a relative warming.

Other co-emitted pollutants, including Black Carbon and Organic Carbon, could also form a part of the climate effects of coal-plant emissions, but these are estimated to be much smaller due to the higher combustion efficiency of coal-fired power plants compared to other industrial coal uses.⁸ For a first-order assessment of the effect of a reduction in sulphur emissions, we applied a set of simple assumptions, given the range of uncertainties that play a role here, from uncertainties in climatic effects of sulphate aerosols, to development of clean-air policies.

We assume as a maximum estimate of the effect of reduced sulphur emissions, that sulphur emissions from coal-fired power plants currently comprise 50% of the global total sulphur emissions⁹, and that this fraction of global sulphur emissions is phased-out linearly from 2015 to 2050 along with coal use. This represents an upper bound of the (relative warming) effect of eliminating co-emitted sulphur, whereas the estimates of differences in long-term warming on the basis of changes in CO₂ emissions only represent a lower bound.

Consistent with most integrated assessment models (IAMs), our reference scenario already projects declining SO₂ emissions even with increased coal consumption, to reflect air pollution controls policies, which are expected to tighten in the coming decades.



Figure 4: Shares of electricity sources in the reference scenario

⁷ Strefler et al (2014). Can air pollutant controls change global warming? Environmental Science & Policy, 41, 33– 43. doi:10.1016/j.envsci.2014.04.009

⁸ Bond et al (2013). Bounding the role of black carbon in the climate system: A scientific assessment. *Journal of Geophysical Research: Atmospheres, 118*(11), 5380–5552. doi:10.1002/jgrd.50171

⁹ Cofala et al (2011). Emissions of Air Pollutants for the World Energy Outlook 2011 Energy Scenarios. Laxenburg, Austria: International Institute for Applied Systems Analysis (IIASA).



Figure 6: Shares of electricity sources in the gas substitution scenario





Finally, we calculate the effect of these CO₂ and sulphur emissions reductions on the global temperature by running emissions pathways for each scenario through the carbon cycle climate model MAGICC.^{10,11} We ran MAGICC multiple times in order to obtain a probability distribution of outcomes such as global mean temperature,

CO₂ concentration, and total greenhouse gas concentration.

Results

Figure 4 shows the shares of electricity in the reference scenario, where coal remains at around 40% until 2050 and then decreases to around 30% in 2100. In the gas substitution scenario, gas will account for more than 40% of total electricity generation in 2100 as shown in Figure 5. The renewable scenario would result in a share of 65% electricity generated by renewables at the end of the century (Figure 6).

¹⁰ Meinshausen et al (2009) Greenhouse-gas emission targets for limiting global warming to 2 °C. Nature 458 1158–62

¹¹ http://www.magicc.org/



Figure 7: Global temperature increase in the different scenarios

By 2050, the mitigation effect of a phase out of coal amounts to about 10 and 20 GtCO₂ in the Gas Substitution and Renewable Energy scenarios, respectively.

For our temperature scenarios, we have calculated the net effect on global temperature increase by using the MAGICC model (Figure 7).

The climate model runs of our three different scenarios with the effect of reduced SOx emissions show that there is substantial effect from replacing coal with renewable energies.

As much as 0.7°C less warming by the end of the century would be the result. This would still lead to a temperature increase of 3°C in 2100. Note that the renewable scenario still include some emissions from the electricity sector due to the remaining shares of gas in the electricity generation portfolio. Including a rough estimate of the phase-out of coemitted sulphur leads to 0.5°C less warming in the renewables scenarios.

For the gas substitution scenario, we achieve a warming reduction of 0.3°C. when the sulphur phase out effect is excluded, or 0.1°C when this is included.

These results show that gas might make little difference in terms of reduced warming, because the reduction in CO_2 emissions barely compensates for the reduced sulphur emissions. By contrast, the reduced CO_2 from the renewables scenario is much bigger, so

that reduced sulphur remains a relatively minor effect in the long term.

We see that the reduction in warming projected by 2100 achieved with a switch from coal to gas is therefore only 25-45% of what is obtained with a switch to renewables.

A rapid phase out of coal would also imply multiple environmental and health benefits, in addition to lowering GHG emissions and mitigating climate change. In 2010, coal-fired power plants produced 24% of global mercury emissions,¹² a harmful pollutant with far-reaching human and ecological impacts. Although 'clean-coal' technology is improving, particulate matter emitted from many coal-fired plants causes smog and severe health problems, particularly in densely populated areas.

Discussion and Conclusions

A phase out of coal-fired power production would lead to up to 0.5° C less warming in 2100 compared to the reference scenario, when reduced sulphur emissions are taken into account and 0.7° C when they are not. It is therefore a significant step towards the total decarbonisation effort required to stay below 2° C.

¹² UNEP, 2013. Global Mercury Assessment 2013: Sources, Emissions, Releases and Environmental Transport. UNEP Chemicals Branch, Geneva, Switzerland

Our coal-to-gas phase out scenario shows that gas will be unable to provide the emissions reductions in the electricity sector required to stay below 2°C in the long run. Instead, development of long-lived gas infrastructure could become a major obstacle for the full decarbonisation of the electricity sector.¹³

Limiting warming below 2°C requires rapid emission reductions of all greenhouse gases and, in particular, carbon dioxide emissions from fossil fuel combustion and industrial use. To achieve this goal with a high probability (85% chance or higher), fossil fuel CO_2 emissions need to be reduced to close zero by 2050.

The electricity sector produces about 40% of global CO_2 emissions and needs to be decarbonised more rapidly than other sectors.

The difficulty here is that the WEO's 2013 policy scenario shows no decrease in coal's share of electricity generation until 2035. Instead, absolute emissions under current policies are projected to increase by about 45% above 2011 levels by 2030.

With warming under current policies projected to be around 3.7°C by 2100, removing coal from the electricity sector by 2050 completely would bring this back to around 3.2°C warming. In other words, phasing out coal emissions alone from the power sector would achieve 25% of the task of limiting warming below 2°C.

Replacing coal with gas, as proposed by some, is clearly not an option: it would only reduce warming by about 0.1°C after consideration of the effect of sulphur emission reductions.

In terms of a carbon dioxide budget approach, in order to have a high probability of limiting warming below 2°C, a budget of significantly less than 1000 gigatonnes of carbon dioxide remains after 2011.

Under current policies, as assumed here, about 4,900 gigatonnes of carbon dioxide would be released to the atmosphere. In other words, the current policies are projected to exceed the carbon dioxide budget by 3,900 GtCO₂.

Phasing out coal emissions from the power sector by 2050 would reduce this exceedance by about 1,400 GtCO₂, or 35%.

It is clear that emissions reductions in the electricity sector alone will not be sufficient to keep the world on a below 2°C pathway. These strategies need to involve major improvements in energy efficiency in buildings, industry and transport. The remaining energy use needs to be replaced by carbon free generation, e.g. renewables. Substantial endeavours are also needed in agriculture and forestry.

These conclusions are consistent with more complex energy-system models and reinforce the urgent need to cease investments in new coal production and at the same time begin a rapid phase-out of this energy source. Deployment of natural gas capacity should be strictly limited as part of a rapid transition towards a carbon free electricity supply by mid-century.

¹³ IEA (2011): WEO 2011

Background on the Climate Action Tracker

The "Climate Action Tracker", <u>www.climateactiontracker.org</u>, is a science-based assessment by Ecofys, Climate Analytics and the Potsdam Institute for Climate Impact Research (PIK) that provides regularly updated information on countries' reduction proposals.

The Climate Action Tracker¹⁴ reflects the latest status of the progress being made at international climate negotiations. The team that performed the analyses followed peer-reviewed scientific methods (see publications in Nature and other journals)¹⁵ and significantly contributed to the UNEP Emissions Gap Report¹⁶.

The Climate Action Tracker enables the public to track the emission commitments and actions of countries. The website provides an up-to-date assessment of individual country pledges about greenhouse gas emission reductions. It also plots the consequences for the global climate of commitments and actions made ahead of and during the Copenhagen Climate Summit.

The Climate Action Tracker shows that much greater transparency is needed when it comes to targets and actions proposed by countries. In the case of developed countries, accounting for forests and land-use change significantly degrades the overall stringency of the targets. For developing countries, climate plans often lack calculations of the resulting impact on emissions.

Contacts

Dr. Niklas Höhne (n.hoehne@ecofys.com) - Director of Energy and Climate Policy at Ecofys and lead author at the IPCC developed, together with Dr. Michel den Elzen from MNP, the table in the IPCC report that is the basis for the reduction range of -25% to -40% below 1990 levels by 2020 that is currently being discussed for Annex I countries.

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¹⁴ www.climateactiontracker.org

¹⁵ e.g. http://www.nature.com/nature/journal/v464/n7292/full/4641126a.html and http://iopscience.iop.org/1748-9326/5/3/034013/fulltext







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CLIMATE ANALYTICS is a non-profit organization based in Potsdam, Germany. It has been established to synthesize climate science and policy research that is relevant for international climate policy negotiations. It aims to provide scientific, policy and analytical support for Small Island States (SIDS) and the least developed country group (LDCs) negotiators, as well as non-governmental organisations and other stakeholders in the 'post-2012' negotiations. Furthermore, it assists in building in-house capacity within SIDS and LDCs.

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Potsdam Institute for Climate Impact Research (PIK)

The PIK conducts research into global climate change and issues of sustainable development. Set up in 1992, the Institute is regarded as a pioneer in interdisciplinary research and as one of the world's leading establishments in this field. Scientists, economists and social scientists work together, investigating how the earth is changing as a system, studying the ecological, economic and social consequences of climate change, and assessing which strategies are appropriate for sustainable development.

www.pik-potsdam.de