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Briefing

Can carbon capture and storage justify new coal-fired electricity?

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Key messages

- **CCS research fails to justify investment in new coal-fired generation capacity**. Even if CCS were now technologically and commercially proven and available, 82% of known coal reserves would not be burnable between now and 2050 according to current estimates. Because CCS is not yet commercially viable, new coal plants built today lock an energy system into a future with higher emissions, higher electricity costs, or both.
- **CCS makes new coal-fired power plants uneconomic**. New coal-fired power generation already faces competition with inherently cleaner technologies. Adding CCS simply further pushes up project, and electricity, costs: of the $8.1 billion in public funding made available to power generation projects, private investors left between 80-90% of these funds unclaimed because projects remained uneconomically viable.
- **CCS R&D remains valuable for industrial uses and long-range plans, but this requires tailoring R&D programmes for these uses**. Unlike coal-fired power, some niche industrial processes do not have economically viable low-carbon alternatives. National policy and R&D strategies need to balance CCS innovation toward such industrial uses.

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Carbon capture and storage (CCS) and its potential for new coal-fired power

Today, burning coal remains the single biggest global electricity source and is the leading cause of increasing atmospheric carbon dioxide (CO_2) (IEA, 2015a; Global Carbon Project, 2015). The current fleet of coal-fired power stations and those in the planning pipeline will alone release more CO_2 to the atmosphere than we can safely emit from all activities and sectors to stay within the 2°C global mean temperature change (Granoff and Hogarth, 2015).

Carbon capture and storage (CCS) is the process whereby CO_2 is captured from a large emitter, transported, and injected into deep geological formations to remain permanently stored. It holds the promise of keeping out of the atmosphere CO_2 emissions from energy or industrial processes that lack inherently low-carbon alternatives.

The coal industry and some policymakers rely on this technological potential to advocate for an energy sector strategy based on continued investment in new coal-fired power capacity, suggesting that CCS will enable that capacity to be compatible with a safe climate (see e.g. Dodson, 2015; ASEAN+3, 2014).

This brief explains why this analysis is mistaken. CCS is ill-suited to address the climate problems posed by the planned fleet of new coal-fired power plants. Nonetheless, CCS innovation is still valuable as part of our arsenal of responses to climate change. Outside of the power sector, the technology holds considerable promise to address activities with no viable abatement alternatives, such as emissions-intensive industrial processes (Gale, 2014). Although the overall process is similar, CCS developments in one sector (i.e. coal-fired power generation) do not generally directly translate to usable solutions in other sectors (Bennett, 2013). Future CCS research and development (R&D) should focus on these uses.

The CCS industry is still innovating and developing; it has not yet reached technical maturity.

The CCS industry has developed significantly in a relatively short amount of time. Many elements of the process have been tried and tested: CO_2 has, for example, been captured from plants, and CO_2 has been injected and stored in oil and gas wells through enhanced oil recovery (EOR).[1]

With an acceleration in R&D in the last decade, we now have good laboratory experience and understanding of how the CCS process works, examples of the constituent sections working individually at scale in various industrial settings, and credible, detailed plans for how to put together all aspects of a project in many locations around the world. Unfortunately, this does not class as being technologically proven. The "full chain" of processes – designing and building the plant, capturing the CO_2, transporting it to a geologically appropriate sight, and injecting it for permanent storage – has not been completed at full scale.

The only example of a built full-chain project is at Boundary Dam in Canada: here, a scrubber attached to a quarter-scale[2] retrofitted coal-fired power plant supplies CO_2 to a local oilfield for EOR (SaskPower CCS, 2015). Partially funded by government subsidies (Touchette, 2015), the state-owned Boundary Dam project opened late in 2014, but technical problems in design and operation have prevented it from operating at full capacity and have led to considerable cost overruns (Reitenbach, 2015).

For a new technology to enter the market, developers need to "prove" its technological feasibility, and then prove the technology is viable at commercial scale. Essentially, coal-powered CCS has yet to be technologically proven as planned even at a quarter-scale. With per-plant investments running to the billions, this stepping-stone from laboratory to full commercial rollout of just the first phase of coal-powered CCS plants is incredibly important and getting past it is going to take years. Although the industry might argue that it is close, it has clearly not yet refined an 'off-the-shelf' product. The investment and time needed to build, test, and learn from projects to reduce costs means that CCS for coal power will not be ready to be commercially deployed at scale for at least a decade (McGlade and Ekins, 2015).

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[1] Injecting CO_2 into depleted oil and gas reserves can drive more oil out while also storing a portion of the CO_2 in situ.

[2] The CCS facility is fixed to the 110 MW Unit 3 at the Boundary Dam Power Station. This is assumed to represent a quarter-scale as most new advanced coal-fired generation uses units of approximately 500 MW.

The pace and scale of CCS development required to legitimise further investment in new coal generation capacity is simply implausible.

The cumulative impact of greenhouse gases (GHG) on our climate means that emissions reduction technologies need to be deployed soon and at scale. Because every geological formation is different, significant investment and effort is needed to characterise and develop potential storage sites. In Europe alone, appraising sites, drilling wells, and building injection rigs would need €10 to 20 billion invested in the decade to 2030 (growing to €35 to 80 billion by 2050) (Whiriskey, 2014); note that these costs do not account for investment in capturing and transporting the CO_2. For CCS to apply to coal power, this effectively means creating a transport and storage industry that is at least as big as the current oil and gas industry—which reflects many of the same infrastructure systems needed to transport and process CO_2—in a matter of decades.

Governments have recognised that CCS requires further technological development if it is to have any meaningful impact on emissions. Over $10 billion of public money, including grants, tax credits, and other financial support, has been committed to CO_2 capture projects in attempt to entice the private sector into CCS demonstrations. While over three-quarters of this money, $8.1 billion, has been made available to power generation projects (Global CCS Institute, 2011), an analysis of publically available data suggests that 80 to 90% of these funds went unclaimed, through cancelled and shelved projects, because developers shelved or cancelled projects (MIT, 2015). Power companies conducted in-depth technical designs and decided that even with the subsidies, the projects were not viable.

To highlight the scale of the disconnect between the problem coal poses and the solution CCS might afford: even if CCS were now technologically and commercially proven and available, 82% of known coal reserves would not be burnable between now and 2050 according to current estimates (McGlade and Ekins, 2015).[3] Perhaps even more importantly, because of the production of further hydrocarbons, there are significant questions over the level of emissions abated when CCS is linked to EOR (as the majority of planned projects currently are) (Burton, 2015).

Further, while the analysis in this brief focuses on the limitations of CCS for new coal fired power capacity, the above scaling problems also bring into question whether CCS is a viable alternative to phase-out and replacement for the existing fleet of coal-fired power capacity.

The cost additionality and technical immaturity of CCS mean including it in a new project makes coal-fired electricity less competitive than inherently cleaner alternatives.

To capture CO_2 at a power station requires adding a large separation unit, which also requires a significant amount of power to run. Adding the extra process currently doubles the capital costs of a plant, while running the separation process effectively decreases the overall efficiency of the plant by around a quarter (Global CCS Institute, 2015). This efficiency penalty means that only the most efficient coal plant ('advanced coal') can feasibly be used with CCS. Together these mean that adding CCS to a coal-fired plant will make the electricity it produces substantially more expensive than both conventional and advanced current coal plants.

In the US, new advanced coal-fired plants currently cost $105 per megawatt hour (MWh). The US is one of the cheapest places to build coal-fired power, and these costs assume the plant runs over a 30-year cost recovery period at 85% of capacity, whereas the global average is 60% (Granoff and Pickard, 2015). Because of its technical constraints, CCS adds a material premium, causing advanced coal with CCS to cost approximately $144 per MWh.

From the US to South Africa to India, new unsubsidised renewable power is already competitive with conventional coal-fired power and cheaper than advanced coal on its own (EIA, 2015; IPPPP, 2015; Kenning, 2015). In the US, electricity from onshore wind costs $74 per MWh. This remarkable milestone has only come about very recently due to the substantial reductions in the cost of renewables—particularly wind and solar (IEA, 2015b).

[3] The figure is 88% if CCS is not considered to be available.

Pricing carbon makes coal without CCS even less competitive. As the industry's reticence to claim government CCS subsidies suggests, no government has yet set a carbon price that makes CCS for new coal power an economically viable option.

Building CCS-ready plants now and retrofitting later will not be cheaper in the long run.

Because CCS is essentially a 'clean up' process, it can be added on to a coal plant once built ('retrofit') or the two processes could be built at the same time ('new build'). An alternative option is to delay CCS installation until prices have "matured" by either:

- building an advanced coal plant now and then retrofitting CCS; or
- building a conventional (less efficient) coal plant now and then both upgrading the coal plant to 'advanced' and adding CCS at the same time.

But these cost delays do not solve the technical limitations. Even delayed installation will require a cost premium against current advanced coal costs. Later installation would require secondary construction costs, outage time, additional materials and extension of the cost-recovery period: all of which work against the synergistic benefits of new-built projects. In fact, these additional costs may make it unrealistic for retrofits to compete against the already high cost of building new CCS now, at $144 MWh. Retrofits would have the further disadvantage of allowing interim unabated emissions.

CCS research still needs support: it could help abate emissions in other sectors.

CCS is fuel- and emission process-agnostic and, by applying it to CO_2 emissions from heavy industries that have no credible low-carbon alternative, CCS might yet offer real GHG abatement potential in the future. While much of the attention around CCS has focused on its application to new coal-fired power, its most promising applications are now elsewhere. Although similarities exist between industrial CCS projects, the capture processes are not directly interchangeable. Carbon capture entails stripping CO_2 from exhaust streams that contain different components in different concentrations depending upon the application (IEA, 2013).[4] Despite apparent similarities, the differences in the capture process are important and largely require tailored solutions that will not be provided by only developing capture at coal-fired power plants.

Even further into the future, CCS has the theoretical potential to reduce atmospheric CO_2 (Caldecott et al., 2015). This could be achieved, for example, by using agriculture and silviculture to remove CO_2 from the atmosphere and then combusting the biomass for energy needs, with the resulting CO_2 captured and stored safely. Again, however, the current costs and uncertainty of such a strategy make it an expensive, risky and ultimately unfeasible substitute for the rapid decarbonization of our current planned energy supply.

R&D should continue to develop CCS for these hard-to-replace carbon-intensive activities and for future applications such as those related to negative-emissions 'geoengineering'. CCS innovation is likely to be important to our long-term toolkit to fight climate change, even if it fails to solve near-term emissions from new coal. This requires rebalancing of current CCS funding away from its application to coal-fired power and towards technological and market development that is focused on these other emission-intensive applications.

[4] For example, the exhaust stream from a cement plant or a steel mill is very different to that from a bio-ethanol plant.

References

ASEAN+3 (China, Japan and Korea) Ministers on Energy (ASEAN+3). (2014) 'Joint Ministerial Statement'. *The 11th ASEAN+3 (China, Japan and Korea) Ministers on Energy Meeting*. Vientiane, Lao People's Democratic Republic: 23 September 2014. (http://www.meti.go.jp/press/2014/09/20140926004/20140926004a.pdf).

Bennett, S. (2013) 'CCS in industrial applications'. *A workshop of the CCUS Action Group in preparation for the 4th Clean Energy Ministerial.* London: 30 January 2013. International Energy Agency. (http://www.iea.org/media/workshops/2013/ccs/industry/cem_workshopreport.pdf).

Burton, B. (2015) 'BHP Billiton's Boundary Dam carbon fudge'. Neutral Bay, Australia: Reneweconomy. (http://reneweconomy.com.au/2015/bhp-billitons-boundary-dam-carbon-fudge-27835).

Caldecott, B., Lomax, G. and Workman, M. (2015) *Stranded Carbon Assets and Negative Emissions Technologies Working Paper*. Oxford: University of Oxford's Smith School of Enterprise and the Environment. (http://www.smithschool.ox.ac.uk/research-programmes/stranded-assets/Stranded%20Carbon%20Assets%20and%20NETs%20-%2006.02.15.pdf).

Dodson, S. (2015) 'World Coal Association calls for investment in CCS'. Farnham, Surrey: Palladian Publications. (http://www.worldcoal.com/coal/13022015/World-Coal-Association-calls-for-investment-in-CCS-1889/).

Gale, J. (2014) 'Global Developments in Industrial CCS & Overview of IEAGHG Industry CCS Activities'. *CCS in Industry Workshop*. Vienna, Austria: 28 April 2014. (http://www.ieaghg.org/docs/General_Docs/IEAGHG_Presentations/IEAGHG_Slide_Pack_-_Austrian_Industry_seminar_Final.pdf).

Global Carbon Project. (2015) 'Global Carbon Budget: Data'. Canberra: Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Ibaraki: National Institute for Environmental Studies. (http://www.globalcarbonproject.org/carbonbudget/14/data.htm).

Global Carbon Capture and Storage Institute (Global CCS Institute). (2015) *The costs of CCS and other low-carbon technologies in the United States - 2015 update.* Canberra: Global Carbon Capture and Storage Institute Ltd. (http://hub.globalccsinstitute.com/sites/default/files/publications/195008/costs-ccs-other-low-carbon-technologies-united-states-2015-update.pdf)

Global CCS Institute. (2011) 'Status of funding support' in *The Global Status of CCS: 2011.* Canberra: Global Carbon Capture and Storage Institute Ltd. (http://hub.globalccsinstitute.com/publications/global-status-ccs-2011/42-status-funding-support#c4_fig44).

Granoff, I. and Hogarth, J.R. (2015) 'The world has a two-degree carbon budget. Coal alone will put us in the red'. London: Overseas Development Institute. (http://www.odi.org/comment/10003-carbon-budget-coal-energy-g7-developing-countries).

Granoff, I. and Pickard, S. (2015) 'How clean is clean coal?' London: Overseas Development Institute. (http://www.odi.org/comment/9991-clean-clean-coal).

Independent Power Producers Procurement Programme (IPPPP). (2015) *Independent Power Producers Procurement Programme (IPPPP): An Overview.* Centurion: Republic of South Africa (https://www.ipp-projects.co.za/Home/GetPublication?fileid=2ff99f76-206c-e511-9431-2c59e59ac9cd&contentid=39cbf366-206c-e511-9431-2c59e59ac9cd).

International Energy Agency (IEA). (2015a) *World Energy Outlook.* Paris: International Energy Agency.

IEA. (2015b) *Projected Costs of Generating Electricity.* Paris: International Energy Agency.

IEA. (2013) 'Global Action to Advance Carbon Capture and Storage. A Focus on Industrial Applications' in Annex to *Tracking Clean Energy Progress 2013.* Paris: International Energy Agency.

Kenning, T. (2015) 'SunEdison scoops 500MW with record low INR 4.63/kWh tariff in Andhra Pradesh'. London: PV-Tech. (http://www.pv-tech.org/news/sunedison_scoops_500mw_with_record_low_inr_4.63_kwh_tariff_in_andhra_prades).

Massachusetts Institute of Technology (MIT). (2015) 'Carbon Capture and Sequestration Technologies: Cancelled and Inactive Projects'. Cambridge, USA: MIT Energy Initiative. (http://sequestration.mit.edu/tools/projects/index_cancelled.html).

McGlade, C. and Ekins, P. (2015) 'The geographical distribution of fossil fuels unused when limited global warming to 2°C'. *Nature,* 517, 187-190.

Reitenbach, G. (2015) 'SaskPower Admits to Problems at First "Full-Scale" Carbon Capture Project at Boundary Dam Plant'. Houston, TX: Power Mag (http://www.powermag.com/saskpower-admits-to-problems-at-first-full-scale-carbon-capture-project-at-boundary-dam-plant/).

SaskPower CCS. (2015) 'Boundary Dam Carbon Capture Project'. Saskatoon: SaskPower. (http://saskpowerccs.com/ccs-projects/boundary-dam-carbon-capture-project/).

Touchette, Y. (2015) 'G20 subsidies to oil, gas and coal production: Canada'. London: Overseas Development Institute. (http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinionfiles/9988.pdf).

U.S. Energy Information Administration (EIA). (2015) 'Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2015'. Washington D.C.: EIA. (http://www.eia.gov/forecasts/aeo/electricity_generation.cfm).

Whiriskey, K. (2014) *Scaling the CO2 storage industry: A study and a tool. A study of the CO2 storage industry in Europe to 2050 – and a tool to measure its feasibility, the requirements and the bottlenecks.* Brussels: Bellona Europa. (http://bellona.org/assets/sites/4/Scaling-the-CO2-storage-industry_Bellona-Europa.pdf).

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