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Let's talk seriously about emission reduction, including CCS

By Professor Robin Batterham

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Focus on CCS - Opinion Leaders Series

Focus on CCS is the theme of a series of opinion articles by world leading authorities on carbon capture and storage (CCS) and their perspectives on the role for the technology in reducing our carbon dioxide emissions. The series is published by the Global CCS Institute to contribute to the conversation about CCS within the portfolio of technologies to help tackle climate change. The views expressed remain those of the author and not necessarily those of the Institute.

Let's talk about emission reduction, including CCS[1]

By Professor Robin Batterham

The 21st Conference of the Parties to the UNFCCC (United Nations Framework Convention on Climate Change) will take place in Paris in December. There are high hopes amongst many that this will result in international agreements that will set all nations on a path to much more serious emission reductions. Let's do a sanity check here: to even reach 21 conferences and still find emissions set to skyrocket from around 37 billion tonnes of carbon dioxide (CO_2) per year to 46 billion tonnes of CO_2 per year, is telling us something. Put simply and with no sense of denial of anthropogenic impact on climate being measurable, 21 conferences and a rise of 25% by 2035[2] suggests to me that current messages, particularly of the more extreme scenario variety, are not having much impact. Numerous other publications suggest the same.

We live in a world where promissory notes abound, eg our G7 leaders meeting recently in Bavaria are targeting zero emissions by 2100. Zero overall implies negative for some areas to compensate for those areas like cement and metal production where CO_2 emissions are inevitable. We need power generation with negative emissions and co-firing biomass with coal plus CCUS is one way of getting there.

Let's pause a moment, take a step back, move away from the hype and the incredible vitriol targeting those whose sense of urgency is less than overwhelming and consider some realities. It helps sometimes to move away from the arguments about how, how much, by whom, etc. and start more from common ground.

It will be a long time before we reach agreement on whether the rest of this century will see 1.5°C rise or 4+°C, the ranges quoted by the International Panel on Climate Change (IPCC). But we already have broad agreement that anthropogenic inputs to the climate are observable. Further, we have very considerable support for the position of minimizing emissions. If we start from this common ground, the nature of the dialogue changes to focus on how much and who pays. This is familiar territory. It is for many of us the daily round: it covers education, infrastructure, support for the arts and sports, let alone health and medical expenses, especially with ageing populations. The difference with minimizing emissions however is that it is not just about how much and who pays, it is critically about technology and of course, which technologies, noting no single technology has all of the answers.

There are some truisms around technology which deserve rehearsal. Firstly, the cost of delivering something falls in real terms, as a result of innovation. There is data covering hundreds of years on this point. As an example, the delivered cost of solar cells and off-shore wind are great examples where costs have fallen and are projected to continue to fall for quite some time. But equally, the costs of producing power using existing routes also continues to fall. As an example, various companies in China have been installing ultra-low emission coal fired generation plants. These plants are huge and are leading edge in several technologies: the ultra super critical boilers, the SO_x, NO_x and particulates

[1] CCS refers to carbon capture and storage, often more correctly noted as CCUS, carbon capture, utilization and storage
[2] BP (2015), *BP Energy Outlook 2035*, BP, Feb. 2015, http://bp.com/energyoutlook#BPstats

removal and above all, the much reduced CO_2 emissions (up to 30% lower) courtesy of the higher efficiency. It is totally reasonable to expect that CCUS costs will also follow this downward trajectory. The Saskpower Boundary Dam project is already suggesting full scale costs would be 30% lower than their first of a kind large plant.

Some of the ultra-low emission plants in China are also very large, to 1000 MW per boiler, with the result that the economic penalty for this low emission performance is only of order 0.5cents/KWh. On grid costs in China from such plants are around half the cost of gas fired electricity. I encourage anyone that has the opportunity to visit one of these plants to do so. It is more like visiting an aerospace operation than a power station, such are the standards of design and cleanliness of operation.

Table 1: Performance of an ultra-low emissions coal fired power station compared with national standards for gas fired power stations[3].

	Particulate matter mg/Nm^3	**SO_2 mg/Nm^3**	**NO_x mg/Nm^3**
Guohua Zhousan	2.46	2.76	19.8
China's gas power unit emission standards	5	35	50

Let's stop and think of the alternative low-emission technologies. Do any allow 30 per cent reduction in emissions for 0.5cents per kilowatt hours? In terms of cost per tonne abated, ultra-supercritical plants replacing older plants looks more attractive than most if not all renewables. At this level, CCUS takes on a new meaning.

The second point on the nature of technology is that existing technologies inevitably face replacement. The well-known progress of computers is a classic in this regard. For the same price, computational power just keeps on increasing—the so-called "Moore's Law". This has happened not just because a particular technology has continuously improved, but because different technologies have been introduced. For example, who knows about the ferrite core memory used in computers in the 50's? For those that weren't around then, computer memory was made by hand by threading fine wires through tiny ferrite cores and 8 kilowatt of memory was a big deal.

Despite the glamorous and oft repeated tales of how a single invention went on to change the world, the majority of technological takeovers are the result of incorporating leading edge technologies, often in combination, to yield marked improvements. Mobile phones are not a single invention. Equally, re-blading a turbine in a power station every few years allows performance to be improved. The recent efforts to use both heating and cooling of turbine blades are a case in point. Such technology allows coal fired power stations to spin up to meet demand at a rate similar to a gas fired power station, thereby turning coal into a load following energy source to facilitate greater penetration of renewables on a grid. The use of coal directly injected into diesel engines (DICE) also allows rapid start up and stopping allowing more renewables into a grid. DICE delivers a higher efficiency than existing coal

[3] Ling Wen. (2015) "Shenhua's evolution from coal producer to clean energy supplier". *Cornerstone* 3(1), 10-14.

fired plants and could also be coupled with CCUS. DICE and brown coal are particularly effective when coupled with a mild hydrothermal processing[4].

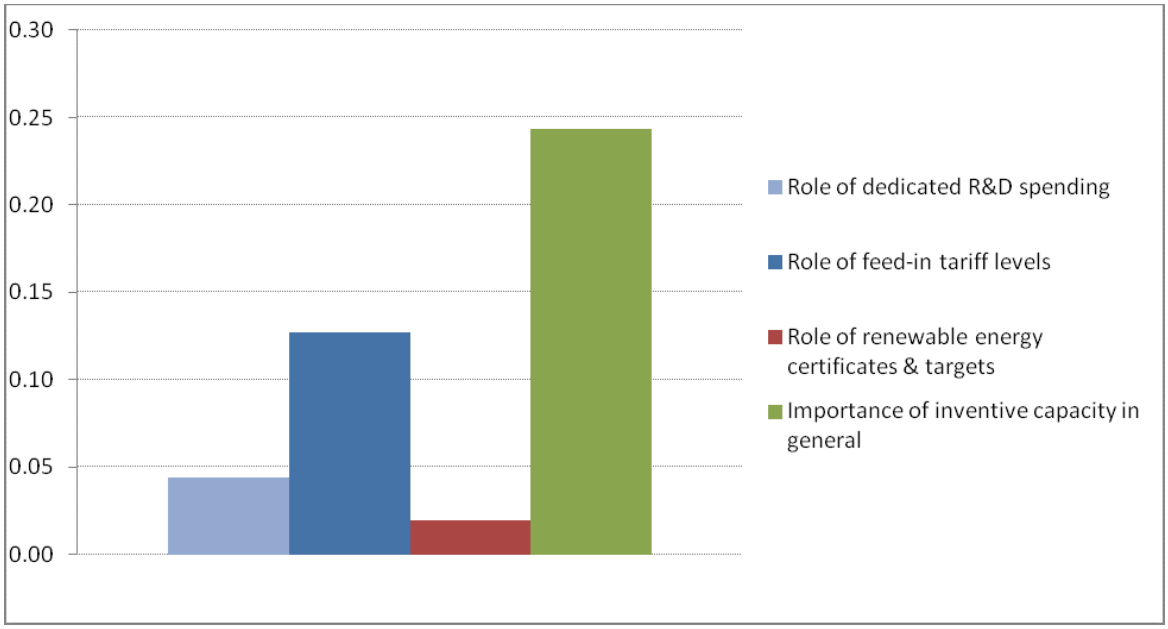
One is reminded that in terms of timing, we see many projections of how existing fossil fuel and nuclear power plants must be phased out because they have reached the end of their economic lives. This to me is somewhat wishful thinking in that, unless mandated, most plants can be renewed as brown field sites meaning that their economic lives can be long indeed.

Brown field economics are often more attractive than green field economics. The total refurbishment of the Boundary Dam brown coal fired power station in Saskatchewan with its "retro-fitted" CCS is a good case in point. Boundary Dam is trailblazing in several ways: It shows that an old asset can be rejuvenated, that emissions can be reduced even for brown coal by 80%, that the "large first of a kind" risks have been overcome and, importantly, it gives us real insight into the costs of CCS.

The lesson of history appears to be that it is dangerous indeed to try and predict the path of technology developments, especially long term costs. Who knows, DICE (direct injection coal engines) with CCUS may be far more economic than combined cycle gas turbines (CCGT) with or without CCS and, of course, capable of load following.

It is technological innovation that will eventually drive emissions down. The OECD has done some very interesting work in terms of what drives innovation in low emission power generation. The global analysis by Haščič et al is not surprising to those of us who have spent a lifetime making innovation happen in industry. Put simply, that analysis found that the overall level of inventiveness in a country is the most effective driver of innovation5. Targets and dedicated R&D are not key drivers of innovation.

Figure 1: Haščič et al - *The effect of different factors on renewable energy patents*



[4] Brockway D and Wibberley L (2014) DICE Power and Victorian Brown Coal. *Brown Coal Industry Australia R&D Roundtable Forum*, 15 October.
[5] Haščič, I. et al. (2010), "Climate Policy and Technological Innovation and Transfer: An Overview of Trends and Recent Empirical Results", *OECD Environment Working Papers*, No. 30, OECD Publishing. http://dx.doi.org/10.1787/5km33bnggcd0-en

The OECD have continued their work on monitoring the economic drivers of change in delivering low emissions. Note their definition of 'clean energy' as including: "solar, wind, small and large hydroelectric, geothermal, marine, biomass and waste- to-energy power plants, carbon capture and storage (CCS) technologies and energy-efficient technologies such as smart grids and electric vehicles"[6]. Their recent report finds that "Production and activities in the solar-PV and wind-energy sectors are increasingly reliant on imported intermediate inputs. Policies aimed at protecting domestic manufacturers may thus hinder the profitability of downstream activities, eg by raising the cost of inputs". Yet again we note that the most effective route for innovation is to encourage international competition.

The OECD results and the language are clear: "Policies that promote open, competitive and demand-driven markets for clean energy will support the continued cost reductions needed for a cost-effective transition to a low-carbon energy system, reducing the amount of public incentives needed to scale up the deployment of clean technologies."

Recent and detailed modeling of the Australian Electricity Market out to 2050 suggests that in the absence of a price on carbon or other forms of support for low emission technologies, deep abatements are still possible. It is only a case of how much the market is prepared to bear[7]. Brear et al suggest that for 80% reduction by 2050 compared to 2000 levels, CCS and nuclear are highly competitive.

The summary argument is then that the lesson of history is that the route to low emissions is primarily about technology. To predict which technologies will evolve, which will emerge, the rate and the costs however is unlikely to be successful. Against this proposition we need to be generous in our thinking and allow a wide range of activities. CCS or more fully, CCUS is just as likely to help deliver our 2050 targets even more economically than a wholesale flight to renewables. At present, the Global CCS Institute reports that CCS is already in use at industrial scale in 13 locations with another nine industrial scale projects under construction worldwide. This is promising and proves the technology but is lagging behind where we need to be, perhaps because we are not open-minded enough.

Emission reduction with reasonable economics and impact should be our target. This is all doable and should include all options, CCS being quite attractive on economic grounds. The discussion should be about "how much do we want to pay?" Given the lack of global progress on emission reduction to date, this also seems to be what the wider population is saying.

Professor Robin Batterham
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[6] OECD (2015), *Overcoming Barriers to International Investment in Clean Energy, Green Finance and Investment*, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789264227064-en
[7] Brear et al. (2015) "Least cost, utility scale abatement from Australia's National Electricity Market." Submitted for publication.