Energy in a Changing Climate

The arithmetic adds up to nuclear

The Australian Government seems genuinely committed to putting a price on carbon. It seems likely that one of the first industries to be impacted will be electricity generation. Two important questions are yet to be answered, however. What is the carbon price that will encourage a widespread shift to technologies which will actually reduce emissions? And what will those technologies be?

To find answers, we conducted a meta-review of 25 authoritative peer-reviewed studies of electricity generating technologies, which was published in the international peer-reviewed scientific journal *Energy*. We looked at cost and life-cycle emission studies to arrive at the most likely costs and emissions of these technologies.

We consider only those low-emission technologies that can provide baseload power which account for more than 75 per cent of the electricity generated in Australia. We used a set of objective criteria to select candidates from present and proposed technologies commonly mentioned in the context of future power generation. For a technology to be considered fit-for-service as a baseload generator, it needed to be scalable, dispatchable without large storage and have a reliable fuel supply, emissions intensity less, and preferably much less, than 300 kg CO_{2eq}/MWh and capacity factor greater than 70 per cent.

We concluded that technology options for replacing fossil fuels, based on proven performance and reliable cost projections, are much more limited than is popularly thought. We identified only five proven low-emission technologies that met our fit-for-service criteria to supply baseload power. They were: pulverised fuel (PF) with carbon capture and storage (CCS); integrated (coal) gasification combined cycle (IGCC) with CCS; combined cycle gas turbine (CCGT) with CCS; nuclear; and solar thermal with heat storage and gas turbines. IGCC is relatively new technology not yet in operation in Australia. CCS is still only in pilot stage anywhere in the world.

It might come as a surprise to some that wind, solar photovoltaic and engineered geothermal systems (EGS), also known as hot rocks, did not qualify to be fit-for-service for baseload. Wind and solar PV need either extensive gas backup or large-scale energy storage for baseload operation. Use of large-scale electricity storage is prohibitively expensive in most networks. The associated extra costs will depend on plant location and are difficult to assess accurately.

Enthusiastic supporters of various renewable energy technologies have long made claims that all or most of Australia's future electricity needs could be met with renewable energy. Our analysis point to the costs involved and hence to the reliance on future major advances on that front in order to be competitive with other, low-emission, alternatives. In our view such reliance is highly speculative and risky as part of any plan to secure future energy.

We believe there are good reasons why weak energy sources like solar and wind may never compete on costs. They require large installations covering large land areas, with costs mainly in the realm of civil engineering works and therefore not amenable to substantial reduction through advances in the energy conversion technologies themselves. The technologies are undeniably elegant and innovative; their limitations unfortunately arise from the diffuse and intermittent nature of their energy sources.

One technical study we covered assessed wind with storage against IGCC with CCS. The wind/storage solution could only compete at a carbon price above $350 a tonne of carbon dioxide, well above anything being contemplated. EGS is a possible future baseload technology, but it is still too early to estimate performance and costs with the degree of reliability we required.

Most of Australia's electricity comes from PF coal and this will be the primary target for emissions reduction. The illustration shows how the median costs per megawatt-hour of electricity vary with the emissions (carbon) price.

The technologies included are the five fit-for-service replacement technologies plus, for comparison, new PF coal plants without CCS. With no carbon price (as now), new pulverised fuel coal is the cheapest technology, but as the carbon price increases so does the cost of electricity from such plants.

The levelised cost of electricity, shown in the illustration, is a good indicator of the average wholesale price the power station owner would need to break even.

The points where the cost line for pulverised fuel coal crosses the others represents the minimum carbon price needed to make the technology switch worthwhile. Leaving aside nuclear for the moment (as it is presently banned in Australia), the cheapest solution is combined cycle gas turbine (natural gas) with carbon capture and storage, which needs a carbon price of just over $30. To justify building either of the coal technologies (PF or IGCC) with carbon capture and storage for new plants would require a carbon price over $40. Retrofitting existing coal plants with carbon capture and storage might have different costs.

The problem is, carbon capture and storage may only make sense if you take a short-term view of emission reductions. While it can deliver the probable reduction targets until 2030, the current technology will not deliver the tougher emission targets recommended for 2050. Coal plants often have a 40-year life, so new coal plants with CCS built over the next few decades may still be operating by 2050, holding us back from meeting those targets, unless they can be modified later.

The only renewable technology that met our fit-for-service criteria was solar thermal with heat storage and gas backup for cloudy days. As you can see from the illustration, using solar thermal power to replace coal would require a carbon price greater than $150. The solar industry is ever hopeful that costs will fall, but current costs are about twice other low-carbon alternatives so they have a long way to go. Future cost reductions for any technology are inherently uncertain and should not be relied on.

The standout technology, from a cost perspective, is nuclear power. From the eight nuclear cost studies we reviewed (all published in the past decade, and adjusted to 2009 dollars), the median cost of electricity from current technology nuclear plants was just above new coal plants with no carbon price. Having the lowest carbon emissions of all the fit-for-service technologies, nuclear remains the cheapest solution at any carbon price. Importantly, it is the only fit-for-service baseload technology that can deliver the 2050 emission reduction targets.

The low cost for nuclear electricity may surprise some. Nuclear plants are renowned for being very expensive to build. But electricity costs are a function of construction costs, running costs (operations, maintenance and fuel) and the total energy generated over the plant's lifetime.

Nuclear fuel costs are relatively low compared to coal or gas (very little fuel is used in a nuclear plant) and these plants typically have a long life and high availability. These factors lead to a low electricity cost over the nuclear plant's lifetime.

The results of this survey represent the scientific/engineering/economic consensus of the world-wide, authoritative, peer-reviewed energy literature. Given the importance of reducing electricity generator emission, and the economic imperative to keep electricity costs at a minimum, it seems essential that the Australian government rethink its nuclear power strategy, as much of the rest of the world has already done. All the arithmetic adds up to nuclear.

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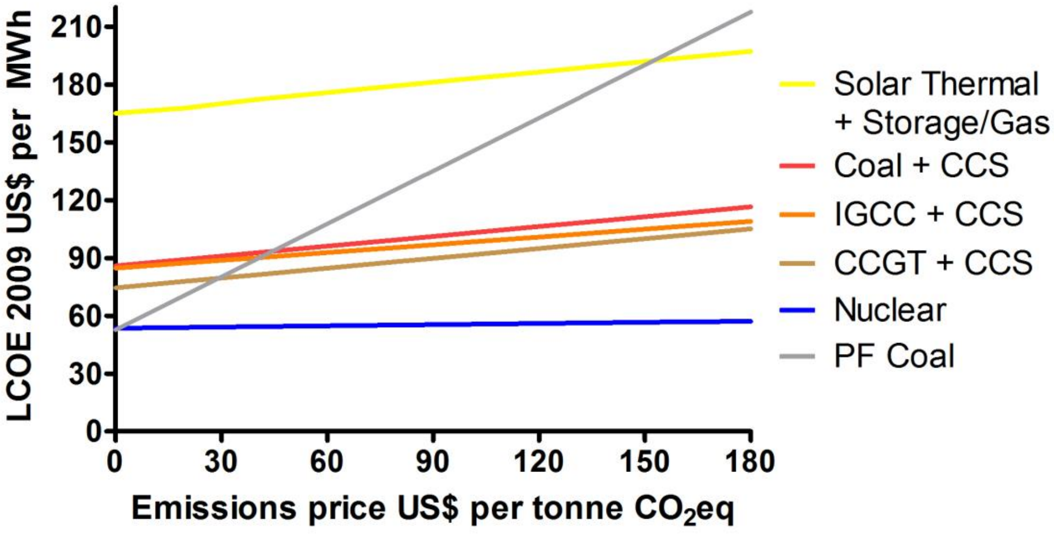

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