Senate Standing Committees on Environment and Communications

Clean Energy Finance Corporation Amendment (Carbon Capture and Storage) Bill 2017

Submission by Simon Holmes à Court

Summary

I thank the committee for the opportunity to comment on the proposed legislation. I write in a personal capacity, having studied low emissions technologies for a decade. I have written several articles and opinion pieces on CCS over the past year.

In my submissions I will explain that:

- CCS is a suite of technologies that can be applied to a range of processes.
- Some CCS opportunities can and should be pursued now — but not via the CEFC.
- CCS is likely to play an important role in industrial decarbonisation — decades from now.
- CCS+coal projects do not meet the CEFC's requirements for risk, commercial and technical readiness, economic feasibility and emissions reduction.

I will sketch out a simplified desktop feasibility demonstrating the basic economics of a hypothetical Australian CCS+coal+EOR project, demonstrating the poor economics of such a project.

CCS is a basket of technologies

It is often overlooked that Carbon Capture and Storage (CCS) is not a technology, but a suite of technologies.

CCS can be applied to a number of industrial processes, including power generation, steel making, cement manufacturing and natural gas separation. The technology used to separate the carbon dioxide (CO_2) from a process gas stream will generally include either solvent/sorbent, membrane separation or cryogenics depending on the application.

With some processes, the separation of CO_2 is already part of an existing process. For example, the well gas feeding into Chevron's Gorgon project in the North-west Western Australia comprises approximately 15% CO_2 which must be removed prior to liquefaction in the normal course of business. As such there is *relatively* little *additional* cost in capturing CO_2.

However, for other processes, such as the combustion of coal, steelmaking and the manufacture of cement, the flue gasses are not separated in the normal course of business. As such, the application of CCS to these processes requires the addition of significant capital equipment and operating expense (energy, staff and consumables) with the sole purpose of capturing CO_2.

Compression of CO_2 for transport is not technically challenging, but requires large amounts of energy. Injection of CO_2 is not considered difficult, however identifying suitable sites and implementing long term monitoring processes is non-trivial and entails a number of risks.

CCS may be important for some processes in the future

The industrial processes currently used in the manufacture of cement, making of steel and synthesis of many chemicals emit significant amounts of CO_2. While research and development into new processes with lower CO_2 emissions is ongoing and some promising results have been achieved, it is generally accepted that achieving significant CO_2 reductions from these sectors will be expensive. While the eventual application of carbon pricing will result in great incentives to develop new, lower-emissions processes, unless and until this research and development is successful, CCS *may* be the least-cost technology for 'cleaning up' these processes.

Further, it is generally agreed in the scientific community that removal of CO_2 from the atmosphere may become necessary in order to lower atmospheric CO_2 concentration. This may be through 'direct air capture' (DAC) or 'bio-energy with carbon capture and storage' (BECCS).

When to use CCS

All CCS process involve significant cost, both in capital plant and operating costs, and give rise to an implied cost of abatement.

Where the cost of capture and storage is relatively low cost in comparison to project size, i.e. the Gorgon roject, CCS makes sense today and should be mandated, as it was for that project. Note that CCS within the Gorgon project is not a self-sustaining business, but rather a 'pollution control system' to meet compliance obligations.

Where new, high emissions projects are built with opportunities for relatively low cost carbon capture and local sequestration, it makes sense to mandate CCS, as was done for the Gorgon project.

Regardless, some decades from now, when all low cost abatement opportunities are exhausted, CCS will likely be necessary for any remaining processes with 'stubborn emissions' or for atmospheric carbon removal.

When not to use CCS

Where the costs for applying CCS are non-trivial there will be cheaper options for reducing emissions in other, unrelated projects. For example, if it were to cost $100/t to fit CCS to a steel making plant but abatement could be easily achieved for $20/t through other projects, it would *not* make sense to invest in the CCS retrofit.

Where the cost of a CCS retrofit caused a process to be more expensive than a substitute process, it would not make sense to proceed with the retrofit. An example is coal-fired power, where a retrofit could theoretically reduce the emissions from a power station by 90% but increase the cost of power from $60/MWh to $180/MWh, equating to approximately $120/tonne abated. **Substituting the coal generation with renewables, gas or hybrid energy systems will achieve abatement at a small fraction of the cost of CCS+coal.**

The state of CCS+coal

Proponents of CCS often boast that there are 19 'large-scale' projects in the world, but will rarely offer up that *only three* significant CCS projects have been built in conjunction with coal power generation. Each of these projects have been small and expensive demonstration plants.

To give a sense of scale, the Eraring power station in NSW emits 12.9 million tonnes of CO_2e in 2015/16. The largest CCS+coal project globally, the US$1bn Petra Nova (Texas, USA) is designed to capture only 1.4 Mtpa — less than 11% of Eraring's annual emissions.

The second largest CCS+coal plant in the world, the CAD$1.5bn Boundary Dam project, was designed to capture 1.0 Mtpa, however after 3.5 years the plant has only captured 1.991 Mt, or 0.583 Mtpa on average. The plant has endured significant outages, has struggled with unexpectedly high operations costs and has been subject to penalties for non-delivery of CO_2 to the downstream user.

The only other significant CCS+coal plant in the world is/was the Kemper IGCC+CCS project, which would have been 528MW, or 18% the size of Eraring. After the schedule slipped more than three years and the cost blew out from US$1.8bn to US$7.5bn, the project was unable to demonstrate sustained operation and was subsequently converted into a standard natural gas power station.

Kemper now has the dubious distinction as the most expensive utility power station every built on a per megawatt basis. If the plant had worked as designed, its emissions would have been similar to a combined cycle gas plant that would have cost in the order of US$550m.

The Carbon Capture and Sequestration Technologies Program at the Massachusetts Institute of Technology, which closed in June 2016, maintained a database of CCS projects. At the last update, a total of 30 proposed CCS+coal projects (as well as five CCS+gas projects) had been cancelled or put on hold. Of another 24 projects in development at the time, the vast majority appear to also have been cancelled or suspended. A selection of the unified list appears in Appendix 1.

One of the cancelled projects is local. In 2006 Australia embarked on a project to build a the ZeroGen project in Central Queensland. The project was expected to capture 65% of its CO_2 emissions, and at 390MW net, would have been the smallest coal power station in the National Electricity Market and was expected to come into service by the end of 2017.

ZeroGen received $188m in grants — $102.5m from the Queensland Government, $38.5m from the Federal Clean Energy Initiative and $47m from the coal industry's Coal21 fund. Originally estimated to cost $1.2bn, detailed engineering studies yielded a revised estimate of $6.9bn. The project collapsed in 2011, thankfully averting an outcome similar to the Kemper Project.

The vast majority of CCS+coal projects ever proposed have not come to fruition. It is fair to say that the only two notable projects are small and expensive demonstrations, a small fraction of the size required to capture the emissions of a typical Australian coal power station.

A CCS+coal project at gigawatt scale would likely require finance (debt plus equity) in excess of $10bn. A loan of, say, $200m would represent perhaps 2% of the project cost and would be among the largest, and riskiest, loans granted by the CEFC to date.

Furthermore, it should be noted that the CEFC is not a 'banker of last result' for unbankable projects — the role of the CEFC is to 'crowd-in' other investors. **Given the track record and economics, it is inconceivable that independent financial institutions would invest alongside the CEFC in CCS+coal projects until a commercially successful implementation of technology at scale has been demonstrated.**

The abatement effectiveness of CCS+coal

All three significant CCS+coal projects — Boundary Dam, Petra Nova and Kemper — were designed to be adjuncts to enhanced oil recovery (EOR) projects.

EOR is a process by which CO_2 is injected into depleted oil wells. The CO_2 mixes with previously unreachable oil and forms an emulsion that can be more readily extracted. The CO_2-rich emulsion is captured at the surface and processed to separate the CO_2 from crude oil. It is estimated that approximately 70% of the CO_2 is recovered and reinjected, with around 30% lost to the atmosphere. So while a project may capture 1 Mtpa, only 0.7 Mtpa might stay sequestered.

The oil follows the same lifecycle as any other crude oil — it is refined and burnt, generally in internal combustion engines, resulting in atmospheric carbon emissions.

As such, the immense efforts of capturing and sequestering CO_2 is undermined by fugitive emissions within the EOR process and the ultimate emissions of the oil extracted.

Taking into account the estimated fugitive emissions from EOR, Petra Nova is estimated to have reduced emissions from its host power station by 4.5%. The project at Boundary Dam is estimated to have reduced the power station's emissions by only 3.5%.

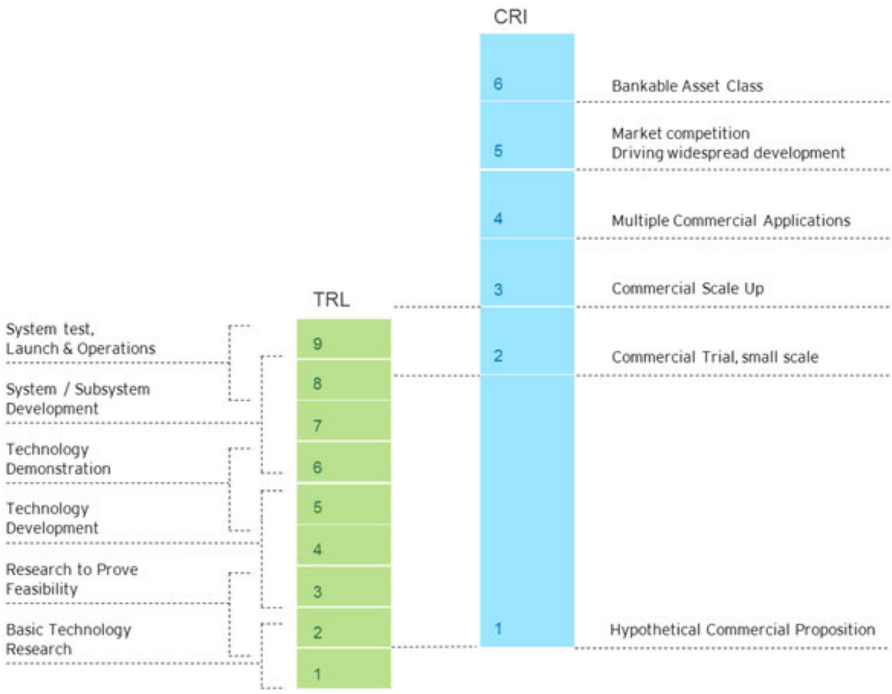
The CEFC's guidelines require that a project must reduce the emissions intensity of a process by at least 50% — more than an order of magnitude higher than the full lifecycle emissions reductions of either project. **It is highly unlikely that any CCS+coal project will ever be presented to the CEFC that meets the 50% emissions reduction guideline.**

Commercial readiness for CCS+coal

When assessing projects, ARENA applies the Technology Readiness Level (TRL) and the Commercial Readiness Index (CRI). Any capital intensive technology will not enjoy mass adoption until it is 'bankable', a status that can only be achieved once the technology has progressed through the TRL scale and ultimately up the CRI scale.

The Boundary Dam project is still working through a number of significant issues (in particular the unexpectedly excessive degradation of amine solution) and is only operating at 58% of design capacity. NRG, the owners of Petra Nova, have not shown the same level of transparency, however, based on public announcements, the plant may have achieved 85% of its design capacity in the first year.

It is reasonable to assign a TRL in the range 7 – 8 to these projects. With only two plants in operation world-wide, and both significantly smaller than typical units within modern coal power stations, a CRI in the range 2 – 3 is reasonable.



The CEFC is not a research and development program. In order to meet benchmark returns and carry acceptable risks, the CEFC should only invest in projects that have demonstrated technical and commercial maturity. **CCS+coal process have yet to demonstrate technical and commercial readiness to the CEFC's standards.**

Commercialisation pathway for CCS+coal

Costs for the Boundary Dam and Petra Nova demonstration projects are understood to imply a CO_2 abatement cost in the vicinity of A$150/tonne. As with any technology, costs can be expected to fall with significant repetition.

If each generation of CCS+coal manages to reduce costs by 30% — an ambitious learning curve — it would take five generations to achieve costs in the vicinity of $25/tonne.

With such high reliance on energy, capital equipment, consumables, skilled operations personnel and custom engineering for each site, it is highly likely that costs would approach asymptotes well before abatement reaches $25/tonne.

The first generation of CCS+coal will have taken almost 20 years. While future generations could be compressed into shorter periods, progress would require strong and consistent demand. Since some technology tweaks will inevitably turn out to be dead-ends, progress will only be likely if multiple projects are developed in parallel.

To be useful, the next generation of CCS projects will need to be 5 – 10 times the size. A program of 3 – 5 generations of multiple large-scale projects could easily take 20 – 40 years and cost hundreds of billions of dollars.

It is increasingly unlikely that any more coal plants will be built in Australia. As such, the best prospects for CCS+coal in Australia are retrofits on existing coal power stations. Few coal power stations in Australia have more than 20 years of service life remaining, and it is unknown how many of these are located near to suitable sequestration geology.

Given these challenges, the high costs of CCS+coal and the fact that there are currently no known *utility scale* CCS+coal projects in development anywhere in the world, no credible commercialisation pathway for CCS+coal has been demonstrated.

Example CCS+coal+EOR project economics

Consider a hypothetical project to retrofit 1 Mtpa capacity CCS plant to the 750 MW Kogan Creek power station in Queensland and utilise the carbon for enhanced oil recovery in the Surat Basin.

In order to model the project economics, it is necessary to determine a range of assumptions. I consider the numbers below to be optimistic, but recognise that cost and other engineering assumptions will always be debateable up until such time as the project is delivered. I would be happy to share detailed analysis with the committee, or rerun the model for different cost assumptions.

Assumption	**Value**	**Note**
Capacity	1 Mtpa	
Capital cost	$1.05bn	30% cost reduction from Boundary Dam — very optimistic, might be difficult to achieve
Project life and loan term	20 years	assumes long life of power station and oil field
WACC	9%	optimistic for potentially contentious, first of a kind large infrastructure project in Australia
Oil price	US$60	oil prices are likely to both increase and decrease during the project lifetime
Additional oil extraction (barrels annually)	707,000 bbl	
Parasitic load	40 MW	same as Boundary Dam
Cost of Power	$60/MW	
Staff headcount	25	half of the reported Boundary Dam headcount
Salaries	$1.5m	based on $60k average salary, possibly low-ball
EOR CO_2 leakage	30%	http://www.pembina.org/reports/iCO2n-eor-summary.pdf
CO_2 released per barrel	0.43t	https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references not including emissions from the downstream supply chain
Amine costs (annual)	$5m	Boundary Dam aimed to use as much, but has used up to four times as much
Plant O&M	$10m	estimate
EOR infrastructure	-	not estimated

With the above assumptions, annual finance costs would be $116.7m with $37.5m of other annual expenses. With a total cost of $154.2m p.a. the cost of delivered CO_2 would be $154/t. (The Boundary Dam project appears to be selling CO_2 in the range $20 – $25 per tonne.)

The EOR process would extract an additional $53.7m of oil per annum, resulting in a net annual loss between the two projects (CCS+EOR) of $100.5m.

The CCS plant would reduce the Kogan Creek's output by a little over 5% and reduce the plant's prima facie emissions by 22.4% from 3.8Mtpa to 2.8Mtpa. However, assuming a 30% leakage from CO_2 recovery in the EOR process, the emissions reduction would reduce to 14%.

If the emissions of the extracted oil are considered, the total reduction are estimated at 5.5%.

If the project construction cost blew out by 20% — as Boundary Dam did — the project would cost as much as it cost to build Kogan Creek in 2007.

Clearly the economics of CCS+coal+EOR do not stack up and would fail to meet the CEFC's investment mandate. Further, the project would clearly fail to meet the CEFC's 50% emissions reduction requirement.

Conclusion

Until such time as there is a significant carbon price in Australia, the only application of CCS will be on projects where capture and sequestration form part of a project's consent obligations — as in the case of Gorgon.

Without a carbon price, CCS will not be a business opportunity, but rather a cost of operating emissions intensive industries. It is highly unlikely that any CCS projects will come before the CEFC.

Furthermore it is obvious that CCS+coal, even with enhanced oil recovery, is a nascent industry which, despite 20 years and over US$10bn investment, has delivered only two significant demonstration projects. While technically impressive, the carbon abatement achieved from these projects are an order of magnitude smaller and an order of magnitude more expensive than the opportunities regularly before the CEFC.

With a lack of commercial viable CCS opportunities on offer, it is difficult to understand why this amendment is before Parliament. That said, *as long as the CEFC can be guaranteed* to remain bound to its rigorous guidelines, the fate of the amendment before the committee is highly unlikely to have any difference to either the CEFC or the development of CCS.

Thank you for the opportunity to brief the committee. I am available to discuss the content with the committee at any time.

Appendix A — Selection of cancelled/stalled CCS+coal projects

Country	Project	Proponent	Region
Australia	Kwinana	BP	WA
	ZeroGen	ZeroGen	QLD
Canada	Bow City	BCPL	Alberta
	Project Pioneer	TransAlta	Alberta
Italy	Porto Tolle	ENEL	
Romania	Getica	Turceni Energy	
Netherlands	Eemshaven	Essent	
	ROAD	E.ON	
UK	Killingholme	C.GEN	
	Longannet	Scottish Power	
	Hunterston	Ayrshire Power	
	Teesside Low Carbon	Progressive	
	Peterhead	Shell and SSE	
	Don Valley Power Project	2Co Energy	
	Captain/ Clean Energy Project	Summit Power	
	White Rose	Capture Power	
Spain	Compostilla	ENDESA	
Germany	Goldenbergwerk	RWE	
	Janschwalde	Vattenfall	
Poland	Belchatow	PGE	
Finland	FINNCAP	Fortum	
Norway	Longyearbyen	Unis CO_2	
	Kårstø	Naturkraft	
	Zeng Risavika	CO_2 Norway	
	Halten	Statoil	
UAE	HPAD	Masdar	UAE
USA	Kimberlina	Clean Energy Systems	California
	Carson	BP	California
	Big Bend Station	Siemens	Florida
	FutureGen	FutureGen Alliance	Illinois
	Taylorville	Tenaska	Illinois
	Indiana Gasification	Leucadia	Indiana
	Kemper County	Southern	Mississippi
	Antelope Valley	Basin Electric	North Dakota
	Sweeny Gasification	ConocoPhillips	Texas
	ZENG Worsham-Steed	Worsham-Steed	Texas
	Trailblazer	Tenaska	Texas
	Wallula	Wallula Resource	Washington
	Appalacian Power	AEP	West Virginia
	AEP Mountaineer	AEP	West Virginia