Carbon Capture and Storage

Information paper

beyond ZERO emissions

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Summary

As far back as 1995, bodies such as the Intergovernmental Panel on Climate Change speculated that yet-to-be-developed carbon dioxide capture and permanent storage (CCS) technology might be applied to industrial-scale fossil-fuel electricity generation. The idea was that CCS could allow continued use of fossil fuels as a cheap energy source while not disrupting our climate. Fossil fuel proponents have suggested that the possible viability of CCS (sometimes referred to as "clean coal") is a reason why fossil fuel use and expansion in Australia should continue unabated.

This paper describes why, nearly 20 years later, it is clear that electricity generation using fossil fuels and CCS (which we refer to as EFF-CCS) will not be deployed at significant scale globally and will not be key to mitigating climate-disruption. The idea of EFF-CCS should not be used to prolong Australian fossil fuel production because:

1. EFF-CCS technology, regulatory regimes, and social acceptance have been slow to develop. Even CCS proponents do not foresee wide deployment until the 2030s. EFF-CCS costs are rising while alternatives (energy efficiency and renewable energy) are being widely deployed as their costs fall. Well before 2030, energy efficiency and renewable energy will play the role once envisioned for EFF CCS. Nowhere in the world has one unit of electricity been produced by an EFF-CCS facility operating under an effective regulatory regime ensuring permanent CO2 storage. Nor are there any firm plans to do so.
2. EFF-CCS cannot effectively operate at anything less than enormous scale. (In this way, EFF-CCS is similar to nuclear.) This necessity for enormous scale impedes EFF-CCS from getting started. In contrast, some energy efficiency and renewable energy technologies are effective right down to the household level.
3. Technological limitations and uncertainties of EFF-CCS remain to be resolved. EFF-CCS has high energy self-consumption and cannot capture all of its greenhouse gas emissions. Scientists' understanding of how CO2 behaves after being injected underground is inadequate to ensure that CO2 is stored forever and not released as a result of natural or man-made earthquakes or other events. BP's termination of its multi-billion dollar CO2 injection project at In Salah, Algeria due to unexpected below-ground CO2 movement highlights the risks of EFF-CCS.
4. Because EFF-CCS combines a number of costly, complex and sophisticated technologies, it will be challenging to widely deploy and verify its effectiveness, particularly in developing countries.
5. Disasters are regularly occurring because of ever-more-exotic ways used to produce fossil fuels. These disasters, contrasted with the growing popularity and deployment of energy efficiency and renewable energy alternatives, are motivating people to reject the old ways of energy production that damage health, food and water supplies, and national security. Claims made by fossil fuel companies and political leaders that prosperity is impossible without fossil fuels are being challenged. As a result, EFF-CCS proponents are finding it difficult to obtain the social license and financing they need to proceed.

6. As interest in EFF-CCS wanes, governments and industry are cancelling projects and reducing funding. Governments are not establishing the policies and regulations needed to drive EFF-CCS development.
7. Studies that show how 100% renewable energy can power Australia, other countries and regions, and the entire world, illustrate that EFF-CCS is unnecessary. This and all aforementioned reasons are why CCS proponents such as the International Energy Agency now say EFF-CCS can be, at most, only a small part of the future energy solution.

Alarmingly, oil companies are co-opting CCS to produce previously-unrecoverable fossil crude oil using underground CO2 flooding techniques. Producing fossil fuels in ever-more-exotic ways, such as by CO2 flooding, delays the full transition to clean energy that people seek and that our economy, environment, and climate require.

Supporting CCS slows progress on viable solutions and risks accomplishing nothing other than further expansion of the fossil fuel industry. Hopes that EFF-CCS might one day be successful are no reason to delay the urgent transition away from fossil fuels and on to 100% renewable energy in Australia and in all countries of the world.

What is CCS?

A series of complex and sophisticated technologies

When carbon-containing fossil fuels (coal, oil, and gas) or non-fossil fuels (e.g. wood and biomass) are burned (combusted), oxygen from the air combines with the carbon in these fuels to form large volumes of the well-known greenhouse gas carbon dioxide (CO2) as a waste product. As a greenhouse gas, CO2 traps the Sun's heat and causes our Earth to warm. Human-produced CO2 is also absorbed by our Earth's oceans causing ocean acidification and endangering marine life, ecosystems, and critical life-maintaining oceanic processes.

Though lesser in volume than the CO2 produced from combustion, waste CO2 is also produced industrially via fossil gas and oil refining processes and during the manufacture of products such as chemicals, fertiliser, steel and cement (1).

The concept that waste CO2 can be captured at industrial scale and permanently stored or sequestered to prevent it moving into our Earth's atmosphere and oceans is known as carbon dioxide capture and permanent storage (CCS).

Many different categories of CCS are described in the literature (2), varying according to:

- the type of fuel burned (e.g. biomass, coal, gas) or other CO2-emitting process involved
- the industry involved (electricity generation, fossil gas production, steel making)
- whether CCS is applied to existing facilities (retrofits) or new
- the process used to increase the concentration of CO2 in the waste stream (pre-combustion methods, the use of pure oxygen versus air)
- the capture technology (chemical, physical, biological)
- the sequestration method (geological, mineralization, conversion to a saleable product, or other)
  - in the case of geological sequestration, into what sort of rock layer the waste CO2 is injected (disused oil or gas reservoir, saline aquifer, or other)
- whether the waste CO2 is in some way "utilized" as it is being sequestered (e.g. enhanced oil recovery).

These many options and combinations of CCS, lead to public confusion – both intentional and unintentional.

Some CCS proposals are aimed at having a large positive climate impact. Some other CCS-related activities can mitigate climate disruption in only minor ways. Others can lead to climate-damaging outcomes. The public needs clearer information in order to understand where CCS is or isn't making relevant progress as a solution to climate disruption.

The CCS category relevant to this paper is the production of electricity using fossil fuels (coal, oil or gas) with CCS, which we refer to as EFF-CCS. This paper does not discuss the other options and combinations of CCS because they involve smaller (though not inconsequential) volumes of greenhouse gas production and are not as critical to the future of the Australian economy or to the stabilization of our Earth's climate.

The sequestration method applicable to the large volumes of CO2 associated with EFF-CCS is the geological method whereby CO2 under high pressure is injected into rock layers around one kilometer or more beneath the Earth's surface.

To summarise, but also to show the complexity of EFF-CCS, the following 21 major steps or processes describe an EFF-CCS application based on an open-cut coal mine:

- locating and gaining the rights to mine a source of coal
- gaining permits and land on which to build an electricity generating plant
- gaining rights to access and dispose of large volumes of cooling water
- locating and gaining rights to use a suitable underground CO2 storage reservoir
- removing and storing the soil and rock that lies above the coal seam
- mining the coal in a safe and environmentally responsible manner including controlling hazardous dust
- maintaining the coal mine in a safe and environmentally benign way, considering risks such as wall collapse, coal seam fires, flooding, and drawdown of any underlying aquifer
- safely and healthfully transporting coal from the mine to the generating plant site
- applying processes to remove and/or contain coal contaminants (e.g. water, sulphur, nitrogenous compounds, arsenic, heavy and radioactive metals, fine particulates)
- disposing of coal contaminants
- burning the coal to generate steam and electricity
- disposing of coal ash in a safe, permanent, and environmentally benign way
- employing chemical or physical processes to capture the waste CO2
- processing the waste CO2 so that it is ready for compression
- compressing the CO2 to high pressure
- safely transporting the CO2 by high pressure pipeline possibly over hundreds of kilometers
- injecting the CO2 underground via many injection wells, some of which are planned to be located out in the ocean
- at the end of the injection phase, ensuring that injection wells are secured in a way that will prevent leakage forever
- monitoring the stored CO2 forever, via methods including wellbore instrumentation, seismic tests, and reservoir modeling
- technically, commercially, and legally dealing with any CO2 leaks that might occur or are suspected to have occurred
- rehabilitating the impacted area at the end of the mine's economic life.

Then, after all of the above activity, another energy source must be found to replace the depleted mine.

Because EFF-CCS combines a number of costly, complex and sophisticated technologies, it will be challenging to deploy and verify its effectiveness, especially if deployed in developing countries with less reliable enforcement of regulations.

> *"We (would) need to set up some sort of international regime for certifying, monitoring, verifying and inspecting geologic repositories of carbon - like the UN weapons inspections systems." (3) - Romm, J., Climate Progress*

The complexity of processes like EFF-CCS or nuclear power make it hard to sell to the public. It is difficult for proponents to gain the public's acceptance, especially when alternatives (energy efficiency and renewable energy) are now in plain view and increasingly popular.

Global scale

CCS will not meet the global scale of the problem

EFF-CCS will not be deployed at significant scale across the world and is not a key solution to climate-disruption.

EFF-CCS has been too slow to develop

Development of EFF-CCS technology and legal regimes under which it would be regulated have been too slow to develop. This is summarized by the International Energy Agency (IEA):

> *"CCS is advancing slowly, due to high costs and lack of political and financial commitment. Few positive major developments were seen in 2013, and policies necessary to facilitate the transition from demonstration to deployment are still largely missing." (4)*

And again the IEA more recently in June 2014 in its publication "What lies in store for CCS?":

> *"CCS investment, demonstration projects and large-scale deployment are well behind the targets envisaged by analysts, governments, and industry." (5)*

The reasons for the slow development of EFF-CCS include its lack of advantages over energy efficiency and renewable energy and the reluctance of governments to apply economic drivers for EFF-CCS such as a carbon price of at least $US 125 per tonne-of-CO2 (6).

> *"I am particularly worried about the lack of progress in developing policies to drive CCS deployment. Without CCS, the world will have to abandon its reliance on fossil fuels much sooner…" –Maria van der Hoeven, Executive Director of the International Energy Agency (7)*

A recent study found the possibility of CCS projects becoming commercially available by 2020 to be greatly exaggerated:

> *"…challenges are found to be 10 times greater than often recognized. … CCS [will not] be widely applied in time for significant contributions to needed CO2 emission reductions." (8)*

In recent years, CCS proponents have recognized that CCS will not be ready for wide deployment until the 2030s.

> *"The idea is that CCS then becomes a commercial reality and begins to make deep cuts in emissions during the 2030s." - Barry Jones, General Manager for Policy and Membership, Global CCS Institute." (9)*

> *"Carbon capture and storage technology is simply not commercially available…" – Peabody Coal (10)*

Nearly twenty years after the Intergovernmental Panel on Climate Change speculated (11) that yet-to-be-developed EFF-CCS technology might be a way to significantly mitigate climate change, not a single unit of electricity has been produced by a complete EFF-CCS facility operating under an effective regulatory regime that ensures permanent CO2 storage (12). Nor are there firm plans to build such a facility anywhere in the world. Globally, 31 CCS projects are listed as "on hold", "deferred", or "cancelled" (13). 21 EFF-CCS plants remain in the "planning" phase and three are "under construction" (including the recently completed Boundary Dam).

EFF-CCS costs are rising

Despite hopes that EFF-CCS costs might fall due to research and innovation, the actual costs for EFF-CCS components currently under construction have more than doubled beyond initial estimates.

Costs at the Kemper Mississippi project have increased from $US 2 billion to $US 5.5 billion and completion has been delayed by one year (14). This illustrates the risks and uncertainties associated with constructing the complex processing equipment that is EFF-CCS.

Two other high-level factors driving up the costs and/or investment risk profile of EFF-CCS are described next.

The costs of developing suitable storage reservoirs are uncertain

Suitable geological storage reservoirs of known sealing integrity are often located far from EFF-CCS fossil fuel sources and electricity demand centres. This means that enormous volumes of high pressure CO_2 must be transported by pipeline over great distances (15), adding to costs. Even CO_2 storage locations perceived to be lower cost, such as the Bass Strait offshore Victoria, may conflict with oil and gas production in the same area (16) which then forces EFF-CCS proponents to consider other possibly more expensive storage options.

In 2014, the IEA is still calling for high-level national and regional storage data to be developed, recognizing that this would then have to be followed by more detailed investigations. The lack of progress on establishing access rights to suitable CO_2 storage reservoirs is now being recognized:

> *"It is of particular importance to boost activity in the area of CO_2 storage, on various levels. … Experience shows that it can take 5-10 years to qualify a new saline formation for CO_2 storage, even when theoretical estimates are already available and look promising." (5)*

The cost of developing new fossil fuel sources is rising

The cheapest and most readily-accessible deposits of fossil fuels are being depleted, driving up the costs of fossil fuel production and making EFF-CCS less competitive against renewables-based electricity. Fossil gas prices in eastern Australia are climbing to record levels as they are exposed to the international markets for the first time (17). Certain proposed coal developments in Australia are far from the coast and would involve costly rail and port infrastructure. Consequently, economic development of these coal deposits is unlikely and it is very unlikely that these expensive-to-develop coal deposits would ever be used with EFF-CCS.

EFF-CCS can't compete with renewables

EFF-CCS costs are rising while energy efficiency and renewable energy are being widely deployed worldwide and can be reliably costed (18). Contrasted with the aforementioned cost increases for CCS, the cost of electricity generated from renewables is estimated to have fallen below that of a new fossil plant even without adding the expense of CCS (19). Well before 2030, energy efficiency and renewable energy will take over the role once envisioned for EFF CCS.

A recent study done by the University of New South Wales, based on Australian government energy technology cost estimates (20) specifically compared the costs of EFF-CCS with renewables and found:

> *"…that only under a few, and seemingly unlikely, combinations of costs can any of the fossil fuel scenarios compete economically with 100% renewable electricity in a carbon constrained world." (21)*

Since that study, the Australian government has published new, lower cost figures for solar energy (22) which further widens the cost gap between CCS and renewables.

Contrast EFF-CCS's commercial stasis over the last 20 years with ongoing global deployment of wind and solar photovoltaic (PV). Electricity produced each year from wind and solar PV has grown from the ~ 14 TWh produced in 1995 to over 1,000 TWh produced in 2013 (18). This is a 25% compound annual growth rate. (Note: 1,000 TWh/yr is five times as much electricity as that needed to power Australia.)

Energy efficiency and renewable energy have advantages over fossil-fuels beyond mitigating climate disruption, including: lower health risks due to lower levels of air pollutants produced (fine particulates, smog precursors, sulphur and nitrogen compounds, heavy metals), and lower impacts on land and water-use. These advantages, combined with concerns about climate change, resource depletion, and energy security, have led governments and communities to strongly support research and global deployment of energy efficiency and renewable energy. Global investment in renewables totaled $US 214 billion in 2013 (18). From January to March 2014, 94% of the new electricity generation capacity installed in the United States was either solar or wind (23).

The lack of EFF-CCS progress also contrasts with astounding advancements in energy efficiency. Examples include the development of LED lighting that uses less than 1/10th the energy of earlier technologies, and advancements in air-source-heat-pump technology that allow living spaces and water to be efficiently heated with renewable energy (24). Energy efficiency is one factor causing the fall in Australian electricity demand (25).

Other than potentially reducing greenhouse gas emissions, EFF-CCS offers no benefits over conventional fossil fuel burning. For the same amount of delivered electricity, because of process inefficiencies (described below), implementing EFF CCS would actually increase pollutant health risks and land and water-use impacts.

EFF-CCS operates only at enormous scale

Though the scale of transition to a zero-greenhouse-gas emission economy is daunting whether it is to be accomplished by energy efficiency and renewables or by EFF-CCS, EFF-CCS is at a disadvantage because it cannot effectively operate at anything less than enormous scale. (In this way, EFF-CCS is similar to nuclear power.) This scale constraint impedes EFF-CCS from getting started. In contrast, some energy efficiency and renewable energy technologies are immediately effective right down to the household level.

The volume of CO2 that would be produced, and therefore must be disposed of, by EFF-CCS is enormous.

> *"Sequestering a mere 1/10 of today's global CO2 emissions would call for putting in place an industry that would have to force underground every year the volume of compressed gas larger than or (with higher compression) equal to the volume of crude oil extracted globally by [the] petroleum industry whose infrastructures and capacities have been put in place over a century of development." (26)*

As an example, consider the approximately 75 million tonnes per year of CO2 emitted from burning fossil gas and black coal in New South Wales. Because no candidate CO2 storage reservoirs have been identified in New South Wales, alternatives sites for storing CO2 have been indentified 700 km away in Queensland or more than 1,000 km away in the Bass Strait offshore Victoria. Although, in reality, CO2 would be transported by pipeline, to comprehend the volume of CO2 to be transported, consider the hypothetical case where CO2 is transported by truck, ten tonnes at a time. Disposal of New South Wales' CO2 would require that a ten-tonne truck loaded with CO2 leave New South Wales bound for the trip to Queensland or Victoria every four seconds. This tonnage of CO2 just from New South Wales is 50% larger than all of the crude oil consumed in Australia.

As at June 2013, the Victorian state government was keen to see further use of Victoria's brown coal (lignite) reserves, possibly by employing EFF-CCS (27). This may be the most expensive form of greenhouse gas mitigation imaginable, given that brown coal as mined from the ground contains a lot of water and therefore the amount of CO2 emitted by burning brown coal (per unit of electricity generated) is around 30 percent greater than black coal, twice that of fossil gas, and infinitely greater than renewable energy. Given the high volumes of CO2 produced from burning brown coal (per unit of electricity produced) and therefore high costs for CO2 capture and storage, brown coal EFF-CCS is unlikely to compete with renewables-based electricity generation.

EFF-CSS technological limitations and uncertainties remain unresolved

EFF-CCS self-consumes massive amounts of energy

The various processes that make up EFF-CCS (CO2 capture, compression, transport, and injection), themselves consume a large amount of energy. For every four EFF-CCS plants built, a fifth EFF-CCS plant would have to be built to power the first four (and itself) (28). This self-consumption would increase the need for even more fossil fuel mining, more water use, more pollution, and more CO2 emissions.

Because EFF-CCS is inefficient in this way, it is unlikely to be retrofitted to old coal-fired electricity generators that are themselves inefficient – burning a lot of coal for every unit of electricity produced. Because many of Australia's coal plants are old and inefficient, the Australian Climate Council recently concluded:

> *"...CCS ... is unlikely to be a viable option for much of Australia's fleet, given the fleet age, high costs, and lack of suitable locations to apply the technology". (29)*

EFF-CCS can't achieve "zero-emissions"

Techno-economic limitations of chemical and physical CO2 absorption processes mean that 100% of the CO2 emitted at an EFF-CCS plant cannot be captured and therefore EFF-CCS cannot achieve "zero-emissions". 65% CO2 recovery is expected at the facility being built at Kemper Mississippi (14) while current research aims at achieving 90% CO2 capture (30).

We must reduce greenhouse gas emissions to zero as rapidly as possible and also remove CO2 from the atmosphere in order to go "beyond" or "below" zero emissions. It is nonsensical to spend trillions of dollars on EFF-CCS technology that cannot be "zero-emissions" when zero-emissions can be achieved by energy efficiency and renewable energy.

Earthquake risk

There are long-standing competing uses for the sedimentary basins that are targeted for CO2 injection, such as waste water injection and fossil oil and gas production that these days often involving fracking (31). These fossil fuel and water operations are known to cause earthquakes (32) (referred to by the industry as "induced seismicity"). Earthquakes compromise the sealing capability of CO2 waste storage reservoirs.

> *"...there is a high probability that earthquakes will be triggered by injection of large volumes of CO2 into the brittle rocks commonly found in continental interiors. Because even small- to moderate-sized earthquakes threaten the seal integrity of CO2 repositories, in this context, large-scale CCS is risky, and likely unsuccessful, strategy for significantly reducing greenhouse gas emissions." – Stanford University researchers (33)*

CO2 injection itself has also caused earthquakes (34) that can damage buildings and infrastructure as well as compromising the integrity of the reservoir involved or neighbouring reservoirs that might in future also be investigated for CO2 storage.

Technical methods and regulations don't yet exist to guarantee that CO2 stays underground - *forever*

For each of the tens of thousands of CO2 injection wells that CCS proponents say will need to be placed all over the world, monitoring would be required for hundreds and even thousands of years to ensure that the injected carbon dioxide never leaks back into our Earth's atmosphere. Were a CO2 leak to occur, caused for example by inadequate well completion methods, well corrosion and degradation, or a natural or human-induced earthquake, all of the effort and money expended to capture and inject the CO2 would have been for naught.

Any CO2 that is injected underground with EFF-CCS must remain in place forever because, unlike nuclear waste, there is no proven method and time period over which geologically-stored CO2 transforms into a more benign material. The technical and legal methods required for monitoring this waste, assessing liability, guaranteeing permanent retention to the extent possible, and dealing with retention failure are still to be decided and agreed by scientists, lawyers, and the public.

What happens to CO2 injected underground cannot be known with complete certainty because it is difficult to "see" what happens underground. To give an idea of the science that still needs to be developed to improve our ability to "see" CO2 underground, suggested monitoring methods include measurements of pressure, temperature resistivity, sonic responses, seismic, microseismic, petrophysical and geochemical sampling including tracer and isotope analysis (35), and "muon tomography" (36).

The gaps in scientists' understanding of underground CO2 movement are illustrated by failure at the world's second-largest CO2 injection project. At In Salah Algeria, the oil company BP produces waste CO2 as a result of fossil gas processing. BP spent billions of dollars to inject waste CO2 underground from 2004 to 2011. The injection was terminated in 2011 when monitoring observations at the site suggested that pressure and probably CO2 had unexpectedly migrated into rock layers other than the target layer (37).

Fossil disasters prevent fossil fuel developers from obtaining social license

In Australia and overseas, there has been a succession of widely-publicised fossil fuel disasters:

- the 2006 Sidoarjo Indonesia mud volcano that displaced 30,000 villagers (38)
- the 2008 Varanus Island gas explosion that disrupted Western Australian gas supplies

- the 2009 Montara Timor Sea offshore oil and gas blowout and fire involving the evacuation of 69 workers (39)
- the 2010 Deepwater Horizon offshore oil and gas disaster in the U.S. Gulf of Mexico that claimed 11 lives
- the 2010 Great Barrier Reef oil spill (40)
- the 2012 collapse of the Yallourn brown coal mine in Victoria (41)
- the 2012 uncontrolled grounding and irreparable damaging of the Kulluk oil drilling rig in the Gulf of Alaska (42)
- the 2012-2013 Pilliga State Forest (New South Wales) aquifer contamination caused by coal seam gas operations (43)
- the 2013 Lac-Megantic, Canada oil-carrying train wreck that claimed 42 lives (44)
- the 2014 Hazelwood, Victoria coal mine fire that burned for several weeks and required evacuation of at-risk residents from the town of Morwell, population 12,000 (45)
- mountain-top removal coal mining in the Appalachian Mountains of the U.S. (46) (47)
- coal mining fatalities (48) (49) (50)
- coal mining health impacts (51) (52)
- unconventional gas mining and fracking well blowouts, fugitive emissions, fatalities, illnesses and other incidents in Australia, the United States and elsewhere (53) (54) (55) (56)

Oil spills in the Bass Strait (57), have resulted from increasingly complex, exotic, and risky extraction methods.

There have been controversial attempts to expand fossil fuel production into new areas or with new methods, such as:

- liquefied natural gas (LNG) developments at Gladstone Queensland
- LNG development in Broome, Western Australia (58)
- coal export terminal development on the Great Barrier Reef (59)
- Victorian brown coal exports (45)
- •unconventional gas developments such as in Gippsland Victoria and the Limestone Coast of South Australia (60) (61)
- Canadian tar sands development and plans for the Keystone XL pipeline in Canada and the U.S.

These incidents and the use of controversial new methods of fossil fuel production contrast with the familiarity that people are gaining with energy efficiency and renewable energy alternatives. Communities are no longer interested in suffering from the impacts of fossil fuels when energy efficiency and renewable energy alternatives are now available. Rather, people and communities are becoming increasingly motivated to scrutinize and reject the old ways of dirty fossil energy production that damage and endanger health, food and water supplies, and national security (62), and that delay the urgently-needed transition to a sustainable economy, environment, and climate. The credibility of fossil fuel companies and political leaders is questioned when they claim that fossil fuels are a critical part of a prosperous future.

This growing gap of trust between society and the fossil fuel industry increases the costs and effort that EFF-CCS proponents must expend to obtain the social licence and land-access rights needed for fossil fuel production (63), plant construction, waste transport, and waste disposal. Project costs increase when public protest stretches out fossil fuel development timelines (64). Financiers are also increasingly reticent to involve themselves with projects that engender environmental, health, and other concerns in the public consciousness and lack social licence (65).

CO2 transport and underground injection involves real or perceived risks including water contamination, earthquakes (34) (33) and asphyxiation. The community of Barendrecht in the Netherlands stopped Shell's investigations into CO2 injection beneath their land (66). Similar protests have occurred in Germany (67).

Like the nuclear power industry, CCS carries the risk that because of a single high-profile environmental or health incident or disaster, it loses community support. Billion dollar assets can quickly become liabilities when the local and/or global community shifts from support to opposition.

Interest in CCS is waning among governments and industry

As doubts about the future viability and competitiveness of EFF-CCS grow, governments and industry are reducing funding. Governments are not establishing the policies and regulations needed to drive complete end-to-end EFF-CCS development (4) (7).

The Massachusetts Institute of Technology database lists 31 projects as now being cancelled or inactive (13).

In October 2013, the Global CCS Institute announced that since their survey a year prior, five projects had been cancelled, one reduced in size, and seven postponed (68).

> *"One major CCS demonstration facility at a West Virginia coal plant was shut down in 2011*

> *because it could not sell the carbon dioxide or recover the extra cost from its electricity customers and the equipment consumed so much energy that, at full scale, the project would have sharply cut electricity production." (3)*

In 2009, the Australian Member of Parliament Ian Macfarlane said:

> *"The reality is, you are not going to see another coal-fired power station built in Australia. ... You can talk all that stuff you like about carbon capture and storage. That concept will not materialise for 20 years, and probably never." (69)*

Macfarlane's political party came into power in Australia in 2013 and he became Minister for Industry. In its May 2014 budget announcements, the Australian Government proposed cutting $459 million of CCS funding (70). As a result, the Collie-South West CO2 Geosequestration Hub project in Western Australia is "unlikely to ever move beyond the research phase" (71).

Other examples of waning government and industry support in Australia and overseas are:

- In May 2014, the Swedish energy company Vattenfall announced that CCS research would be "deleted in its entirety" (72).
- In 2013, the Australian coal industry suspended the requirement for levies to be paid to the COAL21 Fund, which had been aimed at sponsoring CCS development (73).
- In 2013, the Norwegian government dropped plans for the Mongstad CCS project that it "had once compared in ambition to sending people to the moon" (74).
- In 2012, the company HRL froze development of a A$1.2 billion "clean coal" project in Victoria (75).
- In 2012, the Alberta, Canada provincial government cancelled its funding of the CCS project associated with the proposed Swan Hills Synfuels plant that was estimated to cost at least $1.5 billion (76).
- In 2011, a EUR 1 billion CCS project at the Longannet power station in Fife, Scotland was cancelled (77).
- In 2011, Vattenfall AG announced the cancellation of its plans for a EUR 1.5 billion German CCS project in Jänschwalde and for the exploration of possible storage facilities in eastern Brandenburg (78).
- In 2010, the Queensland government cancelled its involvement with the $4.3 billon ZeroGen project (79).
- In 2009, Santos suspended its carbon storage project in Moomba, South Australia (80) the initial phase of which was estimated to cost A$ 700 million.
- In 2008, BP and Rio Tinto cancelled the $2 billion "Hydrogen Energy" project in Kwinana, Western Australia (81).
- In 2008, Shell and Anglo halted development of the A$ 5 billion Monash Energy Project (82).
- In 2008, the U.S. Department of Energy cancelled its main CCS project, known as FutureGen (83).

However in North America, CCS is finding support when projects are economically driven by monetization of cheap coal deposits and sales of CO2 for enhanced oil recovery (14) (84). This is described in Section 3.

EFF-CCS is unnecessary because we can get there with energy efficiency and renewables

Studies (85) have shown how 100% renewable energy can power Australia (86) (87) (88), other states and regions of the world, and indeed the entire world (89). These studies illustrate that EFF-CCS is unnecessary because the world's energy needs can be met by a combination of energy efficiency, fuel switching, renewable energy, and energy storage.

Even CCS proponents, therefore, project EFF-CCS to play only a small role in future energy solutions. In the International Energy Agency's "Two Degree Scenario", EFF-CCS makes up just 8% of global electricity generation capacity (2) whereas energy efficiency and renewable energy have comparatively larger roles.

Co-opted by the oil industry

Beware of CCS being used to extract more fossil oil

Oil companies are co-opting CCS, using CCS-produced CO2 to recover previously unrecoverable fossil crude oil via underground CO2 flooding techniques. Dangerously, this is having climate-damaging consequences.

CO2 enhanced oil recovery (CO2 EOR), sometimes referred to as "tertiary recovery", originated in Texas in 1972 (90). In this process, CO2 is injected into an oil reservoir from which oil otherwise can no longer be produced. Traditionally, the source of the CO2 used was naturally-occurring CO2 gas extracted from underground deposits; however, CO2 recovered as a byproduct of chemical processes, fossil gas processing, or EFF-CCS can also be used.

The CO2 injected for enhanced oil recovery mixes with oil tightly held within the oil-bearing rock and allows that oil (now mixed with CO2) to move to the surface, via wells, for recovery. Using this method, 1.4 billion barrels of oil have been recovered from depleted fields in Texas (91). In the U.S. alone, up to an additional 137 billion barrels (equivalent to 20 years of U.S. oil consumption) might be recoverable with this method (90). Beyond that, oil industry technologists have identified that further fossil oil deposits (known as "residual oil zones") from which oil cannot be recovered with today's traditional methods, may be made to economically yield fossil oil if low-cost CO2 is available on the market (91).

After separating the CO2 from the recovered oil, CO2 (valued in this industry recently at "well above $US 25 per ton" (92) and as high as $US 40 per ton (14)), is cycled back into the ground again and again. This cycling process may go on for several years, but in the end, some CO2 will likely remain underground. For this reason, the oil industry states that this process can permanently store CO2. But there are two issues:

1. In North America where most of the new CO2 injection activities are planned, no technical or legal mechanisms have yet been established for monitoring and controlling underground CO2 storage. In other words, there are no regulations, contractual arrangements, nor direct incentives in place guaranteeing permanent storage of CO2. Any permanent CO2 storage occurring with these projects is not expected to be monitored and verified and thus should be considered incidental.
2. CO2 enhanced oil recovery can produce between 0.2 and 1.1 tonnes of oil for every tonne of CO2 permanently stored (90) (92) (93). Ultimately, nearly all of the oil will be burned to produce 0.6 to 3.4 tonnes of CO2. Therefore, the ratio of CO2 stored to CO2 released due to oil burning ranges from 0.6-to-1 to 3.4-to-1.

Point 2 above illustrates that using CCS for enhanced oil recovery can be either slightly climate-positive (where the ratio is less than 1-to-1) or very climate-damaging (where the ratio is more than 1-to-1). In their drive for profit, oil producers will inevitably target the most climate-damaging reservoirs where the greatest amount of oil can be recovered by using the least amount of CO2. Nevertheless, CO2 EOR proponents point out that other methods of producing fossil oil can be even more climate-damaging than using CO2 flooding (91).

The Massachusetts Institute of Technology (MIT) CCS project database (13) lists five commercial CCS-related CO2 EOR operations as existing prior to 2007 and another seven CO2 EOR projects as having started since then. Another 17 CO2 EOR projects are listed by MIT as under construction or in the planning phase. The proponents claim these projects will have positive climate benefits (94) when in fact the impact of these projects may be very negative or at best marginally and incidentally positive.

With oil valued at over $US 100 per barrel, the economic drivers for the oil industry to access greater volumes of CO2 will remain strong:

“Although CO2 EOR technology is mature in the U.S., many reservoir targets have not been flooded because of limited CO2 supply.” (91)

Two notable CCS-related projects under construction, Southern Co.’s Kemper Mississippi project (14) and Saskpower’s Boundary Dam Project (84) are cited as key examples of EFF-CCS progress.

“Through the development of the world’s first and largest commercial-scale CCS project of its kind, SaskPower is making a viable technical, environmental and economic case for the continued use of coal” (84).

These projects would not have been sanctioned but for the oil industry’s demand for CO2 in North America and financial support from governments. The Kemper Mississippi project allowed a new and previously uneconomic brown coal (lignite) mine to be developed. According to a spokesperson:

“The most important advantage is the plant’s proximity to a new coal mine and to old Mississippi oil fields. The coal mine has 4 billion tons of minable lignite, enough to supply the new 582-megawatt power plant for a thousand years. Though long-neglected as a feedstock because of its high moisture content, lignite coal, after drying out for three days, is fine for the type of plant Southern is building. [A spokesperson said…] tapping the deposit was ‘like waking up and finding money in your attic.’ ” (14)

Using coal to produce fossil oil in ever-more-exotic ways delays the full transition to clean energy that people seek and that our economy, environment, and climate require. Continuing to support CCS may accomplish nothing more than further expansion of the fossil fuel industry.

Conclusion

This paper has described why EFF-CCS will not be deployed at significant scale, is not a viable way to mitigate climate disruption, is unnecessary and dangerous, and why hope for CCS success is no reason to allow Australian fossil fuel use to continue domestically or overseas.

The view that EFF-CCS will someday be a significant climate solution is misjudged and dangerous. Supporting EFF-CCS slows progress on viable solutions and risks accomplishing only further expansion of the fossil fuel industry.

EFF-CCS support should be recognized as yet another way that fossil fuel interests are preserving business-as-usual and delaying effective climate action. Hopes that EFF-CCS might one day be successful are not a reason to delay Australia's or any other country's urgent transition away from fossil fuels and to 100% renewable energy.

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