

Article

A Social Exploration of the West Australian Gorgon Gas, Carbon Capture and Storage Project

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Abstract: Carbon capture and storage (CCS) appears to be essential for lowering emissions during the necessary energy transition. However, in Australia, it has not delivered this result, at any useful scale, and this needs explanation. To investigate the reasons for this failure, the paper undertakes a historical and social case study of the Gorgon gas project in Western Australia, which is often declared to be one of the biggest CCS projects in the world. The Gorgon project could be expected to succeed, as it has the backing of government, a practical and economic reason for removing CO₂, a history of previous exploration, nearby storage sites, experienced operators and managers, and long-term taxpayer liability for problems. However, it has run late, failed to meet its targets, and not lowered net emissions. The paper explores the social factors which seem to be disrupting the process. These factors include the commercial imperatives of the operation, the lack of incentives, the complexity of the process, the presence of ignored routine problems, geological issues (even in a well-explored area), technical failures, regulatory threats even if minor, tax issues, and the project increasing emissions and consuming carbon budgets despite claims otherwise. The results of this case study suggest that CCS may work in theory, but not well enough under some contemporary forms of social organisation, and the possibilities of CCS cannot be separated from its social background. Social dynamics should be included in CCS projections to enhance the accuracy of expectations.



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1. Introduction

Through a case study, this paper explores the social, organisational, and ecological contexts of carbon capture and storage (CCS), as displayed by the Chevron Gorgon gas project in West Australia, and suggests explanations for its apparent failure. The prime suggestion is that technology is a social venture, which cannot be separated from its complex social background.

In social studies of science and technology, it is standard to assert that technology is invented, understood, developed, used, promoted, managed, installed, regulated, designed, financed, and sold in differing social, economic, and power relations and that these factors have consequences. Technologies may be driven by these relations, take them for granted, or be designed to reinforce them, although technologies frequently have disruptive unintended consequences. Technologies can work in theory but be found socially impractical, be hindered by social practices (intentionally or unintentionally), or have less success than supposedly technically inferior inventions. Some good introductions to this subject include [1–3]. However, this paper requires no specialist knowledge.

Technologies can also involve compelling ‘social imaginaries’, especially those technologies which exist in theory or fail to work the way they are intended. These imaginings may then function as a rhetoric to persuade people of an existing, or forthcoming, “beneficial reality” [4]. Consequently, technologies can be used politically, or to avoid facing disturbing problems. In illustration, this paper explores the unintentional social and technical undermining of carbon capture as a working solution for greenhouse gas (GHG) emission problems.

It seems important to understand that societies are a subset of complex interactive systems [5,6]. They are composed of people and groups who modify themselves and their reactions in response to what they *perceive* as happening in the system, and by what happens to them. Societies have their own internal systems such as economies, knowledge, and politics and interact with other complex systems such as ecologies, climate systems, and technical systems. These complex systems overlap with each other, and cannot be easily isolated in analysis, hence the discussion of factors in this paper which some might consider relatively unimportant to the CCS process. As a result of these overlapping interactions, technological projects may increase in complexity (and difficulty of control and prediction) as other parts, and social organisations, are added to them, often leading to “tipping points” or breakdown [7]. Supportive of this position, it has been argued that experimental rigs which work at a small scale may have problems when expanded and that the bigger the carbon capture project, the more likely it is to fail [8]. This does not bode well for building a series of carbon capture projects adequate to curtail carbon pollution.

1.1. Paper Structure

The paper proceeds by briefly describing its methodology and the previous work on the history of particular carbon capture projects and their social embedding. Then it puts forward the proposition that climate change is socially generated and driven, and tied into maintaining existing patterns of power, development, and consumption. Social excess produces pollution beyond the capacity of world ecologies to process, particularly when those ecologies are being further damaged by extraction. Section 2 very briefly describes carbon capture in general, then describes carbon capture in Australia, which has a long history of encouragement and funding, but little relative success. Section 3 gives the case study history and analysis of the Gorgon project, arguing that while it is an excellent exemplar for CCS, it has missed its targets and failed to significantly reduce the emissions from the use of its products. This arises from the commercial imperatives of the operation, the lack of incentives, the complexity of the process, the presence of routine problems, geological and ecological issues, technical failures, regulatory threats, tax issues, and the project increasing emissions and consuming carbon budgets despite claims otherwise. While the Chevron Gorgon project should be straightforward, it is overwhelmed by complexity and avoidance of the problem of increased GHG emissions from its operation and products.

1.2. Methodology

The methodology involved tracking news articles on the Gorgon project and following up references in those articles to official documents, or other pieces of non-duplicating journalism, to check their accuracy where possible. I collected a total of 213 news articles and reports stretching over the period 2006–2021 together with other background material. My main interest was in the political, managerial, and economic processes involved, but it was impossible to read these documents without realisation of recurring technical problems, which might not have been expected. There is bias in my analytic procedure as I was looking for disorderly processes and problems. The normal bias is to ignore or play down disorder, blame it on unique circumstances, or condemn it. For instance, the in-house history of the project appears to downplay problems despite being a “lessons learnt” piece [9]. As I have argued previously [10], repeated or expectable disorder is a socially significant part of any process, indicating the way things are done, the systems they interact with, and the problems and processes that organisations wish to avoid.

All social and historical research on the Gorgon project is indebted to the journalist Peter Milne, of *BoilingCold*, who obtained many apparently hidden, or nonavailable, documents from Chevron or the West Australian government, through freedom of information requests. Secrecy, whether intentional or otherwise, seems an established part of the project process.

When conducting case studies through history, sociology, or anthropology it is difficult to separate “data” from “discussion”. Data involves interpretation [11]. Rather than “seeing the events” with their own senses, or interpreting those events directly, the scholar is dependent upon other people’s interpretations of events, and these methods of others (and the analysts own methods) can create interpretations and hence affect the way reality is perceived and acted upon [12]. “Objectivity” comes with social filters. The reports I read may be trying to justify or criticise the project. The reporters almost certainly hold existing views and purposes which influence reports; they may be writing for a specific audience, and so may the analyst. Hence, these reports have to be fitted together through discussion to see what sense they make as a pattern. The data parts become meaningful in terms of the whole narrative, and the whole narrative becomes the “results”. Any interpretation can be overturned by more data and more refined processes of interpretation. Case studies also require a recognition of the potential uniqueness of the case and its context. Comparison is useful but should come after consideration of a number of case studies; otherwise, important factors can be more easily missed as the analysts are not expecting them. This paper aims at presenting a set of hypotheses and interpretations which can guide further interpretation and investigation.

1.3. Previous Work

I was unable to find many detailed histories of particular CCS projects, let alone many which investigated their social context in any depth. Most of the articles in the premier journals for sociological research into energy (*Energy Research and Social Science*) concerning CCS seem to be about public opinion, public evaluation, and communicating acceptance of carbon capture [13–15]. Likewise, an anonymous corporate case study of the ZEPP [16] project in the Netherlands seems primarily interested in how to reduce social opposition in advance of the project.

However, some previous studies show the use of historical case studies. We are fortunate to have the Trupp piece about the Gorgon project, mentioned previously [9], but it does not go into social or economic details, and it seems to avoid fairly well known problems with the project. The best technical history or case study of an individual CCS project is Cook’s edited collection about the Otway Project [17]; however, it tells us more or less nothing about the economics. The Otway CCS project was primarily a research project (which implies an unusual social set-up for normal CCS), and it limited the social side of the research to consultation with the local community, which largely seems to have been oriented at persuasion rather than research. Ackerboom et al. [18] write an important paper which includes a short history of CCS in the Netherlands, rather than of individual projects, which remarks that “while CCS is technically a straightforward proposition, its deployment has historically been hindered by the lack of a sound business case and a compelling and stable socio-technical narrative”. They also indicate significant governmental support for the projects, which may render those projects similar to the Gorgon project, although there is also significant social opposition (partly because the projects are near habitation) and questions over liability, which are missing in Australia. The absence of a profit motive for doing CCS also seemed important to them, as will be argued here. A previous paper by myself on the general history of CCS in Australia [10] argued that despite political and monetary support over the last 20–30 years, CCS has not made any noticeable impact on Australia’s emissions and primarily functions as rhetoric to justify sales of fossil fuels and as a fantasy to defend against real climate action or emissions reduction. A case study by the National Consumer Research Centre in Finland of the Snøhvit liquid natural gas facility in Norway [19] found the site had been caught in controversies about the gas field and ongoing political uncertainty over fossil fuels. “As a consequence of its high ambition level and the controversies surrounding it, the project has experienced a sequence of delays and cost overruns”. They remark that even “even local support cannot be totally controlled by the project managers”, which is unsurprising in a complex human system but appears to

indicate the idea that societies are easily manipulated into agreement with technology and are thus separate from the technological process.

This previous research gives at least some indication that it may be fruitful to pursue the social embedding of CCS projects.

1.4. The Problem: Emissions as Social Excess

Currently, some parts of *some* (not all) human societies are significantly disrupting global ecologies and climate systems [20]. They are consuming resources faster than the planet regenerates them, while simultaneously polluting and disrupting the planet's regenerative capacities, producing instability. Societies seem on the edge of a vast series of (probably rapid) chaotic changes including sea level rises, droughts, floods, wild storms, people movement, and wars. As we are dealing with interacting complex systems, uncertainties about when we will cross the line are normal [21]. Consequently, it seems safer to be cautious than not.

Carbon dioxide and methane (or "natural gas") are currently the main greenhouse gas (GHG) pollutants. CO₂ and methane are normally processed by the global ecology in a "reasonable time frame", being broken down into carbon and oxygen by metabolic processes. CO₂ has also been absorbed by the oceans, gradually increasing acidification and creating harsher conditions for some ocean life, with possibly compounding effects. GHGs are only a problem because industries are producing far more than can be processed by the global ecology within that "reasonable time frame", especially given the simultaneous destruction of ecologies through other forms of pollution or extraction (such as deforestation, fossil fuel mining, and some forms of agriculture). It has been repeatedly estimated that dominant societies, through their social organisation, industries, development, and profit drives, consume, disperse, and destroy in a year more than the planet can regenerate [22–24]. This process, known as "overshoot" or the "metabolic rift", is often seen as a hallmark of capitalist and developmentalist organisation dependent on "economic growth" [25,26].

Dominant societies seem dependent upon, and structured around, pollution and ecological destruction. The dire paradox we face is that pollution from burning fossil fuels both enables modern societies, their science, technology, business, prosperity, and military capacity, and produces climate change which could become catastrophic enough to destroy those societies. By being considered as an "externality", pollution also makes production cheaper, and profits higher for powerful social groups. The increase in CO₂ emissions over the last 70 years of "development" is marked. While there are differences in estimates, the Oxford University *Our World In Data* website, estimates that, without factoring in land use changes, humans released "only" 6 billion tonnes of CO₂ during the year 1950. This increased to 22 billion tonnes during 1990 and reached over 36 billion tonnes in 2019 [27]. The IEA tells us that emissions declined in 2020, due to COVID-19 [28], but 2021 is "set to be the second largest annual increase in history" [29].

A recent study in Nature's *Communications Earth and Environment* journal estimates that "the [carbon] budget for a 67% chance of remaining below the [1.5 °C] target is [a total of] 230 GtCO₂ from the year 2020 onwards" [30] (p. 3). Commenting on the article, the authors add "This is equivalent to between six and 11 years of global emissions, if they remain at current rates and do not start declining" [31]. The chance of a decline with current action is minimal. The updated UN NDC Synthesis Report predicts "a sizable increase, of about 16%, in global GHG emissions in 2030" while "limiting global average temperature increases to 1.5C requires a reduction of CO₂ emissions of 45% in 2030 or a 25% reduction by 2030 to limit warming to 2C" [32]. There is relatively little sign of social and political will to reduce GHG pollution as dramatically as needed, and some signs the social systems will continue to increase it.

Given the overt dangers, and the scientific advice, this reluctance to reduce emissions almost certainly arises from a social "lock-in" by powerful decision-makers and companies, making it harder to reduce fossil fuel burning than to increase it. Lowering fossil fuel usage threatens organisations which have depended upon those fuels for their success. It is

unlikely in this scenario that one technological innovation which preserves current social organisation will be enough to solve the entire complex system of problem generation. We may need a change in social organisation to succeed [33].

In particular, polluting societies need to avoid misleading situations in which emissions from fossil fuels increase at the same time as renewable energy increases so that the increase in emissions is hidden by a lowering of “carbon density”, “emissions intensity”, or “emissions per unit of energy”, or a small fraction of new emissions being caught and stored. Reducing the effects of climate change needs *actual* decreases in greenhouse gas (GHG) emissions: otherwise, harsh changes are inevitable. The idea of a “carbon budget”, or amounts of GHG we can emit before likely generating uncontrollable damage, makes the situation clear.

2. Carbon Capture

2.1. Carbon Capture in General

It seems logical that if we could *capture* most of the GHG emissions from burning fossil fuels, or *extract* those emissions from the atmosphere, *store* them somewhere safely out of the atmosphere forever, or *turn them into something useful or harmless*, then some climate change pressure might be lessened. The pressures could also be reduced by *stopping* emissions, but the social ordering and lock-in discussed above can make this seem improbable, adding further strength to the importance of CCS.

The IPCC and the IEA have suggested that carbon capture and storage (CCS), in which CO₂ is stored underground; carbon capture utilisation and storage (CCUS), in which the carbon is utilised for some other project; and carbon dioxide removal (CDR) from the atmosphere with storage are essential for keeping climate change within socially survivable bounds. (I shall use the term CCS to cover all these ideas for convenience.) The IPCC 2021 report talks of “anthropogenic removals [of CO₂] *exceed[ing]* anthropogenic emissions, to lower surface temperature” [34] (p. 29) (emphasis added). The 2018 IPCC *Special Report: Global Warming of 1.5 °C* states that the “shares of nuclear and fossil fuels with carbon dioxide capture and storage (CCS) . . . increase in most 1.5 °C pathways” [35]. Fateh Birol, head of the IEA, is reported as saying the following: “Without [CCS], our energy and climate goals will become virtually impossible to reach”, even if CCS’s record was “one of unmet expectations” [36]. Many more expressions of the importance of CCS could easily be given. Whether it is sensible to put hope in long-term unmet expectations is another matter.

In 2021, the IEA reinforced the consequences of a limited carbon budget: “Net zero means huge declines in the use of coal, oil and gas Beyond projects already committed as of 2021, there are no new oil and gas fields approved for development in our pathway, and no new coal mines or mine extensions are required” [37].

That is, there should be no new sources of emissions at all. In this view, CCS with increased emissions is not useful. A study in *Nature* [38] also insists that to maintain a 50% *chance* of remaining under 1.5 °C, nearly 60% of oil and methane, and 90% of coal, must remain unextracted, or, presumably, their emissions must be completely stored.

While it is theoretically possible for CCS to solve the emissions problem, this does not mean it is capable of solving the problem, solving it quickly or cheaply enough without significant risk, or is being used to solve the problems. There are no working examples of CCS operating at the scale needed. The IEA said in 2021: “Only one commercial power plant equipped with CCUS remains in operation today. Based on projects currently in early and advanced deployment, the potential capture capacity of all CCUS deployment in power is projected to reach ~60 MtCO₂ in 2030—well short of the 430 MtCO₂ per year in the Net Zero Emissions by 2050 Scenario” [39].

The Carbon Capture and Storage Institute is more optimistic and estimates that the capacity of CCS projects in development (not completed) grew to 111 million tonnes per annum in 2021, a tiny proportion of 36 billion tonnes of emissions per year. Much of that CO₂ is being used for enhanced oil recovery, which further increases emissions [40]. At the same, time members of the Institute write “the number of projects is far lower than

what is needed to make a significant impact on climate change”, although they suggest “organisational competency” is increasing [41] (pp. 4, 6). A suggestion from 2013 [42] that not enough CCS is happening to be useful is still relevant.

Even when successful, the amount of emissions stored from a project can be trivial compared with the emissions released by the companies involved. For example: “Any progress Shell demonstrates in removing carbon from the atmosphere using CCS (1 m tonnes per annum at Quest and up to 4 m tonnes at Gorgon) should be seen in light of Shell’s total emissions of 656 million tonnes per annum (80 Mt scope 1 and 2; 576 Mt scope 3)” [43].

It is generally assumed that technologies become cheaper and easier to use over time, but this is not always the case [44]. CCS is an established technology, with little rapid improvement likely. It has been used since at least 1972 “when several natural-gas processing plants in the Val Verde area of Texas began employing carbon capture to supply CO₂ for enhanced oil recovery” [43]. The first international conference on carbon dioxide removal was held in the Netherlands in 1992 [45]. The Sleipner project, in Norway, began in 1996. The IPCC first reported on CCS in 2005 [46]. By 2012, the EU had committed USD 10 billion in taxpayer support [47] (p. 249). Given this history, it should be relatively easy to discover whether CCS is useful, a fantasy with regular failure, or even a mode of locking in GHG pollution.

CCS is probably also affected by the reluctance of governments to get involved in problem solving, and the neoliberal belief that development should be left to subsidised private enterprise. This turns CCS into a commercial activity with no obvious commercial co-benefits, such as profit, unless it involves activities such as extracting more oil, which expands emissions. Lack of profit and a potential increase in liability costs inhibit commercial action, although this could possibly be rectified by financial incentives, robust measures of GHG removal, or cheap pipelines to storage fields [44,48,49]. Later, this paper shall discuss problems of profit (especially as CCS adds to costs and energy use), taxation, liability costs, regulatory ambiguities, carbon accounting, and the politics of trade, in relation to CCS construction. These points resemble the four primary barriers to successful CCS put forward by Davies et al. [50]: (1) cost and cost recovery, (2) lack of financial incentive or profit, (3) long-term liability risks, and (4) lack of coherent regulations.

2.2. CCS in Australia

Australia is a major coal and gas exporter. It is currently second in the world to Qatar in gas exports and second to Indonesia in coal exports. In a media release after COP 26, Angus Taylor, Minister for Energy and Emissions Reduction, said: “Australia’s economy is almost unique amongst developed countries, with an economy specialised in the production of energy- and emissions-intensive commodities. We are the world’s fourth largest energy exporter, after Saudi Arabia, Russia and the United States” [51].

He previously made government backing for methane very clear: “The Government backs the gas industry, backs Australians who use gas and it backs the 850,000 Australians who rely on gas for a job. Gas is a critical enabler of Australia’s economy” [52].

Eight hundred fifty thousand seems to be the number of Australians who work in “all sectors of manufacturing and not all those sectors use gas as a feedstock”. There seem to be close to 8000 employees directly dependent on gas. The indirect number is harder to calculate [53].

Taylor also remarked that the emissions aims for 2030, which were not clarified in response to requests by COP26, were “fixed”. Subsequently, more new large gas fields have been announced, and the Government has issued the *2021 National Gas Infrastructure Plan*, which states: “Unlocking new sources of [gas] supply will be a key focus for industry and governments out to the 2040s” [54] (p. 10).

Australia also has the highest per capita GHG emissions in the OECD [55]. Consequently, Australia has a major incentive to support CCS, so fossil fuel sales can continue to expand. Some people estimate that taxpayers have contributed over AUD 1 billion to CCS out of the AUD 3.5 billion promised [56]. Australian Governments may be classified

as maintaining what Arranz [47] calls an “enthusiastic framing” of CCS, seeing it as a way to solve problems of instability in transition as the population embrace rooftop solar—“Australia now leads the world in solar per capita with 810 W/person, ahead of Germany with 650 W/person” [57] (p. 5)—and (perhaps more importantly) to maintain economic competitiveness and development. This enthusiastic focus encourages “blind spots” to the difficulties, such as CCS in Australia not reducing emissions significantly. The coal industry was previously largely uninterested in CCS, as an attempt to save coal exports. Most projects initiated have been small-scale and subsequently abandoned [4]. The largest has been the Chevron Gorgon gas fields, the subject of this paper.

In 2020, the Australian government proposed new ways of funding CCS. This included changing the scope of its AUD 2.5 billion Climate Solutions Fund, the investment guidelines for the Clean Energy Finance Corporation (CEFC) and the Australian Renewable Energy Agency (ARENA), to become “technology neutral”. “Technology neutral”, as used by the Coalition government, tends to mean pro-fossil fuels. The Labor opposition queried the Government’s attempts to allow the CEFC to fund CCS by saying that “to pretend that a bank [the CEFC] that requires a commercial rate of return can lend to a technology that has not been commercially deployed anywhere in the world is just a fantasy” [58]. Grant King, head of the review making these recommendations, was the former head of Origin Energy (user of gas and coal) and board member of the Australian Petroleum Production & Exploration Association (APPEA), a body which has campaigned strongly against the curtailment of fossil fuels, describing itself as “the effective voice of Australia’s upstream oil and gas industry on the issues that matter” [59].

Unsurprisingly, APPEA has recommended more new gas fields and CCS. Its Chief Executive Andrew McConville said “Carbon Capture and Storage (CCS) is already well established as a safe, large scale, permanent abatement solution Accelerating the roll-out of CCS projects could assist in reducing emissions from the energy, industrial and power generation sectors” [60]. “Australia needs low-cost carbon abatement to maintain its position as a leading energy exporter and ensure international competitiveness in a cleaner energy future” [61].

Again, the aim of maintaining methane exports is clear.

In November 2021, the Prime Minister announced AUD20 billion to fund “new technologies, whether it’s hydrogen, carbon capture and storage, low cost soil carbon management measurement, the green steel and aluminium” [62]. However, some of the funding may not arrive, as members of the Government who opposed climate action of any type have said they will vote against legislation enabling it [63]. Nevertheless, the Australian Government and the major opposition party have both demonstrated consistent support for CCS as part of their support for maintaining fossil fuel exports. While LNG exports may reduce emissions if gas use reduces coal burning, it is not certain if such reductions in coal use are happening in importing countries, and gas-burning continues to consume the limited carbon budget as CCS is nowhere near storing or using all emissions from this burning. More new gas fields and coal mines have been announced recently in keeping with the *Gas Infrastructure Plan*. The Prime Minister announced to the Business Council of Australia that when he heard about the new AUD 16.5 billion Scarborough gas development, he “did a bit of a jig out of the Chamber. I just could not be more thrilled about that. That is such a shot in the arm for our economy and it is going to power us into the future” [64].

The Australian government has heavily promoted CCS and can be said to have glossed over, or even delighted in, increased emissions from the new gas fields they are encouraging.

3. The Gorgon Project

As stated earlier, the project does not exist in isolation from social practices and corporate organisation, and it needs to be considered through the way it is embedded in its context of other complex problem-generating systems. Complexity is routine for any

project this size. This analysis will proceed via various headings, all of which should be thought of as interconnected.

3.1. *Why It Is a Good Exemplar*

The Chevron Gorgon project in West Australia could be considered an excellent exemplar for CCS. In 2019, Chevron said: “The Gorgon CO₂ injection project is believed to be one of the largest greenhouse gas mitigation projects undertaken by industry, which will reduce greenhouse gas emissions from the Gorgon project by around 40 per cent” [65].

That appears to translate to 80% of the CO₂ in the methane, before export.

Chevron has an economic incentive as the Gorgon gas field has too much CO₂ in the methane (14%) [9,66]. The CO₂ needs to be removed for transport, as it freezes when the gas is liquefied. Normally the gas would be released into the atmosphere. There are natural storage basins nearby, so transport is short and simple, while the storage areas contain saline water so leakage should be low. It is clearly politically welcomed, not only in keeping with the Government’s promotion of gas, but also receiving AUD 60 million in government subsidy, as well as significant royalty and tax benefits, all of which increase profitability. West Australian EPA objections were bypassed [67,68], even though the Barrow Island site is a Class A nature reserve (the highest classification). Its distance from major population centres may have helped reduce protest. Western Australia is seismically stable. Chevron has conducted research at the site, possibly from 1998 with a Greenhouse Challenge Cooperative Agreement between the Gorgon Joint Venture Participants and the Australian Greenhouse Office [69]. Drilling had been carried out in the area since the 1960s, so the area is well known [70]. Chevron’s partners in the project, ExxonMobil (25%) and Shell (25%), are among the most experienced fossil fuel companies in the world. The project, therefore, has much in its favour to demonstrate the possibilities, or failings, of CCS.

3.2. *Rates of Construction and Use*

Technological problems are normal in complicated and complex systems (see [10] for a social analysis of software problems). Technology requires social organisation, capacity, and evaluation to implement. The rate of CCS construction will be influenced by the interactions between various social and technical organisations, such as commercial exaggeration of ease, conflict between groups, technical failure, and systemic practices of ignoring problems in favour of profit.

3.2.1. *The Plan*

Chevron still anticipates the Gorgon project will have the lowest greenhouse gas emissions intensity of any LNG drilling project in Australia [71]. The Minister announced the plan was to store “between 3.4 and 4 million tonnes of greenhouse gas emissions each year” [72]. The project uses a solvent (activated methyl di-ethanol amine) to remove CO₂, H₂S, and other impurities, along with a mercury removal unit. Dry low NO_x (DLN) burners reduce NO_x emissions [73,74]. The CO₂ is then transported close to 7 km and injected into a sandstone saline aquifer, more than 2000 m underground, where it is expected to dissolve [9], presumably making the saline acidic and possibly having some ecological or geological effect. As pressure in the aquifer increases with CO₂ injection, this is balanced by pumping water out about 4 km away. This causes some problems, as will be discussed later. This water is then pumped into a different layer of rock above the CO₂ [75]. I assume the water is checked to find out if CO₂ is present, efforts are made to prevent CO₂ escape, and tests are conducted to check for the solvent. Monitoring wells are drilled to discover the movement of the CO₂ in the aquifer [9]. These wells themselves could disturb the confinement, if not properly sealed.

3.2.2. *Slow Progress*

Progress on the whole project has been slow. As already stated, Chevron’s research on the area possibly began in 1998. The project was first formally proposed in 2006.

It began in September 2009, and in 2012 Chevron announced it would begin storing a total of 120 million tonnes of CO₂ at a rate of 3 tons a year in 2014/15 [76]. By mid-2016, according to Chevron's annual report to the Federal Government, the CO₂ pipeline was not completely connected, and injection was delayed for a year [75,77]. In March 2016, two years late, Gorgon produced its first shipment of LNG after a budget blowout of USD 18 billion, suggesting significant problems [75]. Export was shut down due to problems with the propane cooling system [78] (see below Section 3.2.4), some of which were said to be organisational. "The procedures for operating the propane cooler required the operator to know the pressure at the inlet of the propane compressor, but no such indication existed. Other issues Chevron identified, included workers starting up the plant having an 'unclear line of management oversight' and 'inadequate technical resources to back up operations' [79].

Later it appears the vessels were imperfect to begin with.

Exports were supposed to reach 15.6 million tonnes a year by about mid-2017 [80]. Commercial gas output before the CCS was working was said to be averaging 449,000 barrels of oil equivalent per day [81]. Plans were also announced to further expand gas production in 2018–2019, although it was unclear if there were plans to expand CO₂ storage [82,83]. Some of these exports came from the nearby Jansz-Io field which has lower CO₂ content, and through releasing excess CO₂ into the atmosphere. Income was prioritised over CCS.

The first storage injection occurred on 6 August 2019, at least four years late. By the end of June 2020, 2.5 million tonnes of GHG had been stored. By September 2020, they were claiming 3 million tonnes of stored CO₂ [84,85]. Problems remained with storage due to pressure issues. A Chevron report from 2020 states that "investigations into the loss of injectivity at the pressure management water injection wells was ongoing" ([84] see next section). The CCS part of the project was expected to cost USD 2 billion [76], but by 2021 "the capital budget had increased to \$3.092 billion" [84].

3.2.3. Failure to Achieve Targets

The slow progress, perhaps because of prioritising gas sales, resulted in the Gorgon project not achieving its storage targets.

In 2009, before Chevron, Shell, and ExxonMobil committed to the project, they were required to "implement all practicable means to inject underground all reservoir carbon dioxide removed during gas processing operations on Barrow Island and ensure that calculated on a 5 year rolling average, at least 80 percent of reservoir carbon dioxide removed during gas processing operations on Barrow Island and that would be otherwise vented to the atmosphere is injected" [86]. If this target was not met, then Chevron would have to offset the emissions. What was later decided to count as the initial period finished in late 2021.

Some of this disruption to targets resulted from the equipment extracting water from the injection sites failing when they clogged with sand, "despite prior studies to selectively perforate the four water production wells to avoid weak zones that might be prone to sand production" [84]. Chevron promised to "install equipment to extract the 'significant volume of sand' from the water before it is reinjected underground" [87]. Quite where the sand was to be stored, given the delicate nature of the ecology, is not clear, and it is not clear why Chevron failed to detect sand in the water in exploratory investigations. During 2020, CO₂ injection, under a series of permissions from WA's Department of Mining, Industry Regulation and Safety, averaged 70% of maximum capacity despite the water wells not functioning properly. Presumably, Chevron did not succeed in fixing the problem, and in December 2020 this failure led to regulators restricting carbon injection to a maximum of two-thirds of its supposed capacity from 1 January 2021, to avoid high pressure in the reservoirs and potential cracking and leakage (see Section 3.3). Over a year, this would mean an additional 2.64 million tonnes of pollution [88].

In a project report from 2021, Chevron said: "It is yet to be confirmed whether sand production is likely to be a long-term issue. If sand production is found to be [a] persis-

tent issue it is possible changes to the surface facilities may be required" [84] (p. 6). A spokesperson said: "While CO₂ injection safely continues, daily injection rates have been amended which has resulted in additional CO₂ venting in the short-term" [89].

According to Professor Newman of Curtin University, the difficulties were a surprise: "The whole reason for being allowed to go on an A-Class reserve (Barrow Island) was because the sediments were perfect for this sequestration" [65].

Helpfully, the WA government determined that emissions made before an operating licence was awarded did not count, reducing Chevron's liability.

Faced with these failures to meet targets, a Chevron spokesperson said the carbon capture project was complex and bigger than anything undertaken anywhere in the world [90]. With the sand and pressure problem, they said: "Like any pioneering endeavour, it has presented some challenges and we continue to work closely with the regulator to optimise the system, with a focus on long-term, safe and reliable operation over its 40-plus year life" [91]. Innovation may not only cause delays but also act as an excuse.

This led to some political protest; for example, the Conservation Council of WA said Chevron should close the plant until it could demonstrate its CCS system was working, as it was violating its licence conditions [92].

3.2.4. Routine Problems

The project involved massive interconnected and complex infrastructure, which might be expected to generate problems with CCS targets, deadlines, and costs, especially if gas production was prioritised. Work was hampered by breakdowns on the site of processes unrelated to CCS [79,88].

One problem involved a design issue with the compressors which allowed water and CO₂ to mix, forming carbolic acid which could then corrode the equipment. In 2017, checks "found leaking valves, valves that could corrode and excess water in the pipeline from the LNG plant to the injection wells that could cause the pipeline to corrode" [93]. This produced a significant delay, officially announced at the end of 2018, and CO₂ was again vented directly to the air. Team leader for the Gorgon CCS project, Mark Trupp (coauthor of [9]), said: "Carbon dioxide is a corrosive substance. We have had some issues managing the water content of the carbon dioxide that has required modifications to our facilities. That is what has been delaying us" [94]. Chevron might have been expected to realise the presence of CO₂ and water vapour in LNG to be a recurring rather than unpredictable problem, although perhaps not if venting was routine.

As well, the project was faced with other technological mishaps which slowed production and added to complications. Cracks in propane vessels, needed to cool gas for export, were revealed through worker complaints to the media (possibly because the company had appeared to ignore safety issues) and led to a Department of Mines, Industry Regulation and Safety WorkSafe investigation [95]. "Cracks up to 1 metre long and 30 millimetres deep were found in between eight and 11 kettle heat exchangers on Train 2 of the plant" [96]. This meant that Gorgon's three LNG trains were shut down for repair for some months [88]. The precise causes appear to have remained secret, although they seem to have involved faulty welding during manufacture. It is not clear whether these cracks are related to the earlier propane cooling problems discussed above. Rumours asserted the kettles would need to be replaced [97]. Other information suggests the kettles did not comply with Australian standards. Eventually, these problems led to increased inspections [98] and shut down some parts of the plant. The problems resurfaced, and in late January 2021, Chevron warned that continuing repairs would lower output [99]. In March 2021, Chevron announced it would use the June quarter to close the third LNG production unit to check for more defective welding [100]. In May 2021, Chief Financial Officer Pierre Breber said at least one train had been out of action since mid-2020 [101].

3.3. Geology

3.3.1. Sand in Aquifers

This has been largely discussed above. However, the Dupuy Formation in which the emissions are being stored is described by the MIT Gorgon fact sheet [66] (latest revision 2016, before the problems occurred) as “a massive turbidite sand deposit” which might have been expected to be a problem in advance. Chevron claimed in 2021 that “an upgrade to the filtration system for the sand was now complete” [102]. Young [103] states that the regulators “approved Chevron to purge sand from its production wells into sandbags”, so it can be hoped the sand does not contain heavy metals or other poisons which could leak out into the nature reserve. Where the filled bags are to be stored is unclear.

3.3.2. Seismic Events

There are some concerns that CCS might provoke seismic events which could break the storage and undo the effort completely [104,105]. Other analysts (still remarking on long-term uncertainty of CO₂ behaviour underground over thousands of years) seem less troubled [106]. Local geology appears to be relatively stable, which reduces the chance of leaks through crack creation. Geoscience Australia’s search engine records 23 quakes above 5.0 in, or offshore, WA in the last 21 years [107]. The WA Department of Mines, Industry Regulation and Safety required Chevron to install detection equipment so that if microseismic activity seemed high, then Chevron could slow CO₂ injection. Chevron themselves said: “Seismic activity is part of the system design and was considered as part of the regulatory approvals for the system” [88]. Chevron was reported as announcing that more than 800 “micro-seismic” events “had been detected at the site, with the frequency of the events increasing with injection” [108]. This was possibly connected to the pressure issues described above, resulting from sand clogging. While the microseismic events individually could seem little threat to storage stability, it is hard to know what the cumulative effects might be and whether some kind of leakage monitoring system is required or how effective that monitoring system would be. This is a social/political decision.

3.4. Corporate Economics

3.4.1. Problems of Profit and Politics

Chevron and its partners, like all corporations, operate under social imperatives to return high profits and lower costs. They also operate with social privileges when profits are increased by tax concessions or subsidies or pollution controls are waived or ignored.

In this case, normal cost blowouts seem significant. There was a massive rise in the expected cost of the whole gasfield project from USD 19 billion in 2006, USD 37 billion in 2009, to USD 54 billion in 2015 when it was said to be over 90% complete [67,109]. For some of the production time, the price of oil and gas crashed, and plans for expansion were put on hold. In 2015, Chevron reported a 90% collapse in profits [110]. This led to massive asset sales [111], which continued into 2019 [112]. It is unclear what the final project cost will be, what the total losses were from the asset sales, or what effects market vagaries had on CCS development, but evidence suggests that maximising profit from gas sales took priority.

In 2021, Chevron and its partners invested another USD 6 billion in the project, making it “the country’s largest single resources investment” [113]. This investment had nothing to do with improving CCS but involved the interconnected Jansz-Lo field, the gas of which is processed at the same plant and which has less CO₂ in its methane, perhaps avoiding the capture problems or necessities. This project involves building a 27,000-tonne “floating field control station”, a “subsea compression infrastructure”, and a 135 kilometre underwater power cable to carry energy from the Barrow Island LNG plant. It is not clear if that energy is generated by burning gas, adding to site emissions [114,115].

Another problem is that even with CCS at the production site, burning gas by purchasers produces GHG emissions, as does burning gas to power the CCS process. I could find no information on the storage of emissions from powering the CCS. This situation could become vulnerable to governmental regulation and policy if climate change is taken

seriously. There are repeated rumours that the EU will use tariffs to protect its industries from foreigners who are not reducing emissions, which could easily affect Australia's exports. The Blueprint Institute, aligned with those in the Federal Coalition who are concerned about climate, said: "It's just another reminder that we have to take climate action seriously. The choice is clear: reduce emissions to defend our exports and seize new opportunities, or cling to stubborn climate policies at the cost of our economic competitiveness" [116].

Fossil fuels also risk becoming an investment hazard, a stranded asset. In mid-2021: "Santos chief executive Kevin Gallagher led a wave of oil and gas industry leaders warning that achieving net zero emissions will be critical for the natural gas industry to avoid coal's fate of being blacklisted by equity investors and lenders" [117]. Unsurprisingly, Gallagher advocated carbon capture and storage and hydrogen manufactured from methane (with CO₂ as a by-product of manufacture) as ways the industry could reach carbon neutrality—which is only possible if *all* emissions from *all* emission stages are captured. He argued that Australia had the potential to become a "carbon storage superpower" and that Australia needed large-scale projects "to make development of our oil and gas resources viable for investors, financiers and customers so that the wealth of these resources can be unlocked for the nation" [118]. CCS seems to be part of a rhetoric to bypass increasing GHG emissions.

At the same time, the chief executive of Clough, Peter Bennett, expressed worry that "financial backers were deserting the gas industry based on an 'almost hysterical' principle that all fossil fuels were bad", despite industry claims gas was important to help reach net zero emissions [117]. Peter Coleman, former head of Woodside Petroleum, adds that investor concerns about climate change, and the risk of stranded assets, mean the era of massive new LNG projects is over. "It's difficult for me to see a Gorgon happening again, what's fundamentally changed now is the capital discipline in the industry that wasn't there before and obviously the focus on climate change". Coleman also suggested that geological conditions in Australia made CCS unsuitable for wide-scale use here [119].

The uncertain politics of climate action affect future investment. Why invest in more, or better, CCS if it cannot save existing investment? A contradictory problem may arise from the so-called "green paradox" [120], in which fears of resources becoming constrained by legislation lead companies to sell as much as possible before the value runs out. This can produce lock-in for customers which may then undermine pressure for climate action and emissions reduction. If CCS is primarily a disguise for increasing overall emissions, then it makes circumstances worse.

3.4.2. Problems of Privilege: Tax

Australia has a tax regime friendly to fossil fuel miners. In 2019, tax *credits* for oil and gas companies taking Australian fossil fuels rose to AUD 324 billion—that is AUD 324 billion in tax the companies owe but do not have to pay [121,122]. Chevron's partner Shell forecasts it will never pay Resources Rent Tax for gas extracted from the Gorgon and other gas and oil projects in Australia. Juan Carlos Boué, counsel at international law firm Curtis, said: "Shell is saying nothing that the Government and everybody in the know has not been aware of for some time now" [123]. Tax and tax avoidance are also part of the background of CCS and seem extremely favourable for its success.

One way of making CCS financially viable is to have a carbon price or tax. Carbon pricing systems in the EU and UK by July 2021 reached record levels near GBP 45 a tonne. However, according to the London *Financial Times*, some think carbon prices will need to double to make CCS viable and persuade companies to pay for carbon sequestration [124]. Gorgon was being prepared during a period when a promised carbon price gave the project extra viability; however, the carbon price was removed along with emissions targets by the incoming Coalition government in 2013. This probably added to the financial stress of the project. Given that the campaign against carbon pricing has been considered significant, by almost all political commentators, in producing the Coalition's victory, it is doubtful whether any Australian government will introduce a transparent system of pricing in

the near future. Indeed the current government's slogan is "technology not taxes", the technology being largely expected, or imaginary, innovations.

There is some suggestion that plant profits were increased through tax deals, minimisation, avoidance, and transfer pricing through internal company loans. In 2018 to 2019, Chevron Australia paid Chevron US, AUD 6.3 billion capital repayments at higher than market interest rates, plus another AUD 4.2 billion of dividends, for a total of AUD 10.5 billion from Australia, all of which was tax-free [125]. Chevron also campaigned to be allowed to sell carbon credits based on the carbon they stored, which, given that they were storing their own emissions for permission to mine, appears to make the storage count twice [126]. Presumably this is allowed as part of business practice, but it adds to the possibilities of disruption, should a government change policies. It might also indicate where human energy and imagination are being expended.

Financial viability could also have been threatened by a 2015 Senate inquiry into corporate tax avoidance which began to consider closing tax loopholes allowing Chevron, ExxonMobil, and Shell to claim tax-free profits from the Gorgon gas project, through loaning to their Australian branches at higher than normal interest rates [127]. Chevron Australia had a debt-to-equity ratio of 76.2% largely in loans to its parent, which was almost 10 times the debt level of its global parent. The US parent paid a mere USD 248 in tax in the US in 2014–2015 according to Chevron itself [128,129]. Chevron and its backers had campaigned for tax concessions at the beginning of the project, despite apparent exemption from royalties for the gas. Allegations later arose that Chevron had paid larger amounts to Australian political parties than it had paid in tax [130]. The tax case was resolved with Chevron being convicted of transfer pricing in 2017 [131], but nothing appears to have changed by 2021, with APPEA arguing nothing should change [123].

There is also a question of whether the project was being subsidised by tax avoidance. Tax avoidance is not illegal, but it is an unstable way of guaranteeing an efficient business case for a project, while undermining revenue expected by the host country.

3.4.3. Liability Costs Transferred to Taxpayers

As previously stated, Barrow Island is a Class A nature reserve. While leaks could be ecologically disastrous, the project owners are only responsible for leaks occurring during the project's lifetime and for 15 years afterwards—a small window of responsibility for storage which is meant to be eternal. Before the project began, "the federal and WA governments . . . agreed to accept responsibility for any long-term liabilities". This means the taxpayer is further subsidising the ongoing cost of CCS [76], and the company has less incentive to store the carbon safely, as it will not have responsibility for leaks. While it is not that unusual for taxpayers in capitalist society to take on the cost burdens for private projects, this could stir dissent about public subsidising of private profit, and the deleterious effects of commercialising carbon storage.

3.4.4. Regulatory and Legal costs and instabilities

Chevron also engaged in a legal dispute over cost blowouts with the builders of its wharf. The dispute took nearly four years to resolve [132,133]. This seems to be part of a worldwide pattern of companies either underquoting (or underestimating) construction costs or delaying payment of debts, a normality which adds to costs, complexities, disruptions, and delays.

Legal issues also eventuated because of Chevron not meeting storage targets [93], after selling gas for 3 years without CCS [134]. This provoked mild conflict with the WA government. Effective penalties had been diminished in May 2018, when the Environment Minister asked the WA Environmental Protection Authority to decide when the beginning of the five-year period for the 80% of CO₂ in the methane storage requirement commenced. In September 2019, the EPA stated injection should not be assessed from when production began, but from when the LNG trains received their operating licence. This was after 14 July 2016 for one train and mid-2018 for the other two. This gave Gorgon a free

25.7 million tonnes of emissions [75]. Chevron apparently wanted the limits to only count after July 2018, two years after the first shipment of gas, giving them even more profit and freeloading.

In late 2020, the Conservation Council of WA used the Appeals Convener to challenge Chevron's operating licence. They made three complaints:

- Lack of public disclosure about the CCS facility's operations and emissions from the Gorgon project (Secrecy see Section 3.4.5);
- Lack of limits on the amount of pollutants the project could emit;
- The 20-year length of the operating licence before review.

The first two points were rejected, but the Minister lowered the length of the operating licence to 10 years [92]. This does put some pressure on the project, but if it is remotely successful it should meet its targets in 10 years from now. The Conservation Council of WA's (CCWA) director, Piers Verstegen, was not surprised Chevron had failed its targets. In July 2021, he called for "the Environment Minister and the state government to enforce those conditions and require Chevron to meet its promises . . . [CCS] shouldn't be relied upon to justify the increased expansion of the oil and gas industry" [135].

The CCWA requested that general operations and production at the Gorgon project be suspended or scaled back because of these failures, or a limit on CO₂ emissions be enforced, with transparent disclosure of volumes stored [135]. The Minister rejected the request.

Chevron admitted it fell short of targets by 5.23 MT and committed to buy carbon credits and invest AUD 40 million in unspecified "low carbon energy projects" in the state [136]. There are different estimates of the penalty, but taking a contemporary spot price for Australian Carbon Credit Units and using them as offsets, the cost could be between AUD 100 and 200 million. This is relatively small, as Chevron's share of such a bill would count for a few days of its 2020 annual Australian revenue of USD 5.9 billion (USD 7.9 billion). Additionally, Chevron can buy cheaper offsets to gain less penalty [75,137].

The sandy water problems meant that the Department of Mines, Industry Regulation and Safety (DMRS) had issued multiple extensions for Chevron to keep operating, as deadlines for repair were broken [75]. A Chevron report stated: "Field injection rates were curtailed [from an achieved maximum of 147 kg/s] from the 18 December 2020 to meet the CO₂ injection rate restriction of 42 kg/s whilst the pressure management system was offline and being remediated" [138] (p. 2).

Without the water being removed, there was a risk that the increasing pressure required to pump the CO₂ underground would fracture the rock around the injection wells, permanently damaging the system's performance [75].

Sympathetic government means that the potential penalties for failure are low compared to profit, with little incentive to prioritise storage over profit.

3.4.5. Business Hype, Marketing, and Secrecy

(Dis)information is part of market action [10,139]. Business, much like the State, attempts to spin the best result for its action, hide embarrassing events, attack its competitors, build political support, defuse political hostility, and promise to render all competing products obsolete. The problems of hidden data should already be apparent, and the less anyone knows what is going on, the more will probably be hidden.

Typically, Chevron claims: "To advance a lower-carbon future, we are focused on cost efficiently lowering our carbon intensity, increasing renewables and offsets in support of our business, and investing in low-carbon technologies that enable commercial solutions" [115].

However, lowering carbon intensity does not *have* to lower emissions, as pointed out earlier. Chevron's claims about CCS also seem misleading. They state that their targets are equivalent to "taking more than 1 million passenger vehicles off the road each year" [140] (although the Federal Minister Matt Canavan said it was the "equivalent of removing 680,000 cars from the roads each year" [72]), but the project does not remove previously *existing* pollution. While it is better that *some* CO₂ extracted in production be stored, when

taken *as a whole*, even without counting emissions from subsequent burning, the project increases global emissions. A report for the Global CCS Institute and the WA government claimed that Gorgon and another CCS project would store “more than eight million tonnes of CO₂ annually, approximately 11 percent of the State’s annual current emissions”, again implying emissions reduction, when there would be a net increase in WA’s emissions through the projects [141] (p. 9). Similarly, it has been suggested that gas is better than coal (by Chevron for example), but gas is only reducing emissions if coal emissions are phased out faster than gas emissions are phased in.

Chevron has compounded this misdirection by joining other fossil fuel companies in 2018 to campaign to keep their GHG emissions secret, on the grounds that releasing data could help overseas competitors [142]. Chevron specifically remarked that reporting was expensive and “costs must be kept as low as practicable” [143]. If this secrecy is successful, it undoes claims of verifiable storage. Chevron was still declining to provide any data on its storage rates in Feb 2020, while emphasising its supposed future rates of storage [134], although it did announce it had stored its millionth ton soon after [144]. Similarly, when the Department of Mines, Industry Regulation and Safety limited the amount of CO₂ that can be injected because of the pressure problems, “neither Chevron nor the WA government would disclose the cap or the amount by which emissions [had] increased” [92]. Furthermore, much of the information about the project seemed to be hidden and required journalists to make freedom of information applications (see Section 1.2). There is also hardly any mention of carbon capture in Chevron’s 2020 Annual Report [145] or 2020 Corporate Sustainability Report [146]. There does not seem to be any easy comparison of what they store compared to their complete three-scope emissions.

Even failure can be promoted as success. The company’s Australian boss Mark Hatfield said the company was “deploying technology, innovation and skills to deliver cleaner energy and reduce our carbon footprint. The road hasn’t always been smooth, but the challenges we’ve faced and overcome make it easier for those who aspire to reduce their emissions through CCS” [147]. Misleading information also comes from politicians and industry support groups. Angus Taylor, the federal energy and emissions reduction minister, in 2020 cited Gorgon as an “already working” example of CCS [148], while an APPEA press release said Chevron showed the industry was “continuing to walk the walk when it comes to reducing emissions” and “Chevron’s announcement is on top of all the work our industry is already doing to combat climate change” [149]. These claims distract from the project’s failure to produce net emissions reduction.

It is notable that Chevron, Shell, and Exxon are frequently implicated for promoting doubt about climate science to justify continuing sales of fossil fuels [150–152]. This suggests that their treatment of CCS may be a continuing part of that strategy.

3.4.6. Net Zero

In 2019, the WA Environmental Protection Authority argued that large gas projects had to be zero emissions, or buy offsets; otherwise, Australia would not fulfil its Paris commitments. WA’s emissions had increased by 27% from 2000 to 2016 [153]. The recommendation was denounced by fossil fuel companies, including Chevron who threatened to end projects, and by the WA and Federal Governments. WA Premier Mark McGowan indicated the government would ignore EPA advice, just as it did in approving the Gorgon project in 2006 [154,155]. This approach could show that companies do not think zero emissions is feasible, or worth moving towards through CCS, and that Australian governments support this position. Piers Verstegen, director of the Conservation Council of Western Australia, remarked that the actions of fossil fuel companies showed their “only plan is to bully governments into letting them get away with doing nothing” [156].

3.5. Effectiveness

Chevron expects CCS to reduce its *production* emissions by about 40%, storing 80% of CO₂ in the extracted methane. They expect to store 100 million tonnes of CO₂ over the

life of the project while, given the 40% figure, presumably releasing another 150 million tonnes in production during that period. This project does not lower baseline emissions production in Australia. Furthermore, storage in WA does not lower GHG generated by burning the gas elsewhere, so the proportion of CO₂ stored, compared with that released in use, is likely to be insignificant. Significant reductions would need CCS wherever the gas was burned or released. Mark Ogge of the Australia Institute, which is not pro-CCS, argued in 2021 that the Gorgon project would capture just 1.7% of its total emissions (Scope 1, 2, and 3) over 5 years [157], while a report to the US Congress states: “While Chevron claims that its carbon-capture projects will reduce its greenhouse gas emissions by roughly 5 million tonnes per year, this would account for only a minuscule fraction of the company’s emissions, which in 2019 amounted to 697 million tonnes of carbon dioxide equivalent” [150].

According to the same source, “Chevron did not report *any* lobbying on the Paris Agreement, despite spending \$54 million on lobbying since 2015” and despite support for the Agreement being a supposed key corporate goal [150].

Perhaps more significant than Gorgon’s failure to reach its targets, Clean Energy Regulator (CER) data “shows the facility produced over 9 million tonnes of CO₂-equivalent emissions” for 2017–2018, making it “Australia’s highest CO₂ emitting gas facility” (Kilvert 2019). Physicist and climate scientist Bill Hare told the ABC that the “volume of pollution coming out of the Chevron project far outweighs the savings of carbon pollution from rooftop solar”. The ABC reports “Chevron declined to comment on the comparison” and that a former adviser to Margaret Thatcher and regional president for BP Australasia said: “These sorts of issues can set very, very dangerous precedents. They should be required to purchase [carbon] offsets equivalent to the same volume they were expected to inject over the first five-year period” [65]. This would not reduce their emissions, just price them.

Chevron was later classified by the CER as the country’s sixth-biggest polluter [158], capturing only one-third of the GHGs that the approvals required while venting millions of tonnes a year more [159]. An estimate in November 2020 states “Gorgon emitted almost 34 million tonnes of greenhouse gases in the five years to June 2020 from the reservoir CO₂ that was vented instead of buried, as well as gas combusted to power the plant and excess gas burnt in a flare” [87,160]. However, as already seen, in Australia, these increased emissions were largely not a problem for the company, as it already had the right to emit 25 million tonnes from 2017 to 2020 before having to buy offsets, diminishing its incentive to fix the pollution problem [161,162]. If we are serious about reducing greenhouse gas emissions, then increased methane production, release, and burning will not solve the problem, especially when new fields are coming online.

4. Conclusions

The limitations of the research are obvious. Data could be expanded by uncovering more records (perhaps needing more freedom of information requests, or archival exploration in Chevron and Government offices), through interviews with administrators, and workers, and possibly through day-to-day fieldwork, although the problems of “studying up”, describing the intricacies of real corporate processes, and gaining permissions are well documented and increased by normal business secrecy. Research could also be usefully expanded into studying the dynamics of CCS within Chevron’s role as a major fossil fuel energy producer and its competition and cooperation with other fossil fuel companies (including its partners on this project). There are numerous technical details that I could not uncover.

However, this study has demonstrated that CCS is not simply just a technological problem. Technology is embedded in social and ecological relations, particularly in corporate and developmental organisations. It cannot be separated from these relations. If analysts do not consider the social background, then they will miss important dynamics of the CCS projects and expectable blocks in their effectiveness. Therefore it seems useful to look for disorders in the narratives of success promoted by those engaged in CCS and in the

way that social processes and technical processes are intertwined. The processes turn out to be far more complex than a narrow focus on the need for CCS, or the technical possibilities of CCS, would suggest. Problems compound. Problems with sand, cracked equipment, acid formation in pipes, on-site energy consumption and emissions, the cumulative effect of seismic events, workers, wharves, regulators (even friendly ones), tax avoidance, secrecy, propaganda, liability evasion, and export-oriented governments, along with a primary business focus on profit, have the capacity to disrupt a project's significance in generating real emissions reduction. This is the case, even if regulatory issues were not significant for the project because of governmental enthusiasm, and low levels of protest. Due to standardised corporate secrecy, there were almost certainly more problems with the project than I have described here. However, given the expertise of the companies involved, and the length of their presence at the site, these kinds of problems cannot be considered to be secondary, or easily resolved by requests for increased competence.

Decisions about CCS are social, political, and economic decisions about profit. They involve an emphasis on mining and sales rather than storage, corporate reactions to losing prior capital investments in fossil fuels, and attempts to persist in burning gas and "unintentionally" increasing emissions in so doing. Focus on profit can lead to undue simplification. This may explain why in 2017, the departing Australian director said that Chevron clearly had not done enough background work: "We have to verify every single aspect of these projects in advance, because we're on the hook for them, regardless of the kind of contract that we sign" [163]. This understanding may be impossible given the complexities, but it does indicate some recognition of a lack of awareness about potential problems.

Social context means that while technology can work in theory, there is no reason to assume it will be used properly, no matter how essential it seems. Technology can be used as a mode of rhetoric or fantasy to reinforce, or hide, social relations and destructive inclinations. CCS seems to be being used in this way. Rather than reducing total emissions, or coming under necessary carbon budgets, it seems to be used to contend that increasing emissions can be ignored or to distract from those increasing emissions. I see nothing in the evidence which suggests that Australian governments are going to use CCS to enforce, or encourage, lowering of total emissions or to promote a universal and high carbon price which would seem to be needed to provide an economic rationale for CCS.

These fundamental problems can be seen in the Gorgon project, which should otherwise be an example of easy success. The relevant governments provide support to increase gas exports, are largely relaxed about tax avoidance and broken regulations, and accept long-term taxpayer-funded liabilities. The geological/ecological situation seemed straightforward, with storage that was nearby, but potential problems were not recognised during exploration. The project was unambitious, in only attempting to store excess CO₂ in the methane which needed to be removed for transport. It did not store gas burnt or released at the site, nor gas burned at the customer's site. Nevertheless, Chevron faced significant difficulties, made slow progress, was troubled by routine problems and cost blowouts, released considerable emissions, and failed to produce anything like net zero. There is no indication that the Gorgon project, even if it is fully successful, will reduce the emissions from the fossil fuels it excavates and sells, and given the problems it faced, it seems unlikely that storing a significant amount of emissions produced by burning would be possible. Given that this project is recent and using the best knowledge available, it seems to suggest that it is unlikely that enough large-scale CCS projects will be built for emissions reduction purposes, in the current social order.

It seems that the social drives promoting "free" GHG pollution, and promoting profit, disrupt CCS or make it unlikely to be a significant contributor to reaching zero net emissions or to solving the problems of climate change—in fact, possibly quite the opposite. The social organisation of CCS is perhaps fatal to its success, irrespective of technical difficulties.

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