Submission to WA State Climate Policy

By

Boyd Milligan

Adjunct Senior Research Fellow

Curtin University Sustainability Policy Institute

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Introduction

Please accept this documents and attachments as my submission being in response to a call for the public business and other interested parties to respond to its document:

"Climate Change in Western Australia: Issues Paper – September 2019"

My response is based on the following facts:

The Western Australian economy is heavily dependent on a carbon emitting economy, significantly more so than the rest of Australia and significantly more son tan almost any other similar region in the world. The following figure indicates the economic impact and carbon emissions for which they are directly responsible, of our WA major industries, primarily based in the Pilbara:

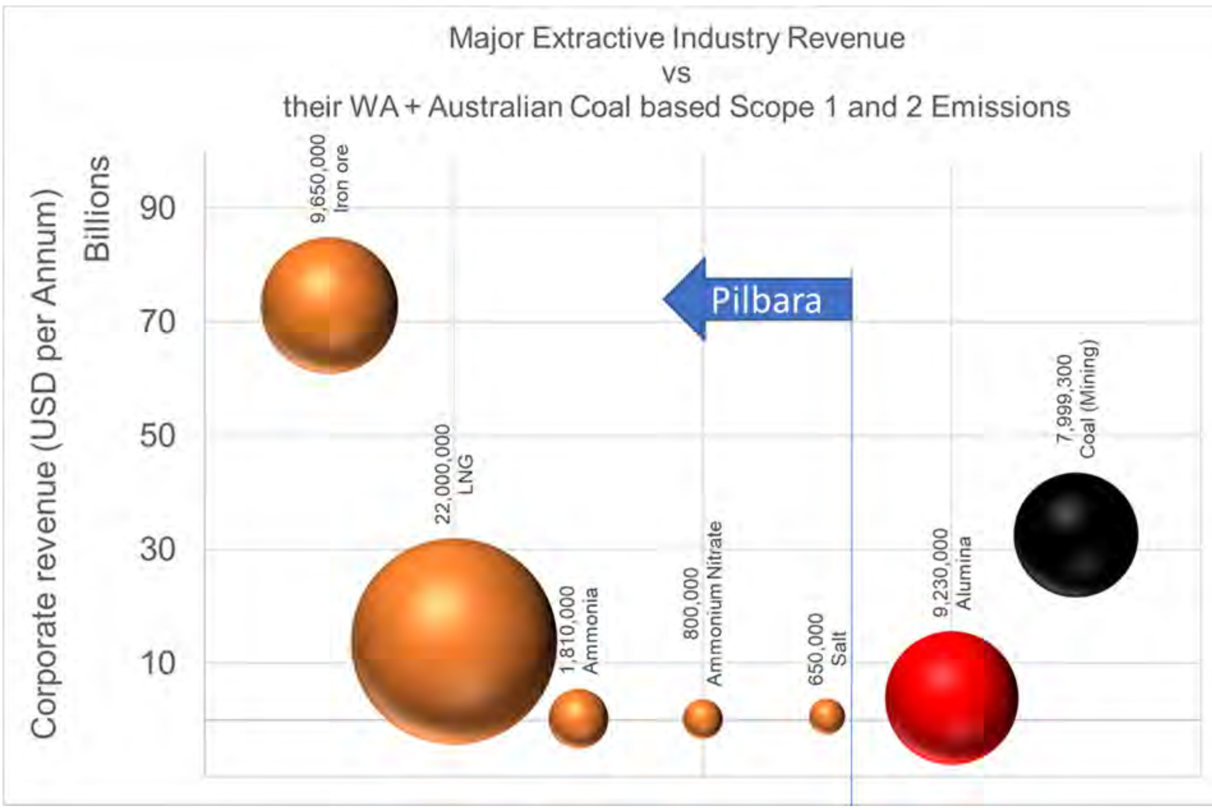

Figure 1: Annual Western Australian Carbon Footprint (scope 1 & 2) Carbon Emissions related to WA's extractive industries

These emissions impose a heavy burden on Western Australians and Australians under the Paris Agreement, as indicated by the following table:

Scope 1 & 2 GHG tpa	Annual GHG Emissi	WA Majors	Pilbara	WA LNG
WA	88,500,000	49.9%	39.4%	24.9%
Australia	530,800,000	8.3%	6.6%	4.1%

Figure 2: Tabulation of an estimate of the Major Extractive Industries share of WA's annual carbon footprint

Further these industries significantly contribute to the currently unbearable global impost on the environment, as indicated in the following graph, with subsequent economic cultural and societal impact:

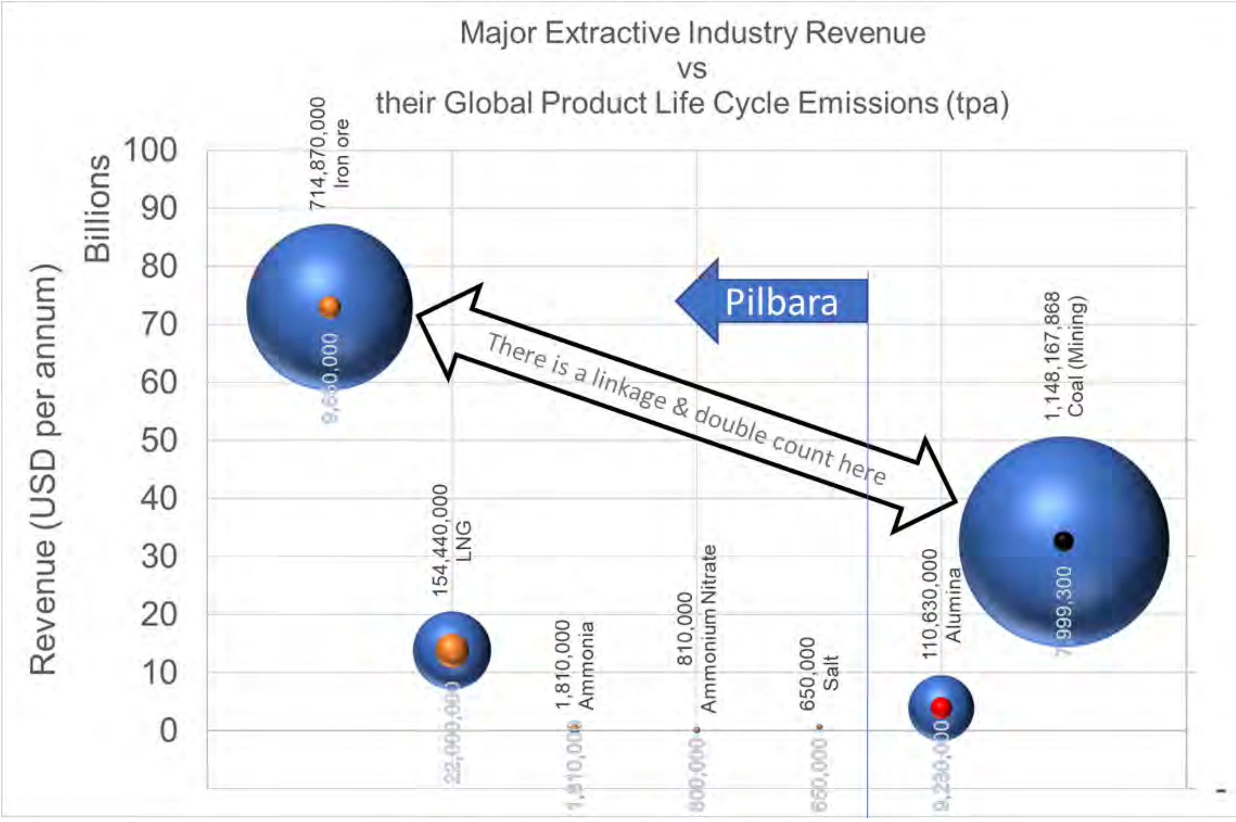

Figure 3: Annual Global (lifecycle) Carbon Emissions Impact of WA's extractive industries

Others have noted that Australia is the source of approximately 3.5% of the worlds GHG's from fossil fuels placing it as the 7th largest fossil fuel-based producer overall. Australia is a significant GHG contributor through its natural gas production and export: it is the 8th largest producer and 4th largest exporter of natural gas GHG emissions. These figures do not include the downstream (scope 3) emissions associated with the refining of our various mineral resources such as iron ore, offshore. What Australia, and as noted in the abovementioned graph particularly Western Australia, does is important to both ourselves and the rest of the world.

The science as indicated by the latest IPCC publication (IPCC, 2018) indicate that the world is facing an existential threat and everyone needs to react appropriately. As people everywhere react to this need the world will eventually be a anthropomorphic carbon constrained one.

Our economy, being as it is based on these industrial carbon imposts, therefore faces an economically existential moment.

Whilst the issue of iron ore mining and life cycle emissions can be relatively easily decarbonized through production of green carbon adjacent to a Western Australian raw steel production precinct, itself alongside our current iron or extractive industries, the same cannot be said of the LNG industry.

The LNG industry relies on scenarios for global energy demand published by the International Energy Agency (IEA) that are not compliant with the Paris Agreement, suggesting gas will displace coal without competing with cleaner renewable energy. Our analysis has shown that there is no statistical support for gas replacing coal in general, but also particularly where our LNG exports are targeted. Further our own research is indicating that natural gas itself is an "agnostic facilitative" fuel which may facilitate implementation of renewable energy supply, but historically and mostly has similarly facilitated the use of coal. In recent times coal has been mostly impacted by solar and wind generation, not natural gas, as renewables have become the preferred economic choice.

The first of two of my and Professor Peter Newman's[1] recent submissions, attached and entitled "Macroeconomic Failure of an Industry: Is there a Sustainable Pathway for the LNG industry in Australia?", address the poor economic outlook for the Australian LNG industry in our increasingly carbon constrained world, and includes far reaching policy recommendations. This report was submitted to the Australian Senate References Committee enquiry into Australia's Oil and Gas reserves.

The second, entitled "A Response to the EPA: In response to a Request for Input regarding the Question: How should the WA EPA consider greenhouse gas emissions when assessing significant proposals in Western Australia?", also attached addresses policy recommendations for large resource projects in Western Australia. Many of the recommendations it contains have implication beyond the remit of the EPA and are also relevant to this enquiry.

The policy issues rather than recommendations summarized below and detailed in depth in these two submissions may be associated in the following "Issues and opportunities for Western Australia" from your issues paper:

Issues for energy industry innovation

- Western Australia's fugitive emissions have increased significantly in recent years, and now contribute 14 per cent to the State's total greenhouse gas emissions.

Opportunities for industry innovation

- Harnessing our world-class renewable resources to break the link between energy and emissions can put Western Australia's energy intensive businesses at the forefront of cleaner production trends and provide a competitive advantage in a low-carbon world.
- Many mining and energy projects are located in areas with abundant, high-quality renewable energy resources such as solar. Integrating renewables into a project's energy mix can offset fuel costs, enhance energy security and help manage the risks of fuel price volatility and future carbon pricing.
- LNG can displace higher emissions fuels in shipping, reducing greenhouse gas emissions from the export of fuels and minerals.

[1] Both from Curtin University's Sustainability Policy Institute

- Opportunities to lower the carbon footprint of LNG production and minimise emissions across the energy value chain include improved leak detection and remediation, changes to venting and flaring practices, and greater adoption of industrial-scale renewables.
- The global trend to decarbonisation will increase demand for low-carbon energy carriers such as hydrogen produced from renewable fuels. Western Australia is well positioned as a future producer of renewable hydrogen, which would facilitate export of the State's renewable energy resources to Asian markets.
- Global demand for lithium-ion batteries and the shift t o electrification of transport present exciting opportunities to develop a sustainable, value-adding battery industry. Investment and leadership is required to ensure we move beyond the processing of precursor materials into the manufacture of battery components and battery cells, and development of service technologies and expertise.

Regional prosperity

- How will climate change affect your regional community?
- What steps can we take to further enhance the resilience of our regions and our primary industries?
- How can we support the agricultural sector to participate in the low-carbon transition?
- What opportunities do carbon offset markets present for Western Australian land managers, including Aboriginal groups?
- What matters should the State Government take into account in developing a strategy for carbon farming in Western Australia?

The Reports' Policy Issues Summarized

We recommend that the State of Western Australia should develop a significant leadership role in managing the negative impacts of GHG emissions from LNG production, and by default other large-scale natural resources exploitative industries, such as the iron ore industry. First movers may gain a competitive economic advantage and develop a subsequent industry of global significance.

Our conclusion is that Australian gas exports are significant contributors to global GHG emissions and thus pose an existential threat to Western Australians through impacts of climate change and the global response to the LNG industry. As a host to the pre-eminent exporters of LNG in Australia, Western Australia has the capacity and means to further the Paris Agreement objectives rather than be seen as a major cause of not reaching them. It can do this by undertaking a lead role for equitable, sustainable and ambitious plans to eliminate environmental threats posed by LNG GHG emissions, and potentially develop associated subsidiary industry in a new era for the Pilbara as a resource hub for the future economy in the Indian Ocean/Asian region.

We conclude that a potential exists for significant tension to develop over economic imperatives and damages consequent on this region's contribution to GHG emissions, between and within both the State and private sectors. Our research indicates that collaborative innovative and willing cooperation and contribution by both these actors and others can achieve ongoing economic prosperity and meet recently stated emissions reductions in a timely manner. This may be considered an opportunity rather than a threat if managed well.

Our conclusion is that Australia, amongst the world's 195 sovereign states (and to an even greater extent, Western Australia), not only contributes more to climate change than most, but also has wealth and national income relatively greater than almost all nations. Australia thus has one of the best capacities to aggressively, equitably and sustainably advance our contribution to this global challenge, even beyond the political commitments to date.

We conclude that all jurisdictions (Local, State and Federal) must act in accordance with the combined Paris Agreement principles and targets identified by the recent IPCC report. We show that Western Australia is a globally significant contributor to the threat of climate change and therefore our society must act either unilaterally or in concert with the Federal policy setting, whichever best drives to achieve the global needs, but never abdicating our responsibility to take aggressive and escalating (progressive) action based on equity and sustainability principles for our jurisdiction to exceed the global average target of net zero emissions by 2050.

We conclude that this is not only an environmental necessity but an economic one too.

We conclude that the current externalised costs to the Australian people of hosting the LNG industry in Australia are unsustainable and unfair. However, should these costs be internalised to the industry, the current industry may also be commercially compromised.

Further, we conclude that current policies and further aspirational policies signalled by both the Australian LNG industry and most tiers of Australian government are at odds with clear and present existential economic and environmental threats to the Australian future quality of life though anthropomorphic climate change.

The LNG industry is literally banking Australia's LNG export economy and to a lesser degree Australia's broader economy on the hope that the world will allow them to continue to grow their exports and without constraining carbon emissions, despite everyone else limiting theirs. This has been based on prior IEA scenarios suggesting gas would reduce emissions overall in direct contradiction of the IPCC, which concludes that natural gas also needs to reduce, along with other fossil fuels. The figure (*Figure 4: Converging Carbon Limited Demand Projections for Global Natural Gas Supply*) below resolves this.

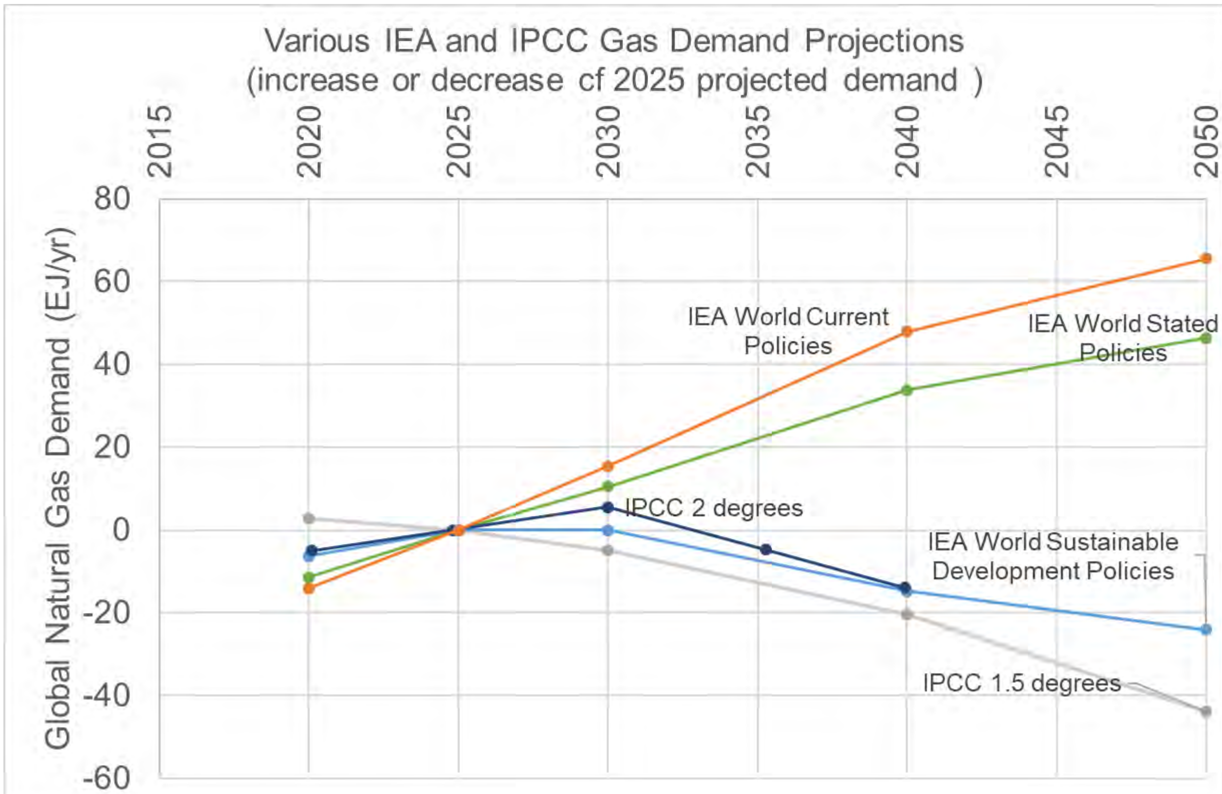

Figure 4: Converging Carbon Limited Demand Projections for Global Natural Gas Supply

The evidence is now clear: the IEA and IPCC are saying the same thing: the consumption of natural gas must reduce globally, and that high cost and heavily polluting LNG is a risky option especially for developing countries such as China and India.

Further our own research is indicating that natural gas itself is an “agnostic facilitative” fuel which may facilitate implementation of renewable energy supply, but historically and mostly has similarly facilitated the use of coal. In recent times coal has been mostly impacted by solar and wind, not natural gas, as renewables have become the preferred economic choice.

We conclude that economic reliance on LNG as a primary energy export will be a major impediment to Australia’s well-being when global markets enter terminal decline in the 2020’s.

Is it possible to find an alternative narrative which will alleviate this “wicked” problem?

We project one possible macroeconomic pathway through this and identify policy initiatives for State and Federal Government.

Policy options include:

- Clear and current policies to retain untapped domestic natural gas resources as strategic energy and industrial reserves;
- Support the economic status quo for existing operators; and

- Leverage the scale and natural advantages of agglomeration opportunities around existing plant, especially where synergies in industrial and market opportunities exist such as in the North West and North East of Australia.

Western Australian LNG plants need:

- to be powered solely by renewable energy much like Inpex have announced for their Darwin LNG facility
- Carbon Capture and Storage (CCS) as standard procedure, much as Chevron is attempting at the Gorgon LNG project, with attendant research to develop industries such as sustainable plastics LNG and natural gas and carbon uses such as graphene;
- Australian Offsets such as tree planting and renewable energy projects to be used to create thousands of new jobs for regional Australians, and
- It's infrastructure to be given a longer life into an era where fossil fuels are removed from our economy, by creating green hydrogen for export

The key policy is for the State to embrace is to take a leading role and also partner and guide the LNG and other extractive industries in the region to form a foundation for a networked renewable electrical transmission system. This legacy is industrial strength renewable power production and most importantly electrical transmission infrastructure of a quantity and quality sufficient to reverse Australia's industrial trajectory.

Based on this core market, Western Australia has the opportunity to reconceive its industrial and energy strength, and leverage the third wave of large scale natural resource developments in the North of Western Australia: its world class solar insolation resources located not only in the Pilbara region but just to its North in the arid lands of the south/south west of the Kimberley region. Harnessing this power enables electrical power to channel north west across the coastline north of Derby to both Timor Leste and Indonesia (notwithstanding seemingly ill-conceived private efforts to do so), and south west to the large industrial complex of the iron ore and LNG industries.

The combination of all these markets will attract energy intensive high value add industries such as the aluminium smelting companies currently slowly exiting Australian shores to cheaper cleaner and more reliable energy suppliers elsewhere. The region has the potential to rival and surpass similarly emergent regions but based on renewable energy and local labour. The attraction for Australia and particularly the Kimberley and Pilbara regions is to develop a completely new suit of technologies, based on a world class development, which not only enables the nation to leverage its natural resources into world class manufacture, but to revitalize its manufacturing prospects by: cornering several of the last renewable energy technologies and bringing them to the world; and providing a reason for very high technology energy intensive and high capital investment manufacturers to return to Australia rather than pack up and leave much as has happened over the last 20 years. Additionally, our estimates of the export market is about USD 20 billion plus per annum, eclipsing that for LNG and reaching toward our iron ore exports.

In Other Initiatives

We recommend that the State, perhaps through the EPA consider, aggregate, update, enumerate, and continuously monitor current scientific understandings of the current and potential environmental harm to Western Australia due to GHG induced climate change, past present and emerging, using its identified Environmental Factors framework to adequately inform the process and participants. This forms the basis of a new economy growth phase just as California used environmental regulation to help lead the USA in its economic leap into the next economy.

We recommend that the concept of “free” natural gas fuel be examined in the context of its perversion of the goals of GHG mitigation in the LNG industry, and appropriate regulatory steps be taken to remove this impact. Further we recommend that the concept of “best practice” mitigation efforts be reinforced as being a functional concept to help lead industry into contributing to the transition away from fossil fuels, not limited by current industry practice.

We conclude, based on statistical analysis of energy trends worldwide, that contrary to oft quoted substitution of coal for natural gas, globally and in the jurisdiction of the USA, Australia and China, natural gas is at best a partial substitute for coal (US) or otherwise only indirectly substitutable. The more substantial finding is that substitution for coal is identified to be caused by the increasing penetration of renewables particularly wind energy. Roof-top solar energy is not part of the analysis as national data sources rarely include it because its behind the meter. Natural gas is shown in general to compliment coal in providing energy in jurisdictions with growing economies and populations. It in general is found to supplement the penetration of wind power in adopting jurisdictions.

We recommend exploration and implementation of bilateral mechanisms with approved trade partners to equitably share the economic benefits and costs associated with the lifecycle of scope 1,2, and 3 intensive emitting products, including benefits of substitution and costs of carbon leakage upstream along the supply chain, based on the principle of equity in exploitation of societally beneficial finite natural resources which are (in Australia at least) owned by the people in trust to their State and Federal governments.

We recommend that any offsets and value of carbon credits created be shared equitably between all parties to the proposal including both host governments. For example, purchase of offsets produced in a 3rd party nation by a private project proponent circumvents sharing of such benefits with the producing and consuming host nations.

We recommend that Western Australia, Australia, and other sovereign states driven by equity and sustainability ethics should create a legally binding framework to drive bilateral agreements for export of product with potential significant offshore scope 3 impacts (e.g. fossil fuels like LNG) like those implemented for uranium export to ensure a no harm approach.

We conclude that in the "Cyan or Blue" Hydrogen should be immediately sidelined in favour of development of fully renewable technologies for energy export including "Green[2]" ammonia-based hydrogen transport and ultra-high voltage direct current subsea (UHVDC) technology for electricity transmission. This is the basis of the new economy in our region.

Conclusions

Our research indicates Western Australia can achieve a Win/Win/Win for everyone. We have mapped one way which delivers hope of not only zero GHG emissions in the Pilbara but:

- A significant new export industry valued at about USD 25 billion per annum employing in the order of an additional 20,000 directly employed personnel;
- Catalyst for capture development and exploitation of related "teenage" technology resulting in the deployment of about 15,000 direct manufacturing jobs
- Catalyst for industrial revival of major value add industries reattracting those currently fleeing, such as alumina and aluminium facilities and more
- Catalyst for another investment and construction era greater than that of the recent one around LNG and Iron Ore, implying investment of USD 250 billion in industrial infrastructure over 20 years and a workforce of 30,000 direct construction jobs
- Development of an Industrial Research culture around WA's tertiary institutions leading to around USD 10-30 billion in Research and development activities over the next 10 years, and potentially a hub for tertiary education in the Pilbara and Kimberley regions
- Regional engagement with the NT, Timor Leste and Indonesia for development trade and security value add.

The proposal is to create a world scale industrial cluster around the Timor Sea targeting energy intensive resource value add (e.g. aluminium smelting) and manufacturing industries based on competitive labour coasts, low cost high volume and reliable low carbon electricity supply (approx. 97% reduction from equivalent in gas), thus enabling access to established shipping routes and perhaps establishing some new ones.

This is only likely with close collaboration at a government to government level between Australia Timor Leste and Indonesia.

The first step is for the research community and the state government to:

- Undertake a significantly more resourced due diligence analysis on the transition strategy to a net zero economy driven by new industries in the Pilbara;
- Work to build support at the intergovernmental (WA, Australia, Indonesia and Timor-Leste) level and regional and international infrastructure funds with the ultimate aim

[2] Blue is widely identified as, and nominally the colour identified with fully fossil natural gas derivatives (e.g. blue Hydrogen) and renewable energy represented by green.

of sovereign funding of approximately USD 13 billion to build own and operate the first (of potentially nine) electrical energy links between Indonesia (IndoLink) and the Pilbara (PilbaraLink);

- Work with the Federal Government and other State Governments to understand the positive economics of transmitting electricity (TransNational link) rather than natural gas from the Pilbara and linking the region into the National Rail Network, perhaps even with electrically powered trains;
- Work to gather research and development resources on a scale which ensures Australian technological and hence market leadership for some direct and emerging technologies both integral and subsidiary for the roll-out of this regional development program;
- Work to develop major industrial policies and programs to catalyse Australian and other participant nationals towards entrepreneurial opportunities in direct development of the technologies identified as being critical to the success of the precinct;
- Work to develop cultural, social, environmental and economic policy programs and infrastructure in the regions to address local equity in the Pilbara and Kimberley (for example University industrial support and land management in the region);
- Work to gather a cluster of energy companies to invest an initial combined USD 7 billion to provide the renewable high-quality low cost and high-volume energy to the IndoLink and PilbaraLink transmission paths;
- Work to gather a cluster of energy intensive high value add manufacturers and resource developers who may invest in Australia and Indonesia over the longer term, including local industrial players in the LNG, Iron Ore and Alumina industries, to create the new net zero industrial hub in the Pilbara.

Attachments

Report 1:

“Macroeconomic Failure of an Industry

Is there a Sustainable Pathway for the LNG industry in Australia?”

A submission to the Senate Economics Reference Committee regarding Australia’s oil and gas reserves

Boyd Milligan and Peter Newman AO

Curtin University Sustainability Policy Institute (CUSP)

Report 2:

“A Response to the EPA

In response to a Request for Input regarding the Question: How should the WA EPA consider greenhouse gas emissions when assessing significant proposals in Western Australia?”

Boyd Milligan and Peter Newman AO

Curtin University Sustainability Policy Institute (CUSP)

References

IPCC. (2018). *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Retrieved from

Curtin University

Macroeconomic Failure of an Industry

Is there a Sustainable Pathway for the LNG industry in Australia?

A submission to the Senate Economics Reference Committee regarding Australia's oil and gas reserves

Boyd Milligan and Peter Newman AO

Curtin University Sustainability Policy Institute (CUSP)

Contact Author:

Boyd Milligan BEng (Hons) MBA MIEAust

Adjunct Senior Research Fellow

Curtin University Sustainability Policy (CUSP) Institute

School of Design and the Built Environment

B.Milligan@curtin.edu.au

Co-author

Professor Peter Newman AO

John Curtin Distinguished Professor of Sustainability

Curtin University Sustainability Policy (CUSP) Institute

School of Design and the Built Environment

Date: 28 November 2019

Revision#: 50

Terms of Reference for an inquiry into Australia's oil and gas reserves by the Senate Economics References Committee

On 19 September 2019, the Senate referred an inquiry into Australia's oil and gas reserves to the Senate Economics References Committee for inquiry and report by the first sitting day in March 2020.

That the following matter be referred to the Economics References Committee for inquiry and report on the first sitting day in March 2020:

1. arrangements used by other countries to maximise the benefit to the public of national oil and gas reserves;
2. arrangement that could be considered to maximise benefit to the public of Australia's national oil and gas resources, cognisant of:
   i. sovereign risk,
   ii. existing property rights, and
   iii. federal and state jurisdictions; and
3. any related matters.

Response

We present this report in response to a request to submit.

We focus clearly on the role of LNG in Australia's political economy, currently and with regard to possible futures. Oil and piped natural gas have a part to play but the biggest issue in our opinion is the LNG industry.

Others undoubtable have responded to point 1: other countries' arrangements. We therefore do not dwell on this issue other than with glancing reference.

Point 2 alerts us to the current paradigm under which we traditionally act, one which hasn't delivered to expectations due to successive policy settings rent seeking behaviours of proponents and market conditions.

Subpoint 2 i, we respond to by indicating that the sovereign risk of not acting to protect our way of life is far larger than that for retaining the status quo.

Subpoint 2 ii, we respond to by recognising the initial high hopes and subsequent muted outcomes for macroeconomic advantage we have derived from the LNG industry. We must respect the prior distributive policies around natural gas exploitation undertaken by State and Federal governments, whilst recognising significant advantage to the nation may be garnered by treating the remnant natural gas reservoirs as a sovereign strategic and facilitative fuel and industrial resource for domestic orientation;

Subpoint 2 iii, we respond that both State and Federal jurisdictions have a significant role across many portfolios, complex strategic realignment demands concerted joint action.

Point 3 reminds us that this is an issue at the very root of our society, and that the intersectionality of many subject matters must be considered. This report roams across many incidental matters.

Executive Summary

We conclude that the current externalised costs to the Australian people of hosting the LNG industry in Australia are unsustainable and unfair. However, should these costs be internalised to the industry, the current industry may also be commercially compromised.

Further, we conclude that current policies and further aspirational policies signalled by both the Australian LNG industry and most tiers of Australian government are at odds with clear and present existential economic and environmental threats to the Australian future quality of life though anthropomorphic climate change.

The LNG industry is literally banking Australia's LNG export economy and to a lesser degree Australia's broader economy on the hope that the world will allow them to continue to grow their exports and without constraining carbon emissions, despite everyone else limiting theirs. This has been based on prior IEA scenarios suggesting gas would reduce emissions overall in direct contradiction of the IPCC, which concludes that natural gas also needs to reduce, along with other fossil fuels. The figure (Figure 1: Converging Carbon Limited Demand Projections for Global Natural Gas Supply**) below resolves this.**

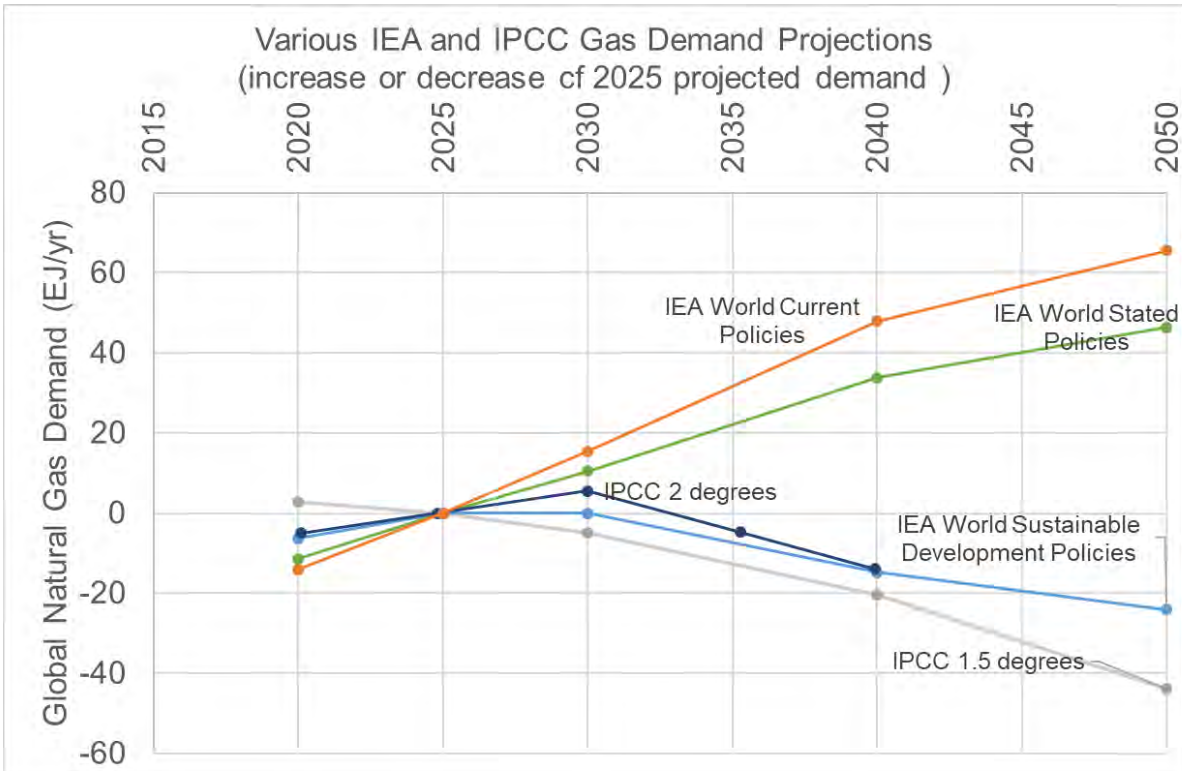

Figure 1: Converging Carbon Limited Demand Projections for Global Natural Gas Supply

The evidence is now clear: the IEA and IPCC are saying the same thing: the consumption of natural gas must reduce globally, and that high cost and heavily polluting LNG is a risky option especially for developing countries such as China and India.

Further our own research is indicating that natural gas itself is an "agnostic facilitative" fuel which may facilitate implementation of renewable energy supply, but historically and mostly has similarly facilitated the use of coal. In recent times coal has been mostly impacted by solar and wind, not natural gas, as renewables have become the preferred economic choice.

We conclude that economic reliance on LNG as a primary energy export will be a major impediment to Australia's well-being when global markets enter terminal decline in the 2020's.

Is it possible to find an alternative narrative which will alleviate this "wicked" problem?

We project one possible macroeconomic pathway through this and identify policy initiatives for State and Federal Government.

Context

Current gross annual revenue across the ten Australian LNG project operators is estimated at AUD 70 billion with the now unlikely possibility of this increasing to AUD 156 billion. This translates to a present value between AUD 884 to AUD 2,040 billion. Future and foreseeable externalized costs borne by the Australian people outweigh the benefits currently paid by the industry. These costs are at best equivalent to and at worst eleven times greater than the value of any benefit. Should the industry internalise these costs, they would represent between 3 and 16% of gross revenue, something that in our trade exposed capitalist democracy would normally share between project equity partners and customers, not the state.

Currently these major externalised costs will be borne by the Australian people, given Australian policy settings. These costs are projected to be between AUD 2.23 billion and AUD 25.4 billion per annum, representing a present value of between AUD 16.3 billion and AUD 198 billion. They are:

- fuel subsidies to the LNG industry, which will cost the Government somewhere between a net present value of AUD 8.0 billion and AUD 100 billion, at an annualised rate between AUD 1.6 billion to AUD 21.6 billion per year.
- GHG offset costs. Under current policy settings, Australians will subsidise the GHG emissions for the LNG industry by at least a present value of AUD 8.3 billion and up to AUD 97.8 billion dollars, at an annual rate between AUD 0.68 billion to AUD 3.83 billion per year.

Total annual dividends paid to the Australian people in exchange for the twin activities of hosting the LNG export industry, and vesting the nation's gas assets to the industry, are estimated to be in the order of AUD 3.52 billion per annum, including:

- significant companies participating in the LNG industry in Australia paid on average AUD 1.3 billion per annum of company tax on revenue of AUD 89 billion per annum for the privilege of operating in Australia (1.4%) for the period 2014-2016,
- AUD 0.82 billion per annum of Petroleum Resource Rental Tax (PRRT, 0.9%) for the monopoly rights to exploit the petroleum resources they control but are otherwise owned by the Australian people.
- royalties on the natural gas used in LNG production of approximately AUD 1.4 billion per annum from 4 out of the 10 operating facilities. The other six extract the gas from federally controlled waters, and thus are only expected to pay PRRT.

Notionally, the dividends may be split into two privileges:

- For hosting the industry and use of social and hard infrastructure, the companies returned 1.4% of revenue, though significantly variable amongst the companies;
- For access and exploitation of Australia's gas consumed in the industry, Australians in recent history achieved a return of 0.9% with a further 1.4% extracted from one large project combined with three smaller ones for royalties.

The total current cash flow return of up to 2.3% to Australians is in return for the gas asset invested in the project. Appropriately leveraged projects may remit cash flow returns in excess of 40% of revenue to the project partners and financiers, in return for the cash asset invested. The later payments return initial capital invested and provides a profit for the investment. The former payments for the gas neither assist in replacing the depleted assert nor give an adequate return.

Further, our estimate of the global GHG amelioration costs attributable to the Australian LNG industry will be at minimum between AUD 307 billion dollars and AUD 629 billion present value. **They represent an indicative increase in supply chain pricing necessary to internalise the costs of emissions of between 26% and 55% of gross revenue for exported LNG.**

These global externalised costs are significant. The moral and ethical conundrum is: "Who pays"?

This document's purpose (Part I) is to collect and standardise data around the Australian LNG industry and its position within the Australian domain. It's role thereafter is at least to underpin recommended policy settings to facilitate visionary and strategic action perhaps as presented in the second volume of this report. The second volume presents options for a better integration of the activities of the industry to leverage a better and sustainable future for both the industry, and the host and asset owning nation, Australia. At best the data will provide an information platform for informed debate around the role of the LNG industry in Australia.

This industry will ultimately become relatively insignificant in Australia, either through exhaustion of quality gas or through a carbon constrained world turning away, perhaps within the current generation's lifetime. What legacy does it want to leave Australia, what legacy do the Australian people want it to leave, to supplant the Australian natural assets it consumes?

Natural gas may be considered to be a low carbon fuel when compared to oil and coal but still in aggregate contributes significantly to the hazard of climate change caused by anthropogenic emissions. Further, if fugitive emissions of methane are poorly managed, it can be the most damaging of all fossil fuels.

LNG clearly holds a dominant economic position as one of the big three energy sources globally. It however cannot compete with renewables as a short to medium term sustainable remedy for the world's energy supply, in its current guise. The industry has the potential to maximise its claim to providing a transition fuel (from fossil to renewable) by embracing a much wider scope for their role as transitional energy suppliers.

The LNG industry has seen a rapid increase in demand as imbalances in regional fossil energy supply force an increasing demand for international trade. This demand is also expected to grow further as China moves for the first time to replace its coal consumption with natural gas, motivated by a desire to reduce local and regional atmospheric pollution causing ill health amongst its citizens (Russell, 2018).

Due almost solely to the resident LNG industry, Western Australia and by extension Queensland and North Territory currently finds themselves to be some of the most polluting regions in the developed world. **The scale of the GHG's emitted both directly and indirectly from Australia's LNG industry is of global significance.**

Our overall analysis shows that this needn't have been the case and need not be the case in the future.

A systematic failure by key decision makers to consider the social and environmental wellbeing of not only the Australian and Western Australian hosts of this industry, but the damage being caused to the global commons is evident.

Australia has a significant responsibility in its stewardship of these resources, and thus for the consequent globally significant emissions.

Australia's contemplation of and action regarding its responsibilities must be considered as an early and urgent function of our body politic and business leaders.

This research seeks to examine the Australian LNG industry and its Greenhouse gas emissions, its consequences and options. It identifies the major institutional players and their impact, and also recommends policies which will enable:

- **the industry in Australia to assume a globally important leadership role in advancing its claim to commercialise a potentially beneficial transitional fuel towards a renewable future, and to ensure positive action is taken in a timely fashion;**
- **Western Australian Government to act to maximise the societal benefit of hosting the industry by setting the policy and legislative environment to springboard into a sustainable economic social and environmental state;**
- **The Federal Government, as a host to an influential proportion of the LNG industry, acts to maximise the societal benefit of hosting the industry by using it to springboard into a sustainable economic social and environmental future**

Others have noted that Australia is the source of approximately 3.5% of the worlds GHG's from fossil fuels placing it as the 7th largest fossil fuel-based producer overall. Australia is a significant GHG contributor through its natural gas production and export: it is the 8th largest producer and 4th largest exporter of natural gas GHG emissions. What Australia does is important to the world.

We will also have to be very careful that we don't endanger the Australian economy by backing gas to continue its upward growth trajectory when the rest of the world may rapidly turn away from gas as a transition fuel and move directly to cheaper renewable options.

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Table of Figures

Definitions

ACCU	an acronym for an Australian Carbon Credit Unit. A unit issued to a person by the Clean Energy Regulator (Regulator) in Australia. Each ACCU issued represents one tonne of carbon dioxide equivalent (tCO2-e) stored or avoided by a project (*Australian carbon credit units*, 2017).
C1	an industry term for methane (a hydrocarbon with one carbon atom per molecule)
C2	an industry term for ethane (a hydrocarbon with two carbon atoms per molecule)
C_2H_6	the chemical name for ethane, indicating 2 carbon atoms and 6 hydrogen atoms per molecule
C3	an industry term for propane (a hydrocarbon with three carbon atoms per molecule)
C_3H_8	the chemical name for propane, indicating 3 carbon atoms and 8 hydrogen atoms per molecule
C4	an industry term for butane (a hydrocarbon with 4 carbon atoms per molecule)
C_4H_{10}	the chemical name for butane, indicating 4 carbon atoms and 10 hydrogen atoms per molecule
C5	an industry term for pentane (a hydrocarbon with 5 carbon atoms per molecule)
C5+	an term for heavier hydrocarbon gases starting with pentane, sometimes called pentane plus
C_5H_{12}	the chemical name for pentane, indicating 5 carbon atoms and 12 hydrogen atoms per molecule
CH_4	the chemical name for methane, indicating 1 carbon atom and 4 hydrogen atoms per molecule
CO_2e	the carbon dioxide equivalent of the GHG emissions for a product or variety of gases used to directly compare the GHG impact, generally measured mass for mass.
CSG	the acronym for coal seam gas, associated in Australia with the large coal fields along the eastern seaboard

Domestic — unless otherwise specified this term implies a boundary within Australia and within the broader Australian market including industrial, commercial, and home activities;

EIS — is the acronym for an Environmental Impact Statement and is one of the few public and detailed documents available to analyse the LNG projects, and is required to gain Environmental approvals from either the relevant state authorities or the Federal one, or in some cases both.

FLNG — is the acronym for Floating Liquid Natural Gas facility, referring to process facilities embodied in a floating vessel.

Gas life cycle emissions — are the emissions released during the supply chain the gas undergoes from first extraction from the gas fields until it is consumed to release its embodied energy for either electrical generation or thermal energy.

GHG — the common acronym for greenhouse gases, those gases which contribute to global warming

GWP — the common acronym for the global warming factor calculated for greenhouse gases, used to convert the actual mass of the gas to the carbon dioxide equivalent of the GHG emissions

GWP_{100} — this paper's convention to indicate that the GWP relates to an agreed standard, the 100 year impact, as these impacts do vary depending on time scale

GWP_{20} — this paper's convention to indicate that the GWP relates to an another standard, the 20 year impact, which may be more relevant due to the rapidly narrowing window of opportunity to act

HHV — the acronym for (higher) heating value, the measure of the energy content accessible from of a fuel when burnt, measured in MJ per cubic metre;

LNG — the common acronym for liquified natural gas manufactured from natural gas and commonly including primarily nitrogen, methane and LPG's.

LPG — the common acronym for liquified petroleum gases found in some natural gases an include both ethane and propane. These gases are also commercially valuable, but are also used in the LNG industry to "top up" the heating value of the LNG product to meet market specifications

LULUCF — is the acronym for "land use, land use change and forestry". In this context it is used to note an exclusion in the GHG inventory figures.

MJ the acronym for megajoule being a measure of energy

Mtpa the acronym for a million tonnes per annum

Natural gas a economic fossil fuel which constituents include a majority of methane, carbon dioxide, nitrogen, LPG's, NGL's and occasionally some hydrocarbon oils, along with a variety of other trace chemicals.

NGL the common acronym for natural gas liquids found in some natural gas and generally includes the Butanes and heavier hydrocarbons. These can be a valuable commercial product.

Petroleum Resource Rental Tax a tax levied on Petroleum producers in Australia in national waters, and is paid after a set level of profitability

Production emissions are the emissions released during the process of conversion to LNG up to the boundaries of the LNG facility, and reflect the emissions which are the direct responsibility of Australia as host for the gas field and LNG facility;

Project Life cycle emissions are the emissions released during the complete production life of the facility from commissioning to de-commissioning, generally over more than 20 years;

Sour gas the name given to the gas in its almost raw state direct from the reservoir, before the acidic gases including carbon dioxide are removed;

Introduction

Australia has been well endowed with natural resources. The nation has grown and matured in part due to their exploitation.

This is particularly so with fossil energy.

The most easily extracted and transported of these, oil, has been part of Australia's story since the 1960's (*Australian Energy Statistics*, 2016). However, in less than 30 years and by 1991, our domestic oil supply changed from a comfortable surplus over gross domestic demand to a deficit. In 2015 the nation supplied 4.6% of its gross domestic demand for oil and had the capacity to supply only 27%. This once dominant and strategically important energy source has been reduced to a minor export commodity in less than 50 years from first exploitation. The majority (80%) of the remnants are still exported in crude form today.

Since oil export began in 1977, the ratio of exported refined product to crude, indicative of value-add in Australia has been low, around 30% until 1995. Decline since then ensures it has become negligible, currently around 5%. In the same period, the same ratio for imported value-added product has risen from an average of 20% to 2015 at 52%. It seems that Australia is not an investment destination when it comes to value add for its jaded oil stock or through its old refineries. In the global chess game of foreign domiciled hydrocarbon multinationals we seem to be extraordinarily compliant.

The legacy of Australia's oil and gas industry should be examined in light of our current dominant position as a natural gas exporter.

Australian fossil hydrocarbon reserves serve as a reservoir of energy assets within Australia. With coal's position in serious environmental doubt, what of "the last fossil fuel" natural gas?

The very first and glaringly obvious learning is that this industry will become insignificant in Australia, perhaps within the current generation's lifetime. What legacy does it want to leave with Australia, what legacy do the Australian people want it to leave, to supplant the Australian natural assets it consumes?

The consumption of these assets should serve to develop an equivalence conceptual: replacement of a natural asset with some sort of human constructed asset, such as national wealth.

The questions for contemplation are: what human construct, to whose benefit is it deployed, at what cost, and to whom, and when?

The answer to these questions is important. In Australia, the LNG industry is visible powerful and has just gone through an intensive growth phase.

The Australian community seems to be taking a breath and asking whether it is all worthwhile.

Woodside first established the Australian LNG industry in the nineteen seventies and eighties in the Pilbara in the North West of Western Australia. Woodside and the state demonstrated the value in this industry, and in doing so undertook a relatively high-risk large-scale project in a remote and unforgiving environment. The result was their successful implementation of the Northwest Shelf Joint Venture.

Once technical development finance and market risks had demonstratively dissipated through this venture, later action by more conservative entrants has been encouraged by little movement in the diligence surrounding and governance of this industry.

Natural gas has been a key economic energy source for the world.

In 2016 global natural gas consumption increased from the previous year by 1.5%, and constituted 24.2% of total energy supply. This growth rate was faster than overall energy demand growth of 1.3%. Oil increased faster by 1.6% (33% of supply), coal declined by 1.7% (28.1% of supply), and renewables including hydroelectricity increased by 6.4% (10% of supply) (*BP Statistical Review of WorldEnergy 2017*, 2017).

In 2016 worldwide 258 million tonnes of LNG was traded (*2017 World LNG Report*), an increase of 5% over the previous year. By 2019 this figure was 393 Mtpa with proposals of a further 843 Mtpa being considered worldwide (International Gas Union, 2019). This trade represents just over 13% of natural gas consumed worldwide, and around 30% of internationally traded natural gas. The remnant was traded using compressed gas in pipelines.

We show that Industry proponents foster a mythology that global trends indicate that the current use of natural gas will grow, and its global trade will grow even faster, facilitated by the increased global mobility of LNG.

The current mythology is that even under carbon constrained scenarios, LNG trade was expected to increase for the foreseeable future (Grant, 2018), even whilst overall natural gas consumption in key markets is expected to fall overall. However, the International Energy Agency now considers LNG for developing Countries' consumption as problematical. The global response to climate change will determine the degree of growth or decline, with tighter targets lowering growth expectations, and placing financial strain on existing or new projects at the high end of the production cost spectrum. Gas quality is also expected to be a key determinant of supply side economics.

In 2016 Australia consumed 44% of its produced natural gas, and exported the balance as LNG (Ball et al., 2017). This proportion continues the relative and real long-term decline for domestic consumption as more LNG facilities are commissioned, and, particularly on the eastern seaboard where no domestic reservation system is in effect. Domestic demand for industrial commercial and home consumption declines due to increasing domestic prices the trend towards electrification and the small but significant inroads being made into the market by renewables. Increasing prices have been attributed to spiralling tension between domestic supply and international export.

The relative and real domestic decline in natural gas consumption has a mirror in the decline of sophisticated value-added manufacture within Australia. Alongside oil a further example is the decline in the energy hungry Australian aluminium supply chain, with closure of smelting plant and increased export of raw bauxite. Western Australian bauxite was shipped for the first time in modern history in 2016 (Burgess, 2016) without further local value add. The south west of Western Australia has been globally significant in alumina production since the industry's development in the 1960's. It has been for more than a decade, and still is, though as a regional industry, is in relative decline (Milligan, 2018).

Australia is the world's second largest LNG exporter, of 18 countries, with current capacity of 69 million tonnes per annum (Mtpa). Qatar is the largest at 78.7Mtpa, with Malaysia being third at approximately 24 Mtpa. The revenue achieved from Australia's export is estimated to be just under USD40 billion per annum at its maximum installed capacity and current contract prices, the greenfield projects have potential to add a further USD 4.7 billion, with identified brownfields opportunities could add between USD 44 and 69 billion per annum.

This is an economically significant business of a global as well as Australian scale.

Western Australia's preeminent role in supplying 55% (based on carbon footprint) of Australia's exported LNG and related product and being the only state that supplies domestic natural gas from the projects has made it a potentially global focal point in this industry, and thus a potential key agent for change.

Queensland and then the Northern Territory provide the remnant with 29% and 16% of CO_2e emissions respectively. Should each state or territory be listed separately in the world's tonnage export per annum, Australia would relinquish its second placing to Western Australia.

On a tonnage of natural gas extracted the percentages are 70% for WA, and 20% and 10% for Queensland and the Northern Territory respectively.

Whilst Qatar has announced plans to increase capacity to 100Mtpa, our study indicates that Australia resources are expected to supply further brownfield developments of around 8 Mtpa from Western Australia's Browse gas fields, greenfield development of the Scarborough resources of about 4.2 Mtpa, and subsequent brownfields development of other sites in the state of between 21.5 and 40 Mtpa. Across Australia potentially current operators are considering a further 73.5 to 89 Mtpa to place Australia as the largest exporter in the world at potentially 158Mtpa.

Project risk has now almost entirely dissipated. Subsequent governance failures to maximise societal benefit can be directly attributable to business and government inaction (in both its policy and administrative functions) or indeed industrial capture at both state and national levels (Fernandes, 2018; Wu, 2018).

Our research indicates that there is a large gap between what is current industry practise in mitigation strategies and what it could be.

Australia's and Western Australia's preeminent position in this industry indicates that the Nation and State have an opportunity be a global leader in supporting this industry to become a valuable change agent. It could ensure that LNG is truly a valuable strategic fuel in the struggle to limit global impacts of GHG's, and to do so in the broader sense of the meaning of transition.

Natural Gas Consumption Carries Significant Local and Global Risk

Natural gas consumption at this scale presents many risks to the sustainability and resilience of the world's social economic and environmental health.

Of the many sustainability challenges associated with its exploration development production transport and consumption, greenhouse gas emissions present a clear and urgent challenge for both the host country and the world in general.

As a benchmark, Australia's total National Greenhouse Inventory for the latest figures in 2018/19 are 538.9 (March to March) million tonnes of CO2e per annum, and Western Australia's was reported at 89.4 Mtpa. Australia has committed to reduce these emissions in line with the Paris agreement and there is mounting pressure to commit to further reductions. These international commitments sit alongside ethical and moral leadership demands for developed nations such as ours, and are at odds with the trajectory of both lifecycle and production GHG emissions from this industry in Australia.

The current level of production of LNG across Australia emits greenhouse gases subject to Australian accounting of just over 52 Mtpa, of which 29 Mtpa is accountable within WA. The former figure represents just under 10% of the Australian 2015 accounts, and the latter just under 34% of the Western Australian accounts. Should the identified greenfield and brownfield industry expansions occur these figure rise to 127 Mtpa (24% of 2015 National accounts) and 76.2 Mtpa (88.6% of 2015 WA State accounts).

Complete lifecycle accounting of the LNG also indicates that the LNG currently produced in Australia will emit 333 Mtpa of CO_2e, mostly elsewhere, of which 226 Mtpa is attributable to WA sourced LNG. Greenfield and brownfield expansion will potentially raise these to 751.8 and 386 Mtpa respectively.

A series of research papers continue to track the amount of carbon humanity can release to the atmosphere from all sources and from now on, until a 2° global warming is inevitable. This has been termed the "carbon budget". At current rates of emissions some estimates indicate the world has only 17 years left before this is inevitable. Further research is indicating that this target will not induce a globally sustainable environment, so more traction is appearing around a 1.5° target. This target gives humanity 4 years at current emission rates. An alternative metric around the same concept is the amount of CO2e emissions humanity can emit before the target temperature rise is inevitable. At the time of writing the 2° rise is predicated by 747,213 million tonnes net remaining budget.

Our research indicates that Australia's operating LNG projects' contribution to the carbon budget is in the order of 10,468 million tonnes (1.4%), and when recognised greenfield additions and brownfield expansions are included this expands to a significant potential of 31,304 million tonnes (4.2% of the global budget). Using the 20 year global warming impact of methane rather than the 100 year impact normally assumed, Australian production will add about 18% more to this figure, to a gross total of 36,938 million tonnes (4.9% of the global budget). These figures indicate that natural gas and particularly Australian LNG consumes too much of the remnant climate buffer before the agreed GHG emissions levels are exceeded. These levels of emissions will also probably cause Australia to abrogate its responsibilities under a variety of international treaties, including the Paris Agreement targets. Morally and ethically, Australian's need to act.

It is time to convert this intractable tension between economic well-being and social and environmental hazard into a means for creating a sustainable world whilst improving the economic social and environmental well-being of Australians and particularly Western Australians.

What is LNG?

The liquefaction process transforms natural gas into a state suitable for bulk transport over longer distances through advanced shipping facilities, with advantages to private enterprise that pipelines, the direct alternative, are unable to offer. It does so however at distinct cost to the:

- competitive economic advantage of the nation;
- the social structure of the host state;
- local regional and global environment

Many of these costs are hotly debated. In terms of this research, the energy requirements and the scale of the plant are the driving forces behind significant centralised GHG emissions with global impact. Australia as the host nation is legally commercially and morally responsible for these globally significant emissions.

LNG is one of a variety of products which is manufactured from the fossil natural gas. Its primary purpose is to form the natural gas into a state which enables its bulk transport and storage. It achieves this by reducing its volume and storage pressure requires by cooling the relevant constituents of the natural gas to about -161°C, at which temperature the methane, nitrogen and LPG's are in liquid form. This reduces the transport volume to 0.22% of its volume at standard temperature (STP) and pressure of 15°C and atmospheric pressure respectively.

Particularly in Western Australia and the Northern territory it is manufactured alongside Liquid Petroleum Gas's (LPG's) and Natural Gas Liquid's (NGL's) which are lucrative product streams. In Queensland, where the coal seam gas is particularly dry, and doesn't have many LPG's or NGL's, LPG's are imported to make up LNG quality specifications.

In Australia the natural resources such as natural gas is owned by the "State". For most onshore natural gas reserves, the State is one of the federated States, but where the reserves are found outside the federated States' boundaries, the asset belongs to the National interest, and administered by the Federal Government.

In Western Australia the LNG is also manufactured alongside a mandated domestic natural gas supply being the equal of 15% of the exported quantity of fossil fuel.

Specifically, natural gas is found in naturally occurring gas reservoirs below the ground, which in the case of Western Australia and the Northern Territory is generally on or near to the offshore continental shelf. Queensland has tapped into another source of natural gas, being coal seam gas.

In comparison to the large conventional gas fields to the North West of Australia, the coal seam gases are harder to extract.

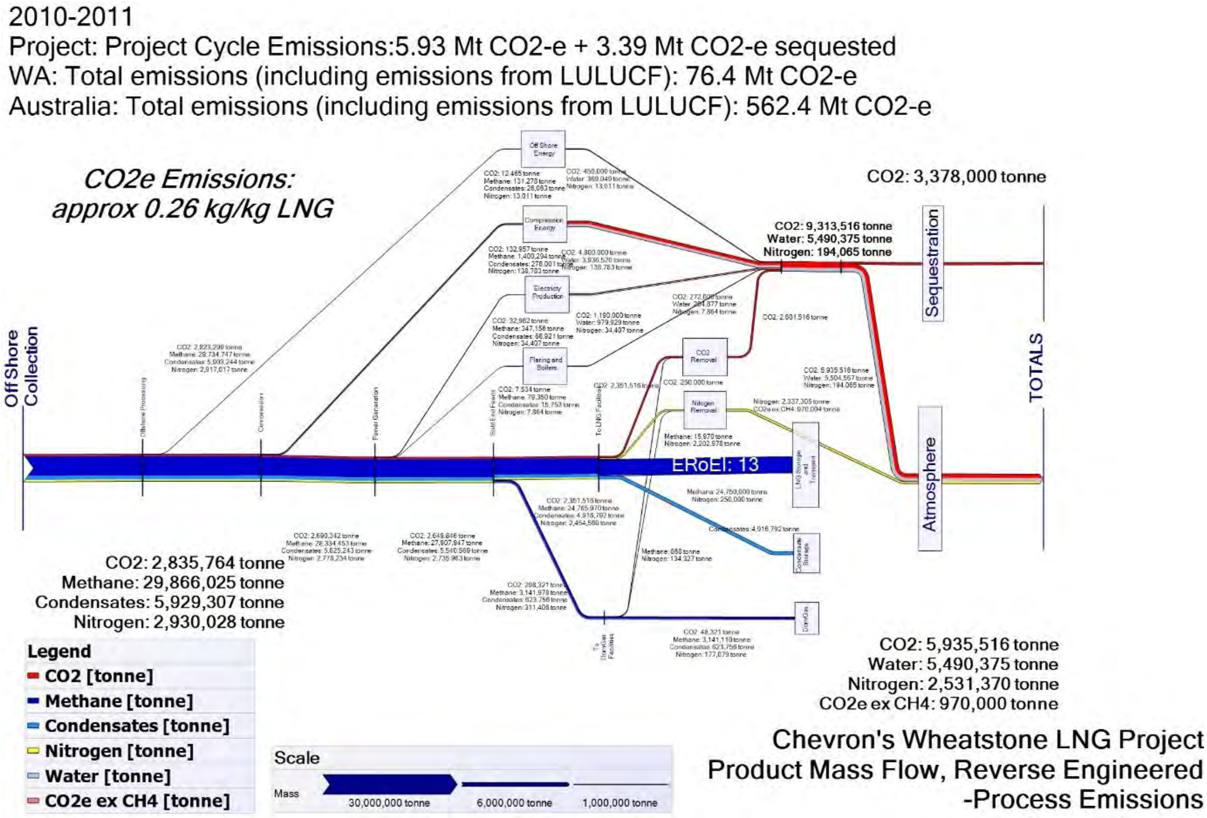
LNG Process Description

Configuration of the plant for an economically successful extraction and liquefaction process varies depending on a variety of factors, but they all have the same basic process.

The following process description may assist in assessing the various components contributing to these GHG impacts and indicate some potential policy options to address them.

The following diagram, entitled “xxxxx” shows mass flows through the original Wheatstone Project proposal, which was the second to seriously contemplate sequestration of CO_2 emissions. The project location is to the north of Western Australia. Whilst the diagram’s primary purpose is to assist with the tracking and flow of GHG emissions, it also identified some key processes common to most LNG plant. The data is indicative of the maximum 25 Mtpa LNG facility originally indicated, not the currently operating facility which has an operational capacity of about 9.2 Mtpa.

Note that the data within this diagram is not normalised as is the later data presented within this report and thus should be treated as being merely indicative.



The sour gas in its natural state is generally pressurised and feeds the distributor network without mechanical assistance. Operations of the offshore assets require power, as indicated by the feed to the top square of the diagram. The thickness of the line to the box is representation of the relative quantities of natural gas required to power each process component.

However, as the field pressure is reduced through gas extraction and depending on how far away the liquefaction and stripping plant is, compression of the gas may be necessary to transport the gas. The longest such pipeline is to the Darwin LNG plat and is in the order of 800 kms long which will always require compression. The existing NWSV pipeline is less than 200km long, whilst the proposed feed from the Browse field is in the order of 900km. Similarly the Queensland pipe networks are in the order of 500km long. Compression requires power which is generally fed from the gas stream itself, as indicated.

Once the natural gas reaches the facility, the liquid components present in the pipeline are captured in the “slug catcher”. These liquids contain some valuable NGL’s and thus are normalised and otherwise treated for later sale or use. The acid gases including carbon dioxide are then stripped from the gas stream as are water and other contaminants. Aqueous solutions of alkanolamines are commonly used to strip acid gas components.

This solvent also captures trace amounts of hydrocarbons including methane which are then released with the acid gas on recycling the solvent. Depending on the quantities of carbon dioxide to be removed from the main gas stream and the design and management of the plant, the quantities of methane in the acid gas is otherwise incinerated, included in the fuel gas stream or released direct to atmosphere. Management of this emission is important in reducing the overall GHG footprint of the plant. Most of the current or proposed facilities have mention of its management. A few don’t.

Only one plant attempts to store the acid gas stream via geo-sequestration and that is Chevron’s Gorgon facility.

The major energy consumption is reserved to drive the refrigeration equipment which not only cools the nitrogen LPG’s and methane to the desired temperature but separates out the remnant NGL’s and LPG’s not desired for the LNG. These remnants are used both for refrigerant replacement and for sale. In the main the refrigeration process requires large compressors to pressurise the refrigerant through a cascading series. Nitrogen has a lower liquefaction temperature and is generally removed at the last “end” flash refrigeration process for the LNG. The nitrogen waste stream however regularly includes a significant proportion of methane. The nitrogen waste gas is may used for fuel gas or released to atmosphere after being processed through a nitrogen stripping column. (Ott, Roberts, Trautmann, & Krishnamurthy, 2015). The released nitrogen can still have about 1% methane, a significant GHG, in the atmospheric release, a further major GHG emission point, especially if there is excess nitrogen beyond the fuel gas balance.

Notwithstanding the methane release, the fuel gas with nitrogen overload may cause additional N_2O emissions, especially as complete combustion can be difficult. No research seems available from the industry regarding the potential increase of otherwise trace amounts of N_2O emissions under this scenario.

Electrical power generation for the whole process is also a significant consumer of natural gas and hence producer of GHG emissions. Typically, about half the energy used to drive the refrigeration compressors is needed to provide electrical energy to the plant. The emissions from this source include CO_2 and trace elements of both unburnt methane and N_20.

Deliberate emissions thereafter are limited to flaring of process gas necessary for the safety of the plant and personnel from time to time, and contributes small but significant annual GHG emissions including CO_2 and trace elements of both unburnt methane and N_20.

Sequestration of a portion of CO_2 produced within the LNG plant is feasible under some conditions. It involves the pumping of the CO_2 acid gas stream back into underground geological formations which are expected to retain the gas for the long term foreseeable future. Geo-sequestration has been studied in some depth, but at this scale has yet to be proven as a longer-term option. To date the industry recognises that this process has fugitive emissions, though no study is able to quantify the experience of actual containment performance in such an industrial setting and quantity. Gorgon is the largest such project to encompass this process, whist Wheatstone was original conceived to also sequester some CO_2, but since was allowed to move from this commitment.

Finally, whilst the process is the main is entirely enclosed, economic and operational expedience dictates that a range of seemingly small and generally unintentional fugitive emissions are present in any plant maintained to current practise. These range from equipment and plant faults, to safety relief systems and general maintenance purging processes. Most of these can and should be either managed or engineered out of the process, but when emphasis is on economic production and safety, the environment can be a poor second cousin. Emissions quantum's from these sources are hotly debated but little evidence is generally presented by industry, and then only that which is the most favourable.

Australia's LNG Industry Structure

The Australian LNG industry mirrors hydrocarbon extraction and processing industry worldwide: a few dominant participants, and some local and generally smaller ones. Essential economies of scale and subsequent enormous demands for capital to institute new facilities are a significant barrier to entry and hence competition by both smaller and new participants. For example, Chevron had to mobilise USD 54 billion to finish its Gorgon project. This is particularly difficult in less developed countries, and thus the industry is dominated by a handful of powerful participants.

This tends to pit nation against nation to extract benefit from their natural resources, with the balance of power more often with the private participants (Chong, 2017). In other industries this dominance can be challenged in a variety of ways, and to reap maximum social benefit from Australia's natural gas resources it may be essential to do so.

Whilst this barrier is not impossible to overcome, concerted strategic action by nation states is essential.

Even the major companies are moving away from this bespoke large project scale for resource development and in Australian and other water floating (i.e. modular) and much smaller capacity facilities are being mobilised with the intent to standardise and "mass produce" to achieve their own economies of manufacture. These facilities bring their own unique set of issues.

This section provides a snapshot of the industrial participants and their interconnectivity in order to understand their capacities and partnerships. This is an important step when endeavouring to bring about change within the industry.

The structure of the LNG industry is synchronous with the overall natural gas production and consumption within Australia. The industry ownership is oligopolistic , dominated by a few very large foreign owned multinational oil and gas companies with multiple shareholdings across the Australian industry. Later in the report relevant issues are addressed related to the completive state of nations along with the tension between burgeoning global networking of such institutions and the power of agglomeration, a function at least partly in the ambit of nation states.

The exhaustion of traditional natural gas reserves from the south east and south west of Australia has seen the increasing dominance of the Northern regions of Australia. Access to this newer gas is primarily due to the development of large offshore markets into which the LNG industry has tapped.

These issues are explored in depth in the following sections.

Natural Gas and LNG

Australia's LNG industry feeds from a portfolio of naturally endowed reserves of natural gas, but is not the only consumer.

"Table 1: Australian Natural Gas Destination by Consumer" presents data for Australian natural gas production and its end use for the 2016 year.(Ball et al., 2017)

Sector	2016	
	PJ/annum	% of total
Residential and commercial	190	11.91%
Industrial	264	16.55%
Gas Power Generation (GPG)	122	7.65%
Liquefied Natural Gas for export (LNG)	1,006	63.07%
Unaccounted for Gas (UAFG)	14	0.88%

Table 1: Australian Natural Gas Destination by Consumer

In 2016 the LNG consumption of Australian gas was significant at 63% and will have relatively grown as the newer facilities have been commissioned.

An energy hungry world will ultimately cause more conflict between the export of gas and domestic consumers. Whilst lamenting the decline of manufacturing industry, successive governments, other than (to some extent) Western Australia's[1], have neglected to act on this vital and potentially strategic resource.

Attracting value-add manufacturing is a key policy goal of all advanced economies, and Australia is a relative late comer to this realisation. One key component to catalyse such economic development policies is identified in the research literature as agglomeration and/or clustering effects, as is energy sufficiency. Evidence of the importance and success of these policy requirements are the significant growth in energy intensive manufacturing in recent times by both China, with coal and the US with unconventional gas exploitation. The success of these industries may filter to even further value for the next tier of manufacturers, until a divers robust and vibrant domestic economy is sustainable.

Later the increasingly poor quality of the gas reserves will be highlighted, however in this context, relative economic advantages for the Australian gas will be eroded, as the increasing poorer quality seen in LNG development becomes evident.

[1] WA has an 15% energy reservation policy for domestic use

Key Policy Issue: what are the limits to growth of the Australian LNG industry in terms of relative advantage of nations to create domestic sustainable economy?

Australian Industry Ownership

"The nationality of a firm is rarely ambiguous. It usually has a major influence on corporate strategy, and it seems to be growing in political importance" (Jones, 2005, 2006)

The Australian industry ownership of the 10 operating LNG facilities or currently under commissioning as well as the single much discussed Browse facility which seems to be perpetually in the planning phase is concentrated within the control of 27 organisations.

A visual representation of the project ownerships linked to project partners is presented in the following diagram, entitled "Figure 2: Australian LNG Industry cross ownerships, identifying projects with link widths proportional to relative ownership by each project participant".

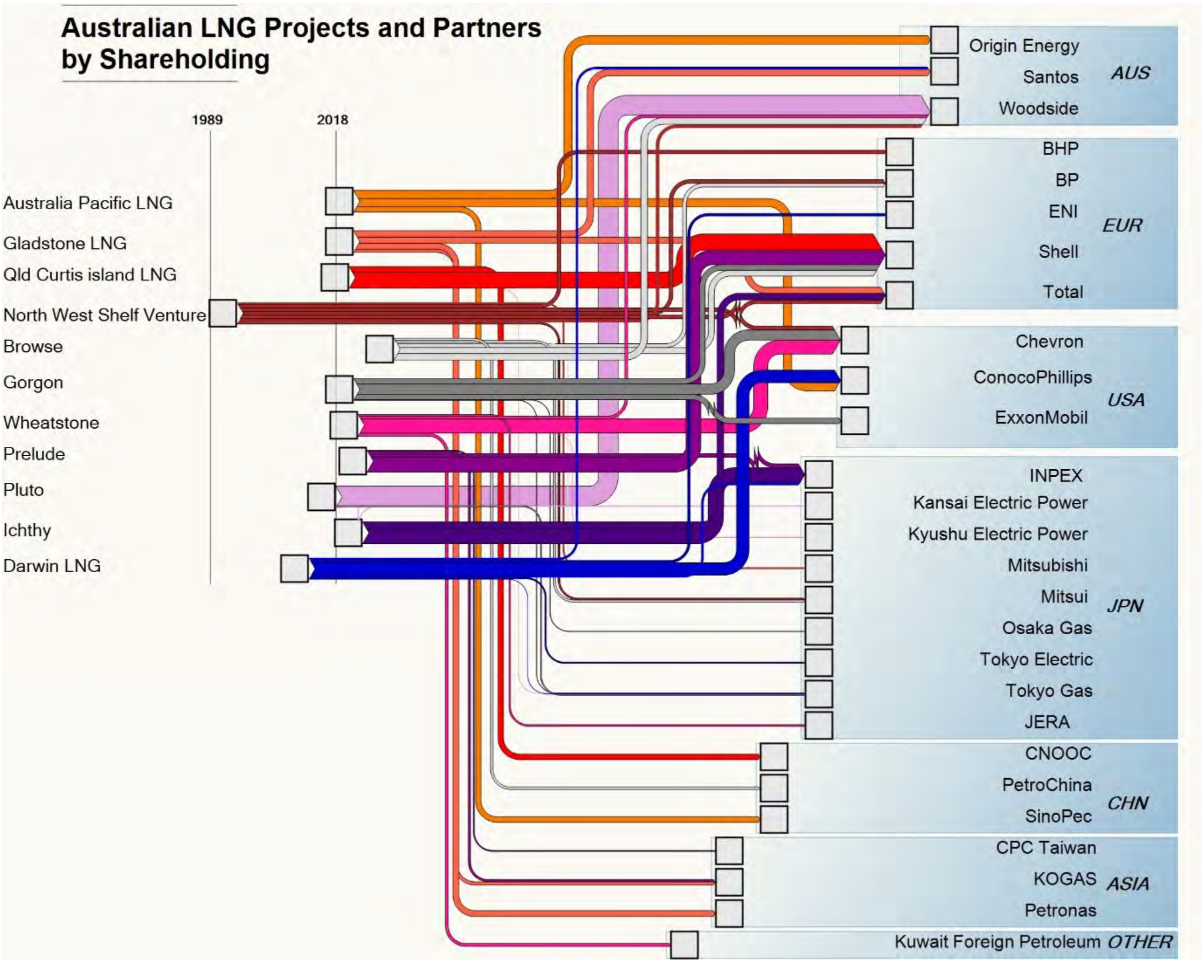


Figure 2: Australian LNG Industry cross ownerships, identifying projects with link widths proportional to relative ownership by each project participant

The graphic highlights some pertinent facts:

- it identifies the 11 projects, being the subject of this report and constituting the current state of play of the Australian Industry;
- it identifies the timing gap between the first facility being the North West Shelf Joint Venture, operated by Woodside, which shipped its first load in 1989, and the second facility being the Darwin LNG facility operated by Conoco Philips and shipping from 2006, followed in relatively short term by the rest with Prelude commissioning now
- Risk mitigation was initially necessary due to the large financial commitments and initial project risk undertaken by project proponents in the NWSV. After a period of successful operation of the NWSV, the perception is that project risk in that region was significantly reduced. In the latter projects a single large proponent tends to dominate each project, accepting a higher percentage of an individual project risk, but probably achieving a lower overall risk profile;
- it identifies some aspects of risk mitigation through multiple project partners with multinational oil and gas expertise. This is particularly noticeable with the original NWSV, which seems to have been a learning experience for multiple companies some of whom later developed their own projects (particularly Chevron);
- it identifies some aspects of risk mitigation through multiple project partners with downstream linkages to long term consumers through project participation, particularly the power challenged Japanese, Taiwan and Korea and original project partners;
- the dominance of Shell, Chevron and Woodside within the market, followed by ConocoPhillips Inpex and to some extent Total of France;
- the relatively minimal influence of Australian private equity, with Woodside being the only Australian based major player in the industry, with major influence being exerted by Royal Dutch Shell and several other smaller European participants, and the big American oil and gas companies;
- Both Origin Energy and Santos are well known Australian gas companies, with dominant positions in the Eastern states. Their participation is generally limited to the LNG facilities in Queensland, which are smaller in impact and size, and as they seek to grow outside domestic markets. Santos was an early participant in the Darwin facility, which may have provided confidence to participate in industry;
- Asian participants may be increasingly influential as they gain experience by being project participants for the later projects. In particular are the three Chinese based oil and gas businesses, Petronas of Malaysia and even one from Kuwait.

Santos is a relatively large Australian Business, which grew from the development of the natural gas reserves at the conjunction of the Queensland New South Wales and South Australian borders to be a nationally significant energy provider. It was subject to takeover speculation by a US based energy company looking to expand operations (Macdonald-Smith, Thompson, & Macdonald, 2018). Australian private influence is therefore potentially further reduced.

In summary, the LNG industry is controlled by large oil and gas companies, most of whom are not domiciled in Australia. The global network advantage of multinationals in this industry is a powerful force against the best interests of nation states such as Western Australia and has little interest in developing agglomeration advantage of these projects in the north to the advantage of the host nation. Strong political leadership may manage this imbalance.

Corporate Citizenship

One de facto measure of the corporate intensions of a large corporate citizen relates to the taxation payments against size of revenue with Australia. The Australian Taxation Office publishes the taxable income and tax paid for the largest 500 companies operating in Australia. Eighteen (18) of the 27 partners identified are included in this list. The remaining 9 are the smaller passive project partners.

Note that these payments only include normal corporate taxation and any reported Petroleum Resource rental taxation (PRRT) which are both a straight federal impost. Royalties are reported elsewhere but are limited to one project in WA and the three projects in Queensland.

On available data, significant companies participating in the LNG industry in Australia paid on average AUD 1.3 billion per annum of company tax on revenue of AUD 89 billion per annum for the privilege of operating in Australia (1.4%). They paid AUD 0.82 billion per annum of Petroleum Resource Rental Tax (PRRT, 0.9%) for the monopoly rights to exploit the petroleum resources they control but otherwise owned by the Australian people.

Royalties have a complex network of cross collection and disbursement mechanisms, well covered by others (McGrath & Neill, 2016). Royalty collections are:

- from the North West Shelf Venture project, which paid on average AUD 1.6 billion per annum in royalties (*Overview of State Taxes and Royalties 2017-18*, 2018) over the same period. The current payments have since dropped to AUD 1.1 billion as the benchmark value of the product has declined; and,
- the Queensland LNG industry consisting of three projects accessing coal seam gas, which may contribute about AUD 0.3 billion per annum in the near future (*Budget Strategy and Outlook 2017-18*, 2017).

In the short term, Australians will receive royalties on the natural gas used in LNG production approximately AUD 1.4 billion per annum from 4 out of the 10 operating facilities. The other six extract the gas from Federally controlled waters, and thus are only expected to pay PRRT.

These authors seem to confuse ordinary taxation imposed on all business for operating in Australia, and notionally used for improvement and maintenance of the general Australian social and built environment, with royalties which are a notional payment for exploitation of a natural and

irreplaceable asset. The separation of the economic motivation for each payment is not explored in their paper, a common misconception.

In 2014 the Australian Federal Senate referred Corporate Tax Avoidance as a topic of enquiry to its Economics Reference Committee. On 1 December 2016, the committee resolved to broaden the scope of the inquiry to include Australia's offshore oil and gas industry. The primary focus is "Tax avoidance and aggressive minimisation by corporations registered in Australia and multinational corporations operating in Australia", and taking a very large strategic overview, not just a narrower economic view.

The committee has asked to receive submissions on the treatment and/or payment of:

- royalties;
- the Petroleum Resource Rent Tax (PRRT);
- deductions; and
- other taxes

by corporations involved in Australia's offshore oil and gas industry, including matters relating to the collection of these moneys by government (*Corporate Tax Avoidance*, 2014).

However, many of the submissions focused directly on the PRRT and royalty binary. This much narrower viewpoint was probably led by the prior Federal Treasury Review of the Petroleum Resource Rent Tax (Callaghan, 2016-2017), commissioned by Treasurer then Scott Morrison. This review preceded the Senate Review, and chronologically set the narrower response set to the Senate review, as most respondents submitted the same documents. Its ultimate finding was that the current application of the PRRT required some fine tuning but did not warrant the (re)introduction of a royalty on the five proponents not subject to one. This broadly follows the industries recommendations.

Broadly the responses fell into two categories:

"No Change" Category

Most of the LNG industry participants, and their industry representatives, APPEA and the Business Council said the existing arrangements were fair and equitable, as did one of the NGO's. Further they said that future employment and investment into the industry was at stake, along with reputational damage around sovereign risk. Each submission pointed to the current benefits of the industry in terms of corporate tax, employment and indirect economic benefits they have brought to Australia. To the average Australian the amounts discussed are impressive. Critically, no participant identified in similar terms the advantages accruing to them, nor the relative scale of the revenues derived from extraction and processing of Australian gas. Should they have done so, the relatively small proportions accruing to the host country would more evident.

Most importantly the messaging throughout by incumbent industry members and their collective voices is that the PRRT positioned as a “tax”, similar to taxes imposed on traditional economic activity. The PRRT is a technique of sharing excessive profitability endowed by access to a monopoly resource with the state. By extension the application of royalties is also positioned as a tax, rather than an input cost for monopoly supply of a sovereign owned scarce and irreplaceable resource.

The economic philosophy (Hotelling, 1931b) around resource extraction has in no way been addressed by any submission and is clearly missing from the dialogue of the major beneficiaries, the proponents. This needs to be revisited.

Significant Adjustment towards Societal Equity

Broadly speaking the submissions within this group were concerned with:

- Australia’s outlier global position (along with the UK) as achieving by far lowest returns on resource assets;
- Reintroduction of royalties for the 5 exempt projects in WA (Gorgon, Wheatstone, Ichthys Pluto and Prelude and new ventures (e.g. Browse or brown field extensions);
- Reduction of industry subsidies;
- Multinational tax avoidance poor corporate behaviour and social equity. Exxon and Chevron were particularly targeted;
- Economic inclusion of the environmental damage of GHG’s;
- Creep within the provisions of the PRRT in favour of industry;
- Too generous expense deductions
- Transparency of system;
- Impose similar restrictions on Australian companies acting with foreign resources elsewhere;
- Targeted expenditure of revenues

Government Institutions

Outline a variety of issues for which the regulatory bodies need to be properly resourced to monitor and act upon including:

- Potential use of phoenix structures to avoid responsibilities. (For example at end of life, and during major incident mitigation);
- Related party loan manipulation in project financing
- use of related party marketing or trading hubs esp. in low tax jurisdictions within supply chains;
- Non-core and core procurement manipulation, including shipping, through hubs "marking up" sales process to Australian entities.
- Artificial boosting of Australia asset values to disguise thin debt, and treating debt as equity of rate for this purpose;
- administration of the PRRT:

- assessable receipts
- deductible expenditure
- transferable exploration expenditure
- starting base expenditure
- governance and record keeping.

Western Australian Government was the only State Government to respond:

- It wants reintroduction of royalties for the abovementioned 5 projects

Interestingly few of the respondent noted the broader economic context of the industry including negative effects of the construction "boom", energy export instead of value-add manufacture, negative impact of resource scarcity on local industry employment and community, doubly impactive with attached domestic price increases, through international profit seeking.

Few commented on the increasingly unsustainable environmental consequences both globally and locally, that the industry continues to externalise.

No one commented on the cost of the monopoly grant to industry participants along with other concessions for which the Australian people are getting less and less in return for, nor the short-term value the industry will bring, as the industry so rightly acknowledges, as other sovereign states compete with better quality resources as the Australian resource diminish.

Presentation of ATO Tax League Data

The data used in our report is accessed direct from the ATO datafiles. In assessing the LNG industry, the royalty rate is less important than overall taxation, because in the main, royalties rates are paid on unimproved gas direct from the geo-reservoirs from which they are extracted and not the value added component implied in LNG production. Indicatively domestic natural gas in Western Australia (DomGas) may sell at the facility boundary for around AUD2.50 per GJ (about 75% less than the current FOB price for LNG) after transportation to the conditioning plant where dehydration and other conditioning processes occur. For comparative purposes, we assume that allowable deductions reduce this to in the order of AUD1-2 per GJ (about 10-20% the current FOB price for LNG), and given royalty rates in the order of a maximum 12.5%, the royalties due on LNG gas may be in the order of 0.125-0.300% of FOB price for LNG. In terms of the economics of LNG industry, this is almost a negligible impost.

Whilst corporate intention may only be loosely linked to taxation records, many of the majors in the list have been operating for many years in Australia and in affiliated oil and gas industries.

In Australia, Woodside is the only project partner whose business is solely LNG and associated product. Its revenue at around AUD 7 billion is smaller than Origin

Energy's (12 billion) and larger than Santo's (4 billion), both of whom are broader domestic energy businesses. Woodside's taxable income as a percentage of revenue was healthy at between 19 and 42%, and positive for all reported years. The other two had patchy reported profitability with only small margins. Woodside paid between 5 and nearly 28% corporate income tax rates, with tax year 2016 figures significantly down on the previous two years. Woodside's tax equates to between 1%, averaged 5.3% and best at nearly 10% of total revenue.

The only reportable taxable income from the Chinese participants was CNOOC who paid the maximum corporate tax rate of 30% equating to 3.2% of revenue.

Some of the European business' have diverse energy businesses in Australia. On AUD 40 billion combined revenue, their taxable margin was 7%, average tax rate was just under 22% at 1.56% of revenue.

The Japanese companies all appeared to pay a reasonable percentage of their declared profits, but in even in comparison to other companies, the declared profits were low in comparison to revenue. Inpex, the only true oil and gas company in the Japanese suite of project partners, reported paying tax at close to the corporate tax rate of 30%, but their tax rate as a percentage of revenue of around AUD 1 billion over the period, was on average tax at 0.2% of revenue, a very low rate.

Inpex's consolidated global annual financial accounts over the reporting periods reported about USD 10 billion of net sales (revenue) per annum, and taxable income at an average of 53.8% of revenue. There is no indication of what income tax it paid on this profit in its domicile (Japan). These figures are the clearest indicator of the overall profitability of the sector.

However, a note of cautious positivity is necessary as Inpex has thus indicated a net profit before tax rate on revenue at over 50% from their operations over the data period. This profitability indicates that the industry in general can contribute much more to the overall economy of Australia.

Inpex also returned virtually no tax in Australia over comparable timeframes. This may indicate both the possible returns available (greater than 50% of revenue) for the industry, and the possibility of profit shifting (virtually 100%) by Inpex.

The Korean, Kuwaiti, Malaysian and Taiwanese partners didn't feature in the ATO's largest company lists, so no data is readily available to review.

No American oil and gas company paid Australian corporate tax or PRRT over the period from 2013 to 2015, despite being amongst the largest ranked by revenue and having a long association with Australia. The combined American partners reported on average just under AUD 13 billion annual revenues. ExxonMobil and Chevron account for about 80% of this revenue and neither reported taxable income in Australia.

In the US, ExxonMobil's annual financial accounts over this period are for the group as a global entity. They report USD 333 billion dollars of revenue and taxable net income at average of 12.63% of revenue. Further it paid on average 4.44% of revenue as tax, an equivalent corporate tax rate of 33.86%, whilst paying none in Australia. Prorated to their own American results, and on revenue reported in Australia which averaged AUD 8.3 billion per annum, ExxonMobil would have paid in the order of AUD 370 million per annum, a total of more than AUD 1 billion over the reportable period. Using Woodside's figures are even more indicative (as Woodside also averaged an 0.7% of revenue from its PRRT to combine with its average tax rate of 5.6%, making a comparable gross tax rate on revenue of 6.3%) ExxonMobil would have paid on average AUD 521 million tax per annum, a period payment in excess of AUD 1.5 billion.

In the US, Chevron's global annual financial accounts as reported and over the equivalent period are illustrative. They report USD 183 billion dollars of revenue and taxable income at average of 11.87% of revenue. Further it paid on average 4.18% of revenue as tax, indicating an equivalent corporate tax rate of 26.90%, whilst paying none in Australia. Prorated to their own American results, and on revenue reported in Australia which averaged AUD 2.8 billion per annum, Chevron would have paid in the order of AUD 115 million per annum, a total of more than AUD 0.3 billion over the reportable period. Using Woodside's figures are even more indicative Chevron would have paid on average AUD 173 million tax per annum, a period payment in excess of AUD 0.52 billion.

Indicatively Chevron settled out of court with the Australian Taxation Office (ATO) in 2017 for a sum reported to be about AUD 1 billion. The ATO were prosecuting Chevron for tax avoidance through transfer pricing (Mather, 2017).

ConocoPhillips in Australia reported a further 10% of the previously mentioned total revenue whilst reporting a 6% profitability before tax, but paid no Australian tax over the period.

In the US system, ConocoPhillips consolidated financials over the same period are a little more complex: the company underwent a restructuring in 2012 and subsequently have some significant amortisations to write off before tax. They report a 10% profit on revenue in the 2012 year and then book losses thereafter. Most indicative however is that over this period the company continued to pay dividends to shareholders of 5.33%, 12.35% and 5.25% of revenue for the years 2013, 14 and 15 respectively, indicating its continued strong positive cash flow, whilst reporting these book losses. Using Woodside's figures are even more indicative ConocoPhillips would have paid on average AUD 105 million tax per annum, a period payment in excess of AUD 0.31 billion.

Indicatively, and over the period examined the American companies have been unable to contribute to the overall social well-being of Australians to the level that the domestic operator has achieved. It is possible therefore to conclude that on the larger scale, the American companies have not achieved satisfactory corporate citizenship.

With average revenue in Australia of nearly AUD 89 billion and on average the reported industry participants has paid 1.4% of revenue as taxation. Using the benchmark of Woodside, Australia may have forgone approximately AUD 4.35 billion per annum over the reportable period, which equates to AUD 13 billion in total.

Corporate Citizenship Conclusions

In summary, on this evidence, Woodside is possibly the best reflection of good Australian corporate citizenship in its industry. Characteristically it is also the only major Australian based project partner of the top three operating in the Australian industry and is one of only three Australian participants of twenty-seven overall.

At the other end of the spectrum, no American project partner paid any corporate tax or PRRT, representing a negatively skewed structural profitability profile in comparison to other partners in Australia. Whilst the underlying reasons for this are not always evident it is easy to interpret the evidence to indicate some form of, at best, tax minimisation and at worst, tax avoidance schemes in play over this period, in favour of the American proponents and to the detriment of Australian society.

Those industry members who have significant divergences from a net Australian corporate tax rate of 30% and a ratio of tax to revenue of less than 10% may be inadvertently advertising their allegiances to others, including their shareholders. senior executives and their home nation, with little consideration of their moral and legal corporate responsibilities towards their host nation, from whom they derive these significant benefits. Clear policy direction to maximise social return to Australia is called for. The Federal Government appears to be taking some belated action through the ATO.

It is therefore easy to conclude that as an industry it has underachieved in its corporate responsibilities during this period. Many factors contribute to this, but one increasingly being recognised, and clearly demonstrated here is the clear divide between domestic participants and foreign and multinational operators, who dominate the Australian industry. Whilst the 2019 figures are due any time, the previous year’s data indicate that Woodside is now adding less value to the Australian economy.

The earlier quote by Jones does seem apt: with the large multinationals operating in the Australian LNG industry, degree of benefit to the Australian society and offshore distance to corporate headquarters appear to be to be inversely related.

The social contract necessary for this industry to operate warrants study.

Many would argue that this tax reduction behaviour is a key characteristic of corporate behaviour, albeit taken to the extreme, and the real failure is in the governance regime of the host country in inadvertently fostering it.

Responses to the little publicised Senate Enquiry show there is unease in the broader community over the value of the industry to Australia.

Energy Subsidies to the LNG Industry

The gross thermal energy consumption rate for the industry is 37.7 GW rising to a maximum potential of 62.3 GW. This translates to electrical equivalences of 12.3 GW rising to 20.5GW.

Our estimates indicate that the natural gas resources used to produce either thermal or electrical energy across the industry has a current gross opportunity cost of AUD 1.6 billion per year as domestic gas, which will rise at maximum scale to AUD 21.6 billion per year as LNG.

Whilst the arrangements between resource suppliers and LNG proponents appears more commercial in Queensland, there is no evidence to indicate that the Australian people derive any direct benefit from this consumed gas extracted in proximity to the Northern Territory or Western Australia. It effectively is consumed by the operator at no cost. The opaque nature of royalties for the NWSV project makes it difficult to identify if royalties are paid on this consumed gas, otherwise all other projects outside Queensland are exempt from royalties.

Consumption of sovereignly owned gas at no cost, rather than market price, for use by the project operators is a clear subsidy to the industry that no other Australian industry enjoys on such a scale.

Excluding Queensland operators, the relevant quantities of gas may be priced at the gate price of domestic gas, or the same for LNG, to estimate the arm's length opportunity cost. Thus, the gross subsidies may be valued at AUD 1.6 billion per annum with a present value of AUD 19.2 billion overall, and AUD 3.6 billion per annum with a present value of AUD 60.6 billion overall if the industry expands to the maximum scale, and five and a half to six (5.5-6) times these figures if the assumed opportunity price is that received for LNG.

The net marginal value (or net direct resource rent achievable) is estimated to be half of these figures. The PRRT nominates 40% return of marginal profitability from hydrocarbon resources. All together free fuel consumption by the LNG industry avoids resource rental to the Government with a net present value somewhere between AUD 8.0 billion against industry revenue having a present value of AUD 600 billion at current scale when the gas would otherwise sold domestically, for example to the operator, and at maximum scale: up to AUD 100 billion against industry revenue having present value of AUD 1,000 billion at maximum signalled scale if converted to LNG equivalence for the international market, based on discounting the cash flows with the relevant Treasury Bond Rate.

This is all about the Development of Northern Australia

Early gas was supplied in Australia by burning coal to make coal gas. For example, the company now known as AGL and originally called Australia Gas Light Company provided coal gas to Sydney in 1837. The East Perth Gas Works site was in operation from 1886 to 1971

Australia has a fifty-year history in development of natural gas, initially replacing the coal gas producers across Australia. The first region was the Cooper basin straddling NSW, Queensland and South Australia. This basin is easily identified on the illustration below (Figure 3: Australian natural gas and LNG Infrastructure), where the black dots indicate producing fields and the red lines indicate pipelines for its distribution. Cooper basin and its first commercial discovery in 1963, is represented by the larger cluster of fields just to the east of the centre of Australia, and with the radial pattern of pipes spreading from it. Its major operator is Santos.

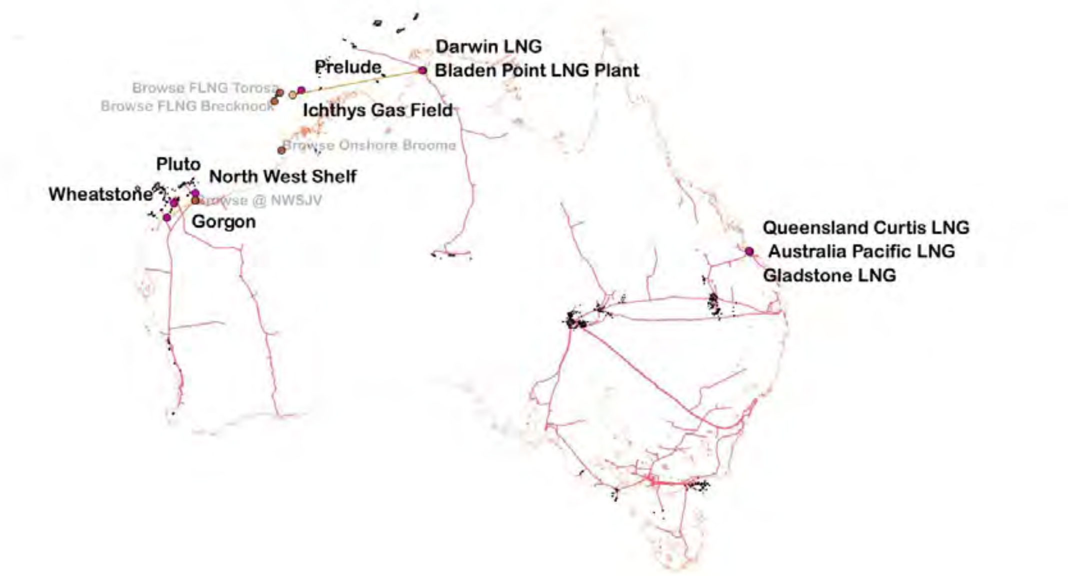


Figure 3: Australian natural gas and LNG Infrastructure

Western Australia's natural gas era commenced in 1970 with the announcement of the construction of a pipeline from Dongara, north of Perth to Kwinana, underwritten by a supply agreement with Alcoa for its Kwinana alumina refinery. The first LNG plant was developed by Woodside with gas from the North West Shelf, landing in Dampier for transformation to LNG. It was also underwritten by State agreements to build a state-owned pipeline for domestic consumption to Perth and Pinjarra. This pipeline transported its first gas in 1984. The Pinjarra component ensured that Alcoa could once again underwrite this major gas development and its own expansion by building another alumina facility at Pinjarra.

This State Government Woodside and Alcoa joint commitment exposed Australia to the LNG business for the first time, achieving the first LNG export in 1989. It also is a prime example of the advantages of regional clustering (agglomeration) and the role of government with active sponsorship. This sponsorship included investment in productive infrastructure through the building operation and ownership of the Dampier to Pinjarra pipeline, by State Government. This active participation led directly to several nation-building and synchronous industrial developments which still underpin Australian lifestyle today.

Darwin has been supplied with natural gas for local consumption from the Amadeus basin in central Australia since 1986.

The eastern states, and particularly Victoria developed a further appetite for natural gas when Esso and BHP commenced piping natural gas from its Bass Straight offshore oil and gas fields in the early seventies.

This illustration shows the location of the gas fields around Australia, the pipelines which deliver the gas for domestic consumption and the exporting LNG facilities. Effectively the LNG facilities are clustered around four important natural gas accumulations:

1. The offshore Carnarvon basin from which the NWSV, Gorgon and Wheatstone projects derive their gas;
2. The offshore Browse basin, currently supplying the Ichthys and Prelude Projects and may supply to Woodside's Browse project sometime in the future;
3. The offshore Bonaparte Basin between Australia and Timor-Leste which currently supplies the Darwin LNG facilities; and
4. The onshore Surat and Bowen Basins, which supply coal seam gas to the three Gladstone based Projects, being the Gladstone, Australia Pacific and Queensland Curtis projects

Whilst the LNG developments in Queensland provide an relatively new industry for the region, they are already approaching a longer term limit on significant further development. Their activity is having a direct impact on local industrial and commercial development through competition for a resource, coal seam gas, that is more difficult to extract, has significant impact on otherwise productive land, faces a significant problem in achieving a social contract with residents, and has been attributed as the primary cause for scarcity and spiking natural gas prices in the market.

Alternatively, the longer-term limits on development in the broad arc offshore from Carnarvon to Darwin are subtler, so a significant focus in this region is warranted. This is exacerbated by knowledge that seemingly massive unconventional natural gas reservoirs under the on-shore Canning basin inhabit the region. These resources are identified to be far larger than the conventional resources offshore, but also are known to be deeper, less productive per well and face many of the environmentally damaging issues faced by shale gas's in the USA and coal seam gas's in Queensland NSW and Victoria.

Note that it is impossible to be entirely accurate in investigating this industry as data on quantities and qualities of the feed gas, which incidentally belongs to the people of WA, and related emissions, which impact on the Australian people and their commitments, is kept confidential by most project proponents. We conclude that this secrecy increases in parallel with the growing awareness within the general community of the impact of GHG's will have on our lived environment. The industry thus appears to act as if there is something to hide.

Our study of the data shows proponents who only require environmental approval from the Federal Government report the least data around climate change impacts in their EIS's. This may partially explain more recent moves to rationalise environmental approvals and have the Federal Government as the responsible entity in carriage of this duty.

Current Operations

Our research has subjected the current operations for the 10 operating or near operating LNG facilities, and the one more controversial yet to be developed project (Browse) to intense study Our process involved the review and "normalisation" of the data presented in the requisite Environmental Impact Statements (EIS). This process is necessary to understand the issues and quanta associated with each development.

For WA, it has 5 operating or near operating facilities and one potential greenfield project that is well known. These projects exploit:

- 84 Mtpa being 70% of the raw resource extracted for production of LNG in Australia, indicating its dominance of the industry
- Comparatively less at 58% of Australian consumption, and 12.6% of raw resource compared with 15.3% Australian average of the raw resource consumed in its processes, indicating that it is probably the most efficient of the operations almost entirely due to having the best gas quality overall, in terms of transport distance effort to extract and constituent gases, for LNG production;
- Also comparatively less (57%, 20.8% and 25.7% respectively) of the produced emissions from the process;
- About average rates of embodied CO_2 released (68%, 5.7% and 5.8% respectively), aided by the 80% of Gorgon's embodied CO_2, which is expected to be geo-sequested; and,
- Relatively less of the economic product is LNG as each project has an additional requirement to supply the States domestic market, and the raw resource appears to have better NGL content than other projects, which increases the rate of raw resource consumption relative to the LNG proportion.

WA projects are estimated at today's pricing to generate revenue of USD 28 billion per annum for its LNG alone (AUD 36.4 billion per annum).

For Queensland, it has three operating facilities all in very close proximity to each other near to Gladstone. These projects exploit:

- 24 Mtpa being 20% of the raw resource extracted for production of LNG in Australia;
- Comparatively more (23%, 17.4% and 15.3% respectively) of the raw resource consumed in its processes, indicating that it is probably less efficient than the Western Australian facilities. Given the quality of the gas feed, this is assumed to be due to the high energy requirements to extract the coal seam gas and transport it over significant distances;
- Also comparatively more (30%, 38% and 26% respectively) of the produced emissions from the process for the same reason;
- Also significantly less (3%, 1.2% and 6% respectively) of the rates of embodied CO_2 released from the process, entirely due to the lack of CO_2 in the raw resource. Significantly this does not mean that these are the most carbon efficient of the facilities. This will be highlighted later in the report;
- Relatively more of the economic product is LNG as this is the only product of the process, given the unique nature of the coal seam gas. In fact LPG's are imported and added to ensure compliance with international quality requires of the LNG.

Queensland projects are estimated at today's pricing to generate revenue of USD 11.3 billion per annum for its LNG alone (AUD 14.7 billion per annum).

For the Northern Territory, it has two operating facilities all in very close proximity to each other near to Darwin. Each, however, draws its feed gas from different fields with different characteristics. These projects exploit:

- 13 Mtpa being 10% of the raw resource extracted for production of LNG in Australia;
- Comparatively more (20%, 29.2% and 15.3% respectively) of the raw resource consumed in its processes, indicating that it is probably less efficient than the Western Australian facilities. Given the quality of the gas feed, this is assumed to be due to the high energy requirements to extract the CO_2 and transport the feed gas over significant distances, one at 400 km and the other at 800 km;
- Also slightly over average (14%, 34% and 26% respectively) of the produced emissions from the process for the same reason;
- Also significantly less (28%, 16.1% and 6% respectively) of the rates of embodied CO_2 released from the process, entirely due to the of CO_2 in the raw resource; and,
- Less of the economic product is LNG as both field are relatively rich in CO_2 LPG's and NGL's, but also have no demand for domestic gas supply.

The Northern Territory projects are estimated at today's pricing to generate revenue of USD 4.2 billion per annum for its LNG alone (AUD 5.5 billion per annum).

The following summarises the scope of each project and identifies some of the unique challenges each project faces pertinent to this report.

The North West Shelf Venture

This plant is estimated at today's pricing to generate revenue of just under USD 9 billion per annum for its LNG alone (just over AUD 11 billion per annum).

Based in Western Australia, this Woodside managed project is the founding project of Australia's LNG industry, shipped its first cargo in 1989. It is fed from the Carnarvon Basin's North Rankin and Goodwyn offshore gas fields. Initially the plant was designed to export 4.4 Mtpa of LNG, but has over time increased this capacity to 15.6 Mtpa, the largest and comparable in capacity to the new Gorgon facility.

The facility uses 32 Mtpa of feed natural gas to produce 15.5 Mtpa of LNG, 6.2 Mtpa of domestic gas, and about 3 Mtpa of NGL's. In doing so it consumes 3.7 Mtpa of the feed gas, produces 5.4Mtpa of emissions of which 1.5 Mtpa is embodied CO_2 gas. Though it is one of 5 operating in WA, it consumes 38% of the states feed stock. It is by far the largest supplier of domestic gas.

One of the factors in its early design has been to balance the gas feeds from each field to satisfy both domestic gas and international LNG gas specifications. Old data shows that the North Rankin field had a embodied CO_2 constituency of around 3.3% v/v and for nitrogen methane and ethane 0.7%, 85% and 5.9% respectively. Similar old data shows that the Goodwyn field had a embodied CO_2 constituency of around 1.6% v/v and for nitrogen methane and ethane 1.5%, 81% and 6.7% respectively. This speciation of raw gas seems almost ideal for the task at hand, as the CO_2 and N_2 content is not high and there is enough ethane to ensure the LNG meets specification.

There doesn't appear to be any plans to increase the capacity of this plant. Current gas supply to this plant appears to be coming to an end, possibly in the early 2020's and the search is on for replacement natural gas.

Originally the facilities also provided 550 TJ/day of natural gas to the State domestic market, primarily to Alcoa. This capacity was expanded along the way to 850 TJ/day in 1995.

Over time the facilities have also provided excess LPG's and NGL's to various markets.

Gorgon

This plant is estimated at today's pricing to generate revenue of just under USD 9 billion per annum for its LNG alone (nearly AUD 12 billion per annum).

Also based in Western Australia, this Chevron managed project perhaps one of the most capital intensive of Australia's LNG industry costing a reputed USD 54 billion.

It shipped its first cargo late in 2016. It is fed from the Carnarvon Basin's Gorgon and Jansz gas fields. Initially the plant was designed to export 15.6 Mtpa of LNG, the largest and comparable in capacity to the older NWSV facility, but over time may increase this capacity to 20.8 Mtpa. It expects to geo-sequester around 80% of the embodied CO2 in the fed gases in the previously depleted fields surrounding Barrow Island where its facility is nearing completion of its commissioning stage.

The facility uses 25 Mtpa of feed natural gas to produce 15.8 Mtpa of LNG, 2.3 Mtpa of domestic gas, and about 0.6 Mtpa of NGL's. In doing so it consumes 2.5 Mtpa of the feed feedstock, produces 5.3 Mtpa of emissions of which 0.85 Mtpa is embodied CO_2 gas. Though it is one of 5 operating in WA, it consumes 30% of the states feed stock.

It has committed to reducing the released CO_2 by geo-sequestering about 3.4 Mtpa as a rolling 3 year average (Gunter et al., 2009). This sequestration goal is the second largest operation of 29 large scale carbon capture and sequestration facilities in the world, after a hydrocarbon recovery program in the US sequestering 7 Mtpa (Institute, 2018). In late 2017 Chevron reported the need to defer its sequestration commitment by up to 12 months due to process infrastructure failure.

One of the factors in its design has been to balance the gas feeds from each field to satisfy both domestic gas and international LNG gas specifications and manage the high CO_2 loads presented by its feed gas. Scarce data shows that the Gorgon field had an embodied CO_2 constituency of a high 14.5% v/v and for nitrogen methane and ethane 2.5%, 77% and 3.23% respectively. Similar scarce data shows that the Jansz field had a low proportion of embodied CO_2 , it being 0.28% v/v and for nitrogen methane and ethane 2.35%, 91% and 3.7% respectively. This speciation of raw gas presents a lessor quality of feed gas with a need to remove significant quantities of the acid and inert gases, as the CO_2 is very high and N_2 content is reasonably high. The LPG's seem to balance needs well: there appears to be enough ethane and propane to ensure the LNG meets specification.

In April 2018 Chevron Australia announced the expansion of the subsea gas gathering network required to maintain long-term natural gas supply (Ackroyd, 2018). It claims a AUD 5.1 billion spend over 4 years.

There doesn't appear to be any plans to increase the capacity of this plant immediately but the EIS was approved with an addition 33% capacity, should conditions change. The life of this plant has been nominated by proponents at 60 years.

This facility does supply domestic gas.

Over time the facilities may also provide excess LPG's and NGL's to various markets.

Wheatstone

This plant is estimated at today's pricing to generate revenue of USD 5.2 billion per annum for its LNG alone (AUD 6.8 billion per annum).

Also based in Western Australia, this Chevron managed project perhaps one of the newest. It shipped its first cargo late 2017. It is fed from the Carnarvon Basin's Wheatstone and Iago gas fields. Initially the plant was designed to export 8.9 Mtpa of LNG, , but over time may incrementally increase this capacity to14.2 Mtpa, perhaps by 2021, and then to 26 Mtpa, perhaps by 2024.

The facility uses 13 Mtpa of feed natural gas to produce 9.2 Mtpa of LNG, 1.5 Mtpa of domestic gas, and about 0.4 Mtpa of NGL's. In doing so it consumes 0.98 Mtpa of the feed feedstock, produces 2.45 Mtpa of emissions of which 0.90 Mtpa is embodied CO_2 gas. It is one of 5 operating in WA and consumes 16% of the state's feed stock.

Woodside disclose that they supply 20% of gas from their 65% owned Julimar and Brunello gas fields in exchange for 13% of products. They also indicate that the rest (80%) is from the Wheatstone and Iago Fields

One of the factors in its design has been to balance the gas feeds from each field to satisfy both domestic gas and international LNG gas specifications and manage constituent gases presented in its feed gas. Scarce data shows that the Iago field had an embodied CO_2 constituency of 2.9% v/v and for nitrogen methane and ethane 4.79% which is high, 84% and 4.34% respectively. No data has been sourced regarding the Wheatstone field. This speciation of raw gas presents a lessor quality of feed gas with a need to remove significant quantities of the inert gases, as the N_2 content is reasonably high. The LPG's seem to balance needs well: there appears to be enough ethane and propane to ensure the LNG meets specification.

Initially the proponents considered geo-sequestration of the embodied CO_2 similar to the Gorgon project, but through a series of political moves managed to achieve environmental approval without direct sequestration.

The life of this plant has been nominated by proponents at 45 years.

This facility does supply domestic gas.

The facilities will provide excess LPG's and NGL's to various markets.

Pluto

This plant is estimated at today's pricing to generate revenue of USD 2.8 billion per annum for its LNG alone (AUD 3.6 billion per annum).

Also based in Western Australia, this Chevron managed project perhaps one of the newest. It shipped its first cargo late 2017. It is fed from the Carnarvon Basin's

Wheatstone and Iago gas fields. Initially the plant was designed to export 8.9 Mtpa of LNG, , but over time may incrementally increase this capacity to 14.2 Mtpa, perhaps by 2021, and then to 26 Mtpa, perhaps by 2024.

The facility uses 7.7 Mtpa of feed natural gas to produce 4.9 Mtpa of LNG, no domestic gas, and about 0.88 Mtpa of NGL's. In doing so it consumes 1.7 Mtpa of the feed feedstock, produces 2.4 Mtpa of emissions of which 0.30 Mtpa is embodied CO_2 gas. It is one of 5 operating in WA, it consumes 9.1% of the state's feed stock.

Due to high nitrogen content, this plant has had difficulty in delivering its required 15% for the domestic market. It is studying the idea of supplying LNG to the mainland, but has as yet to commit. It thus is currently operating outside State requirements.

Scarce data shows that the Iago field had an embodied CO_2 constituency of 2.9% v/v and for nitrogen, 4.79% which is high, methane and ethane, 84% and 4.34% respectively. No data has been sourced regarding the Wheatstone field. This speciation of raw gas presents a lessor quality of feed gas with a need to remove significant quantities of the inert gases, as the N_2 content is reasonably high. The LPG's seem to balance needs well: there appears to be enough ethane and propane to ensure the LNG meets specification.

The life of this plant has been nominated by proponents at 45 years.

This facility does supply domestic gas.

The facility will provide excess LPG's and NGL's to various markets.

Prelude

This plant is estimated at today's pricing to generate revenue of USD 2.0 billion per annum for its LNG alone (AUD 2.6 billion per annum).

Whilst the gas reserves are offshore from Western Australia, this Shell managed project is one of the most secretive of all. A reading of the proponents EIS to Federal requirements requesting environmental approval indicate its comparative lack of detail, especially around GHG's. It appears on track to ship its first cargo in 2019. The FLNG plant is fed from the Browse Basin's Prelude and later its Concerto gas fields. Nominally the vessel is designed to produce 3.6 Mtpa of LNG, and on exhaustion of the Prelude field move to the Concerto field, estimated to occur around 2024.

The facility will use 6.8 Mtpa of feed natural gas to produce 3.6 Mtpa of LNG, no domestic gas, and about 0.97 Mtpa of NGL's. In doing so it consumes 1.9 Mtpa of the feed feedstock, produces 2.0 Mtpa of emissions of which 1.2 Mtpa is embodied CO_2 gas. It is one of 5 operating in near WA, it consumes none of the state's feed stock, as it operates in Federal waters.

One of the factors in its design is its simplicity. It has no requirement to balance the gas feed to satisfy anything other than international LNG gas specifications. It however needs to manage constituent gases presented in its feed gas.

Atypically and unlike others, Shell has not attempted to be secretive regarding the speciation of the gas feed. Data shows that the Prelude field has an high embodied CO_2 constituency of 9.5% v/v and low nitrogen at 0.60% with methane and ethane being 72% and 9% respectively. This field is a “wet” field at 59% ratio of methane to total hydrocarbons (for example when compared with very “dry” coal seam gas at 99.8+%), which indicates it is very rich in LPG’s and NGL’s, a lucrative revenue stream. Data shows that the Concerto field has an even higher embodied CO_2 constituency of 10.9% v/v and low nitrogen levels at 0.75% with methane and ethane being 78% and 6% respectively. This field is a less wet field with a 75% ratio of methane to total hydrocarbons but is still relatively rich in LPG’s and NGL’s, so its exploitation will continue to provide a lucrative revenue stream.

This speciation of raw gas presents a lessor quality of feed gas with a need to remove significant quantities of the inert gases, as the CO2 content is very high. The LPG’s seem to balance needs well: there appears to be enough ethane and propane to ensure the LNG meets specification.

The life of this plant has been nominated by proponents at 25 years combined for both field.

The facilities will provide a relatively large proportion of LPG’s and NGL’s for various markets.

The plant is sized specifically for a smaller gas field and is a floating liquified natural gas (FLNG) facility, a relatively untried technology. An advantage is that there are no gas fugitives nor energy consumption due to the absence of long pipelines.

The Western Australian Government have previously reviewed the issues peculiar to the Western Australian Industry of FLNG. [complete summary of findings and reference]

In comparison to shore based plant, FLNG has a series of strengths and weaknesses (Songhurst, 2016). This author also provides a good summary of the technology and state of play. Also provided is a matrix of strength weaknesses and opportunities and threats for this technology as perceived from a proponent’s point of view. Factors pertinent to this report extracted as a subset of the original are presented here:

Strengths	Weaknesses
• Avoids gas pipelines and land-based facilities • Less NIMBY (not in my back yard) issues	• Unproven experience • High OPEX and maintenance costs • Minimal Local Content • Immature safety and risk profile

Opportunities	Threats
• Relocatable • Monetise otherwise stranded fields • No requirement for land • No requirement for onshore infrastructure • Lowers barriers to entry to industry	• Lack of finance from institutions • Inexperienced operators entering market • Geopolitics demanding more local content

Green highlighted factors that when considered from a hosting country perspective are positive contributions. Those highlighted in red are significant dangers to the well-being of the host society. Of all of these the major issue already pertinent and relatively obvious through analysis of Shells original EIS, the reference to "NIMBY" - not in my back-yard syndrome. Industry participants are perhaps drawn to the concept of less scrutiny because it's out of sight thus out of mind. The Shell EIS clearly details significantly less technical information and data regarding operations and unlike others makes little attempt at disguising poor disclosure.

Clearly the need for host nation infrastructure and land is also seen by proponents as a hurdle over which they don't wish to jump.

This speaks directly to the long-term trend for networked foreign and multinational private companies to take only what is necessary to produce, and avoid issues on which sovereign leverage can be sought to garner more corporate "largesse", such as local manufacture employment taxation and royalties.

A GHG related issue is that the Shell EIS makes no comment on actual emissions especially with respect to Nitrogen removal. The acid gas removal system does not seem to further combust the CO_2 mixture to remove the highly GHG effective methane contents such as normal with most onshore facilities. This is indicated by the emissions of the boiler feed which do not feature a nitrogen rich flue speciation.

It also does state that the acid gas system vents directly to atmosphere without further either incineration al la Darwin or catalytic reaction. For high CO_2 content gas fields such as these, this creates a major source of methane leakage from the system into the atmosphere.

Similarly, the process power is through steam turbines with and from gas boilers. These generally have a higher efficiency than an open cycle gas turbine, about 48% vs 40% in ideal circumstances. However combined cycle systems as being implemented both retrospectively and for new facilities across Australia, are now reaching efficiencies in the order or 60%. The drive for this may be reduced capital needs and smaller footprint, both desirable characteristic in the current economic climate.

In stage 2 with the introduction of gas from the Concerto field, there is more than enough nitrogen to fulfil demand within LNG, so there is excess to be considered and removed. The implications are that the plant will need to consider how to ameliorate the CH_4 removed with the Nitrogen. The plant may already have this capability, but this needs to be verified. A normal practise is to use the methane so derived as a constituent of the feed gas for the plant power requirements, both electrical and thermal. This analysis assumes its used for power (i.e. gives the benefit of the doubt to the proponent).

Ichthys

This plant is estimated at today's pricing to generate revenue of USD 2.4 billion per annum for its LNG alone (AUD 3.1 billion per annum).

Based onshore in Darwin in the Northern Territory,, this Inpex managed project one of the newest. It is due to ship its first cargo in 2018. It will be fed from the Browse Basin's Brewster gas field and then the Plover gas field later. The plant was designed to export 8.4 Mtpa of LNG, but will start this year at half this and quickly increase this capacity to the design capacity of 8.4 Mtpa, perhaps by 2019, and then to add feed from the high CO_2 content Plover field by around 2033.

The facility will use 8.0 Mtpa of feed natural gas to produce 4.2 Mtpa of LNG, no domestic gas, and about 1.1 Mtpa NGL's. In doing so it consumes 2.2 Mtpa of the feed feedstock, produces 2.45 Mtpa of emissions of which 1.4 Mtpa is embodied CO_2 gas.

Data shows that the Brewster field had an embodied CO_2 constituency of 9.5% v/v and for nitrogen, low at 0.6%, methane and ethane, 72% and 9% respectively. Data also shows that the Plover field had an very high embodied CO_2 constituency of 17% v/v and for nitrogen, a low 0.54%, methane and ethane, 75% and 4.22% respectively. This speciation of raw gas presents a lessor quality of feed gas with a need to remove significant quantities of the inert gases, as the CO_2 content is high, particularly the Plover feed stock.

The LPG's are high and a platform is installed at the offshore gas fields to remove condensates and ship to market direct. This splits the plant, as the liquefaction plant and final NGL removal is being undertaken onshore in Darwin, some 840 kms by pipeline. This is by far the longest pipeline known for a facility of this kind. This facility was subject to some tension from the Western Australian Government as they advocated a facility in Western Australia, only 200 km from the fields on the remote Maret Islands, just off the Kimberley coastline in Western Australia, but as the fields are in Federal waters, ultimately had little leverage.

The life of this plant has been nominated by proponents at 40 years.

This facility does not supply domestic gas.

The facility will provide excess LPG's and NGL's to various markets.

Darwin LNG

This plant is estimated at today's pricing to generate revenue of USD 1.8 billion per annum for its LNG alone (AUD 2.3 billion per annum).

Based onshore in Darwin in the Northern Territory,, this is an ConocoPhillips managed project and the second to be commissioned in Australia. It shipped its first cargo in 2006. It pipes the gas 500 km from its offshore fields to Darwin. It is fed from the Bonaparte Basin's Bayu gas fields and then from the Barossa gas field later. The plant was designed to export 3.7 Mtpa of LNG, but seems to achieve in the order of 3.1 Mtpa, perhaps by 2019, and then to add feed from the high CO_2 content Barossa field by around 2019.

The facility will use 4.5 Mtpa of feed natural gas to produce 3.1 Mtpa of LNG, no domestic gas, and no NGL's, which have been pre-extracted offshore. In doing so it consumes 1.4 Mtpa of the feed feedstock, produces 1.8 Mtpa of emissions of which 0.6 Mtpa is embodied CO_2 gas.

Data shows that the Bayu field without its NGL's which are removed on site had an embodied CO_2 constituency of 6.1% v/v and for nitrogen, 3.9%, methane and ethane, 80% and 8.3% respectively. Data also shows that the Barossa field had an very high embodied CO_2 constituency of 16% v/v and for nitrogen, a low 0.32%, methane and ethane, 79% and 2.67% respectively. This speciation of raw gas presents a lessor quality of feed gas with a need to remove significant quantities of the inert gases, as the CO_2 content is high, particularly the Barossa feed stock.

The LPG's are high and a platform is installed at the offshore gas fields to remove condensates and ship to market direct. This splits the plant, as the liquefaction plant and final NGL removal is being undertaken onshore in Darwin, some 450 kms by pipeline.

The life of this plant has been nominated by proponents at 27 years.

This facility does not supply domestic gas.

The facility will provide excess LPG's and NGL's to various markets.

Gladstone LNG

This plant is estimated at today's pricing to generate revenue of USD 4.1 billion per annum for its LNG alone (AUD 5.3 billion per annum).

Based onshore near Gladstone in Queensland, this is a Santos managed project. It shipped its first cargo in 2016. It pipes the gas 420 km from its coal seam gas fields. It is fed from the Surat and Bowen Basin's Fairview and Acadia Valley gas fields. The plant was designed to export 7.2 Mtpa of LNG from two process trains, but has environmental approval to add a third train expected around 2025 to increase capacity to10 Mtpa.

The facility will use 8.6 Mtpa of feed coal seam gas to produce 7.2 Mtpa of LNG, no domestic gas, and no NGL's. In doing so it consumes 1.4 Mtpa of the feed feedstock, produces 3.0 Mtpa of emissions of which 0.14 Mtpa is embodied CO_2 gas.

The coal seam gas is difficult to extract, requires multiple wells with renewal with either new wells or continued fracking. Power requirements are significantly more, perhaps to do with the well water disposal, which requires significant treatment.

Very scarce data shows that the Fairview field has an embodied CO_2 constituency of 0.62% v/v and for nitrogen, 3.14%, methane and ethane, 96% and 0.0004% respectively. Very scarce data also indicates that the Acadia Valley field also has a very low embodied CO_2 and is roughly the same as the Fairview site. The lack of LPG's and NGL's means that to make international LNG specifications, the plant imports LPG's to add to the process.

The life of this plant has been nominated by proponents at 25 years.

This facility does not supply domestic gas.

Australia Pacific LNG

This plant is estimated at today's pricing to generate revenue of USD 4.9 billion per annum for its LNG alone (AUD 6.4 billion per annum).

Based onshore near Gladstone in Queensland, this is a ConocoPhillips managed plant with Origin Energy managing the coal seam gas fields. It shipped its first cargo in 2016. It pipes the gas 450 km from its coal seam gas fields. It is fed from the Surat and Bowen Basin's Walloons gas fields. The plant was designed to export 8.6 Mtpa of LNG from a twin process train, but has environmental approval to add a fourth train expected around 2025 to increase capacity to 29 Mtpa.

The facility will use 10.0 Mtpa of feed coal seam gas to produce 8.6 Mtpa of LNG, no domestic gas, and no NGL's. In doing so it consumes 1.4 Mtpa of the feed feedstock, produces 2.5 Mtpa of emissions of which 0.15 Mtpa is embodied CO_2 gas.

Very scarce data shows that the Walloons 1 field has an embodied CO_2 constituency of 1.0% v/v and for nitrogen, 2.0%, methane and ethane, 97% and 0.09% respectively. Very scarce data also indicates that the Walloons 2 field also has a very low embodied CO_2 constituency of 0.24% v/v and for nitrogen, a high 5.0%, methane and ethane, 95% and 0.05% respectively. This speciation of raw gas presents a lessor quality of feed gas with a need to remove significant quantities of the inert gases, as the N_2 content is high. The lack of LPG's and NGL's means that to make international LNG specifications, the plant imports LPG's to add to the process.

The coal seam gas is difficult to extract, requires multiple wells with renewal with either new wells or continued fracking. Power requirements are significantly more, perhaps to do with the well water disposal, which requires significant treatment, and a lot more collection and transport pipeline needs.

The life of this plant has been nominated by proponents at 30 years.

This facility does not supply domestic gas nor NGL's.

Queensland Curtis LNG

This plant is estimated at today's pricing to generate revenue of USD 4.6 billion per annum for its LNG alone (AUD 5.9 billion per annum).

Based onshore near Gladstone in Queensland, this is a Shell managed plant supplied from Queensland's coal seam gas fields. It shipped its first cargo in 2015. It pipes the gas 0ver 450 kms through its collection pipe networks and then along is main transmission pipeline km from its coal seam gas fields. It is fed from the Surat and Bowen Basin's Walloon and Curtis gas fields. The plant was designed to export 8.6 Mtpa of LNG from a dual process train, but has environmental approval to add a third train expected around 2025 to increase capacity to 13.2 Mtpa.

The facility will use 9.6 Mtpa of feed coal seam gas to produce 8 Mtpa of LNG, no domestic gas, and no NGL's. In doing so it consumes 1.6 Mtpa of the feed feedstock, produces 3.8 Mtpa of emissions of which 0.05 Mtpa is embodied CO_2 gas.

Very scarce data shows that the Walloons and Curtis fields has an embodied CO_2 constituency of 0.2% v/v and for nitrogen, 2.3%, methane and ethane, 97.5% and 0.01% respectively. This speciation of raw gas presents a lessor quality of feed gas with a need to remove significant quantities of the inert gases, as the N_2 content is high. The lack of LPG's and NGL's means that to make international LNG specifications, the plant imports LPG's to add to the process.

The coal seam gas is difficult to extract, requires multiple wells with renewal with either new wells or continued fracking. Power requirements are significantly more, perhaps to do with the well water disposal, which requires significant treatment, and a lot more collection and transport pipeline needs.

The life of this plant has been nominated by proponents at 20 years.

This facility does not supply domestic gas nor NGL's.

Future Possibilities

Most of the aforementioned projects have plans to increase production when market conditions are right.

The Woodside in its submission to the Senate Enquiry into Aggressive Tax Strategies in the oil and gas sector, notes that demand is likely to outstrip supply in about 2022. This means that all companies will be working on their expansion strategies now, as the lead time for most projects in this industry are at minimum 6 years. Further, as noted earlier, the demand by China for coal replacement energy is coming to fruition at last, so demand may exceed supply even earlier. Oil and gas prices are now a long way from the recent bottom.

Only the NWSV and Prelude projects haven't forecast expansions.

In WA and outside the Browse project which is discussed separately below, highlighted capacity expansion at existing sites may derive a further USD 16.6 billion per annum revenue to USD 44.6 billion per annum, an uplift of 60% from the existing USD 28 billion per annum.

In Queensland, highlighted capacity expansion at existing sites may also derive a further USD 16.6 billion per annum revenue to USD 28 billion per annum, an uplift of 147% from the existing USD 11.2 billion per annum.

In the Northern Territory, highlighted capacity expansion at existing sites may also derive a further USD 7.2 billion per annum revenue to USD 11.4 billion per annum, an uplift of 174% from the existing USD 4.2 billion per annum.

Browse

The Browse project has been the subject of three proposals for its development, two of which have had EIS processes implemented and approvals sought.

Its real design capacity, derived from inspection of two of three EIS proposal investigated is in the order of peak plant at 8.4 Mtpa. The concept of a mega LNG precinct seems in retrospect a "fishing" exercise.

The plant at this capacity is estimated at today's pricing to generate revenue of USD 4.7 billion per annum for its LNG alone (AUD 6.1 billion per annum).

The gas reserves are offshore from Western Australia, the FLNG Woodside project managed project is one of the most secretive of all, whilst the Broome option was relatively open. A reading of the proponents EIS to Federal requirements requesting environmental approval indicate its comparative lack of detail, especially around GHG's. It appears on track to ship its first cargo around 2025, in whatever guise the project proponents settle on. The plant is fed from the Browse Basin's Brecknock and its Calliance gas fields. The FLNG three plant strategy revealed the initial concept to draw from the relatively low CO_2 yield Brecknock field and draw about one third of requirements from the high CO_2 content Calliance field, and then to move later to majority production from the Calliance as the Brecknock field naturally reduced yield.

The facility will use 13 Mtpa of feed natural gas to produce 8.4 Mtpa of LNG, unknown quantities of domestic gas (and modelled at zero DomGas), and about 0.87 Mtpa of NGL's. In doing so it consumes 4.8 Mtpa of the feed feedstock, produces 2.0 Mtpa of emissions of which 2.2 Mtpa is embodied CO2 gas.

The original was for an Onshore facility at James Price point north of Broome. The area was termed an LNG "precinct" with a proposed initial capacity of 8 Mtpa, but with environmental approval from the Western Australian Government to expand to a massive 50 Mtpa.

Negotiations for this were relatively complex and at times ferocious in the State's attempts to have the facility built in WA, with the potential to also go to Darwin instead. The State Government had little leverage, the Browse gas fields were entirely outside state waters.

The Minister for the Environment at the Time Minister Marmion waived all of his department advise regarding GHG's, as he did with the Wheatstone Project (Mercer, 2013). Perhaps fortunately, the project didn't get up.

Later, the nomination of a islet off the coast of WA as an official island and not a reef significantly changed the State Federal boundaries in the area and a proportion of the fields are in State controlled waters.

Ultimately Woodside and partners ditched the megaproject format and opted for a three platform, two field, project using FLNG technology identical to that used by Shell with its Prelude project. As commercial conditions for LNG came off peak, even this concept was scrapped.

More recently, Woodside and its partners have announced that the gas is likely to be used in the NWSV facilities at Karratha in the Pilbara, to continue feed to this plant, as the NWSV current cleaner and closer fields' yield decline.

The company's plans come on the tail of Chevron's major expansion in the state, making the Pilbara one of the largest economic and most polluting engines of the nation.

Woodside's recent report (McConnell & Grant, 2019a) shows that LNG produced from the Browse Basin, and intended to extend the life of the Burrup NWS Joint Venture plant, will have a local emissions intensity of around 26kg CO2 per Gigajoule. This is, as indicated in their own report, nearly twice the average for Australian LNG exports, making it one of the most polluting facilities in the country, and two and a half times that of the gas it replaces. Consultancy Wood Mackenzie have drawn similar conclusions, stating that "The high CO2 in the reservoir is exacerbated by the NWS infrastructure, among the world's oldest and least-efficient LNG projects.". Further it is over 30% more polluting than China's projected expected gas mix by the IEA (International Energy Agency, 2019c).

It is hard to grasp the size of the issue that the world and Australia faces from the next phase of development in the North West Shelf. Woodside's report estimates total emissions from these projects are 90 Mtpa –several times the global pollution from the proposed Adani coal mine.

The impact of a polluting project increases in significance as time goes on, even if annual emissions are held constant. This is because the same annual emissions amount will consume a greater and greater fraction of the diminishing available global carbon budget every year. The IPCC (IPCC, 2018a) and IEA (International Energy Agency, 2019c) 1.5º Sustainable Development Goals based carbon budget shows that between 2025 and 2040 (the period of Browse major production) global natural gas production must drop by around 16% and reduce in emissions intensity; Woodside's own data shows they expect to produce more and with an increased intensity. As noted consuming nations are unlikely to allow this.

The report relies on scenarios for global energy demand published by the International Energy Agency (IEA) that are not compliant with the Paris Agreement, suggesting gas will displace coal without competing with cleaner renewable energy. Our analysis has shown that there is no statistical support for gas generally replacing coal. Gas is competing with solar and may be supportive of wind power which are now the cheapest sources of power.

In fact, the Intergovernmental Panel on Climate Change (IPCC) says that the world needs to reduce both coal and gas to reach a 1.5C temperature goal established in the Paris Agreement. Woodside will be producing 1,400 Mt of CO2e over the contemplated 15 years which the world cannot afford.

Most importantly, our calculations indicate that the life of the NWSV will be extended by around 15 to 17 years only by inclusion of the more polluting Browse sourced natural gas.

Diminishing, perhaps vanishing, Rates of Return

Whilst this industry plays a significant role now, several factors will inevitably cause this influence to decline:

- In the long and even the medium to short run, its contribution to GHG's is unsustainable;
- By its nature, there is a trade-off between resource quantities, cost of extraction and quality, so there is diminishing social environmental and economic return as the quality of feedstock declines. In the Australian context this is clearly happening now;
- Tension between Australia's long run economic self-interest in being self-sufficient in energy, not only for commercial and domestic needs, but for primary industry growth and sustainability, against export of raw energy for others to sustain and grow their primary industry;

Similarly, the economic and opportunity costs of extraction of coal seam gas used to feed the Queensland facilities has been a point of contention

Key Issues Identified

The industry is a large economic engine based on the wealth of Australia's natural gas and coal seam gas resources. In producing USD 43 billion per annum, it consumes 121 million tonnes per annum of methane-based gas to produce about 76 Mtpa of LNG, nearly 9 Mtpa of natural gas liquids and in Western Australia has the capacity to contribute in the order of 10 Mtpa. This gross annual gas consumption is enough to feed domestic consumption three times over.

In general, the social license for the LNG industry is already under scrutiny over poor corporate citizenship, primarily led by some aggressive taxation planning, and the perceived underperformance in social return (in the broader sense) by most proponents.

The industry the Federal Government and the Western Australian Government have an opportunity to strategically reassess the industries overall impact on the Australian people in a much wider sense that is the discourse now over aggressive tax behaviours, before a new wave of expansionary plans are set to exploit the remnants of the Australian gas fields.

The industry is dominated by foreign domiciled multinational companies, which elsewhere and in other Australian industries have been shown to be to the relative strategic detriment of the Australian people.

Self-reporting and lack of transparency have let down the Australian people, and not enabled good decision making around industry positive and negative attributes.

Key and normalised data is hard to find to inform decisions. This report attempts to help bridge this data void.

The political process has failed to identify adverse secondary economic effects of the industries rampant growth.

Already gas quality issues in particular higher embodied contents of inerts particularly CO_2 and N_2 contents are impacting on the design and efficiency of production facilities as well as environmental performance, which point to less return for proponents and higher prices for consumers.

The industry strategy is changing as they look to exploit smaller fields, indicating that new long-term supply will be more expensive and in more difficult locations and with poorer quality, or indeed not in Australia. The FLNG technology is a direct response to this trend to add flexibility for the industry.

The FLNG system represents some risks around newer technology, less complexity leading to greater inefficiencies, along with more difficulty in auditing performance.

Many of the newer fields are now further off the coastline of Australia. The impacts are multiple. The first is that much of the identified reserves sit in between Timor-Leste and Australia adding a level of sovereign complexity.

Queensland's coal seam gas conversion to LNG produces significantly more waste product than any other source methane conversion for the Australian industry. This is attributable to the energy costs of extraction and treatment of the coal seam gas and its by-products, and related massive collection and transmission systems, which overwhelms the advantage of low quantums of CO_2 embodied in the gas. The three Queensland facilities produce emissions which equate to 38% by weight of the raw resource consumed and 47% by weight of the LNG produced. This disadvantage is magnified in comparison to the Western Australian figures of 21% by weight of raw resource, and 27% by weight of all gaseous product produced.

The Northern territories figures are beyond even Queensland's, at 34% by weight of raw resource and 51% by weight of all gaseous product combined. Two factors combine: the first is the transport distances requiring compression power and secondly the significantly higher embodied CO_2 loading.

Further the Commonwealth will become a more important decision maker and administrator than the States as time goes by. At least its environmental approval process lags the states', and the states' process already lacks diligence around key social and environmental issues.

Whilst the industry is currently in a market driven hiatus, planning is likely to be underway in foreign boardrooms for industry expansion, currently targeted for the period around 2025 either in Australia or elsewhere, due to the typical long lead times.

This smaller field and plant trend may open the industry to a variety of newer players.

Transparency of any data regarding the Australian people's natural gas resources especially around feed quality is difficult to extract, but is important for informed decision making around the wholistic sustainability of the facilities;

A narrative is rarely heard around the benefits to shareholders whenever there is any discussion around change in conditions for the industry.

In general the economic advantage of hosting the LNG industry is under significant review. Social license is also under review. The aggressive actions of some of the industry participants in their profit seeking (cost externalisation) behaviour and similar and morally questionable attempts to rent seek at the expense of the Australian people.

The Governments' responsible are acting belatedly to address some if not all of these behaviours. Whilst there is time to undertake political discussion before the looming, possibly intense, round of inter country rivalry to sponsor the foreign multinational expansion of facilities to deliver Australian or other gas to the export market, we as a nation should have a discussion of the impacts and how to mitigate them.

Greenhouse Emissions

The LNG industry is a significant contributor to Australia's GHG emissions. When the current projects are fully commissioned (planned by 2019) our estimates indicate they will contribute 53.2 Mtpa[2] of CO_2e. This equates to 9.7% of Australia's 2016 reported inventory.

Most importantly, these emissions are virtually uncontrolled by Federal legislation as discussed later. The LNG industry is a Federally protected industry and the safeguards are being tilted further towards industry development, directly at the expense of the global commons.

Further should the industry undertake expansion in both greenfield and brownfield developments as contemplated in the various EIS's, the burden will nearly double to 105 Mtpa, representing an unregulated 19.2% of Australia's 2016 emissions.

The following Figure 4: Geographical Distribution and Representation of Individual project's current and potential future contributions to GHG Emissions, indicates the industries regional and relative contributions by project.

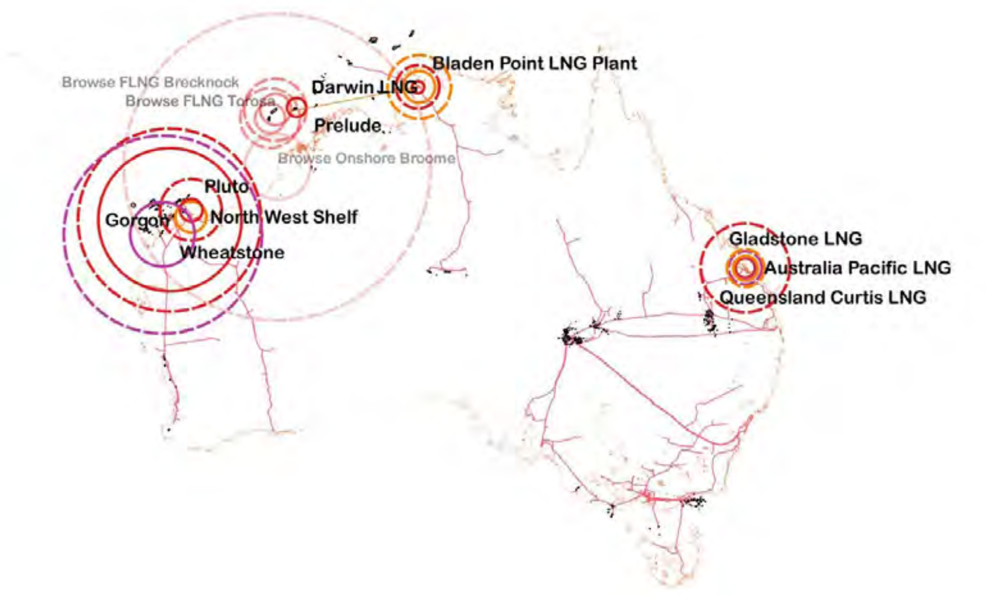


Figure 4: Geographical Distribution and Representation of Individual project's current and potential future contributions to GHG Emissions

Each current and known future project is represented and named. Each one is represented by two concentric circles, the inner and solid circle represents current or immediate future emissions, whilst the broken and outer circle shows indicated

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[2] Including a 3% overhead on our own figures to account for N_2O emissions

potential. Due to uncertainty of the development of the Browse project, its three options' emissions are represented by semitransparent circles.

Clearly the bulk of the emissions are centred in the North Western parts of Australia. Management responsibility falls to the Federal Government, and the Western Australian State and Northern Territory governments.

Globally these Emissions are Significant

Our internal research is beginning to indicate that historically natural gas was an "agnostic facilitative fuel". "Agnostic" is chosen to indicate that the use of gas is indifferent to the "other" fuel it facilitates. Growth in both coal and renewables (primarily wind) has historically been stabilized by natural gas facilitation. Countries with rapid increase in coal appear to have a rapid increase in gas. Historically, the same may be said for wind. Our ongoing research includes early indications that natural gas is however competing against the more recent introduction of scaled solar energy

For example, the previously discussed example of Wheatstone indicates an approximate production cycle emission of about 9.3 Mtpa CO_2e to produce around 25 Mtpa of LNG.

However, the fuel life cycle GHG emissions doesn't end at the facility gates: only the producer State's responsibilities for them. The fuel is transported distributed and consumed by other nation states. Doing so releases the overwhelming bulk of fugitive emissions, and CO_2 from the results of combustion.

The following Figure 5: Gas Lifecycle CO2e emissions for the Wheatstone Project, including original concept of sequestration, highlights the true accounting for gas life cycle GHG emissions for the maximum sized 25 Mtpa Wheatstone facility. Over the fuel life cycle emissions are indicatively about 78 Mtpa with sequestration and just over 80 Mtpa without.

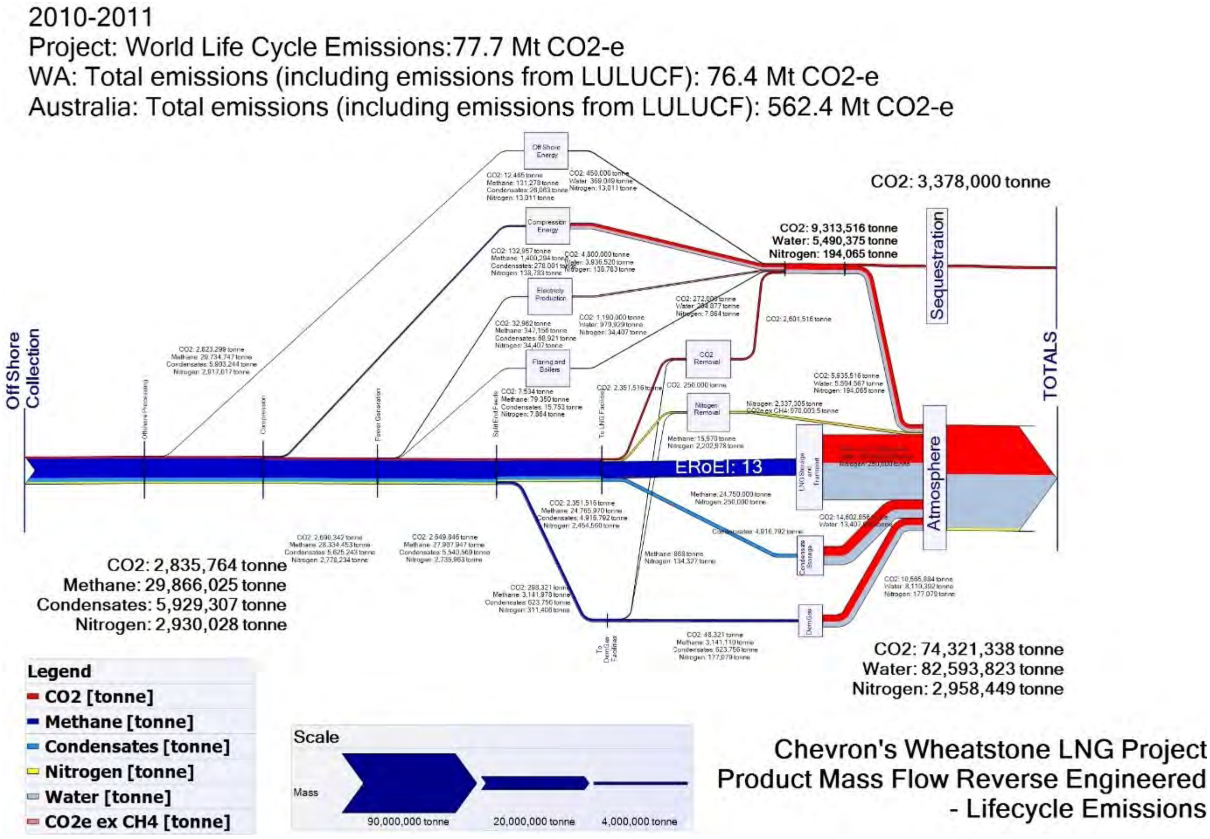


Figure 5: Gas Lifecycle CO2e emissions for the Wheatstone Project, including original concept of sequestration

A series of research papers continue to track the amount of carbon humanity can release to the atmosphere from all sources and from now on, until a 2° global warming is inevitable. This has been termed the “carbon budget”. At current rates of emissions some estimates indicate the world has only 17 years left before this is inevitable. Further research is indicating that this target will not induce a globally sustainable environment, so more traction is appearing around a 1.5° target. This target gives humanity 4 years at current emission rates. An alternative metric around the same concept is the amount of CO2e emissions humanity can emit before the target temperature rise is inevitable. At the time of writing the 2° rise is predicated by 747,213 million tonnes net budget.

Current Australian LNG operations are projected to contribute 11 billion tonnes of CO2e to the global commons, and with further expansions, a total potential of 23 billion tonnes. The latter figure assumes gas qualities remain the same as todays, but this is highly unlikely, as deterioration is already evident. We conclude that the latter figure is likely to be a lower bound.

Australia’s operating LNG projects’ contribution to the global carbon budget is in the order 1.5%, and when the recognised greenfield additions and brownfield expansions are included this expands 3.1% of the global budget. Using the 20-year global warming impact of methane rather than the 100-year impact normally assumed, Australian production will add about 18% more to this figure, to 3.4% of the global budget.

These figures indicate that natural gas and particularly Australian LNG consumes a relatively large proportion of the remnant climate buffer before the agreed GHG emissions levels are exceeded. These levels of emissions will also probably cause Australia to abrogate its responsibilities under a variety of international treaties, including the Paris Agreement targets. Morally and ethically, Australian's need to act.

Australia Overall

Australia's inventory total (excluding LULUCF) for 2019 was reported at 538 Mtpa, still above its 2004 emissions, continuing a recent trend of increases (*National Inventory Report 2015*, 2017; *Quarterly Update of Australia's National Greenhouse Gas Inventory: September 2017 Incorporating NEM electricity emissions up to December 2017*, 2018). The 2015 report identifies a recalculation of fugitive methane emissions and explains in some detail the industry emissions. The 2016 year did not include any of the new LNG plant since commissioned other than perhaps part emissions for the Queensland Curtis plant. It did include the older Pluto Darwin LNG and the NWSV projects. The former report includes some emissions from the Gladstone Australia Pacific and Gorgon facilities, though none at full capacity. The 2017 emissions will start to reflect these inclusions.

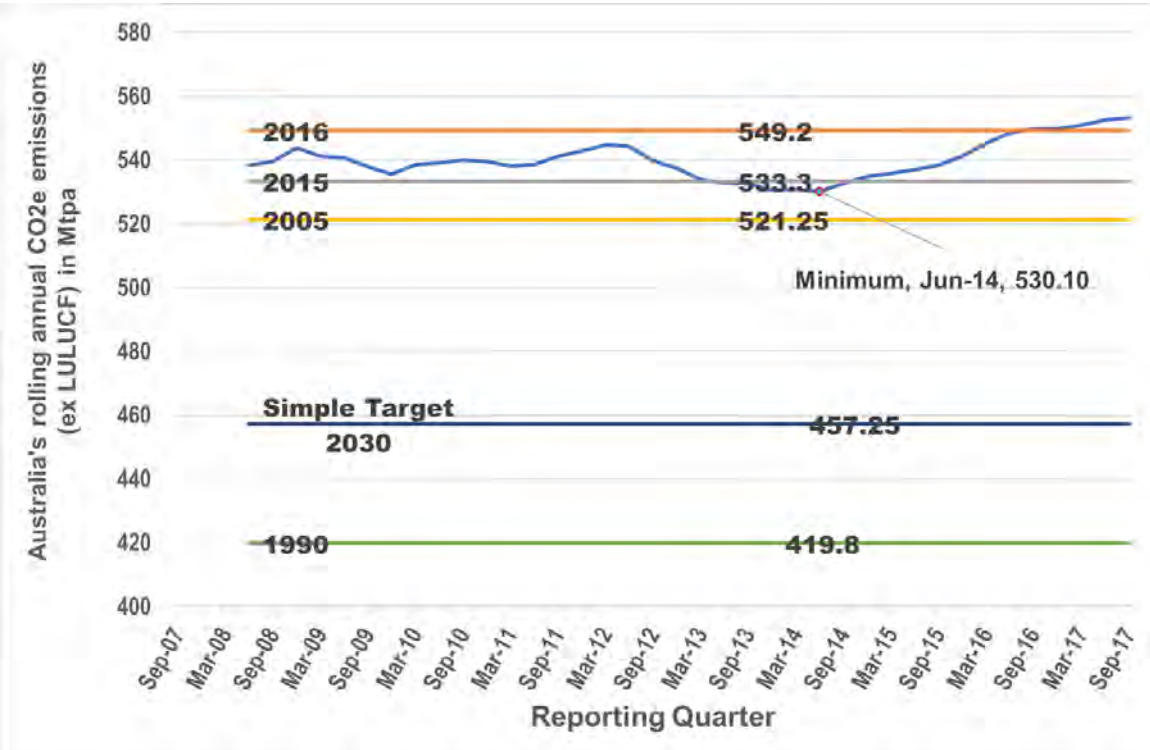


Figure 6: Australia's rolling Annual GHG emissions calculated from the Quarterly Report with last two-year official inventories and the 2004 equivalent

Figure 6: Australia's rolling Annual GHG emissions calculated from the Quarterly Report with last two-year official inventories and the 2004 equivalent, above,

indicates the upward trend for Australia’s inventory since its best point in the June quarter of 2014. Since the first of the new facilities was commissioned in 2015, our estimate of contributions from the LNG industry assuming all facilities are at full production, is for an additional 40 Mtpa, by the end of 2018. The graph clearly indicates this trend upwards. The reports also acknowledge the impact this industry is having. This will be further exacerbated by the addition of up to 3.8 Mtpa due to the failure of the Gorgon project’s geo-sequestration facility until that failure is rectified.

As the international agreements require Australia’s overall economy must reduce emissions to 26-28% below 2005 figures being 605 Mtpa including LULUCF (*Australia's 2030 climate change target*, 2015). The target is 441 Mtpa (inc. LULUCF). From the 2005 LULUCF figure of +82.3 Mtpa, this has reduced to an average of -18.4 fairly consistently over the last 6 years, indicating a change in LULUCF of about -100 Mtpa per year.

A simplistic calculation indicates a reduction of about 64 Mtpa for emissions without LULUCF is required, from the 2005 emissions of 521.25 Mtpa to 457.25 Mtpa.

With the aforementioned indicative additions from the LNG industry, the industry represents either a major opportunity to change or a major weakness in Australia’s moral and legal requirements to reduce emissions according to the Paris agreement.

The good work in other sectors is being swamped by the emissions from the LNG industry. Australia’s international commitments are therefore at high risk.

Our analysis includes all facilities currently in operation or nearing operation in Australia. Whilst these projects are loosely grouped into regional state subdivisions, where operation of all or part of the supply chain operate outside State waters, responsibility for management is either shared with or entirely in the Federal Government’s care. This is the case in many of the Western Australian and Northern Territory facilities.

Western Australia

Early April 2018, the Hon Josh Frydenberg MP Australian Government’s then Minister for the Environment and Energy released the latest accounting for Australia’s GHG inventories. (*State and Territory Greenhouse Gas Inventories 2016*, 2018).

Most notably Western Australia’s emissions have increased as graphed in the following Figure 7: Western Australia's Recent Annual GHG emissions.

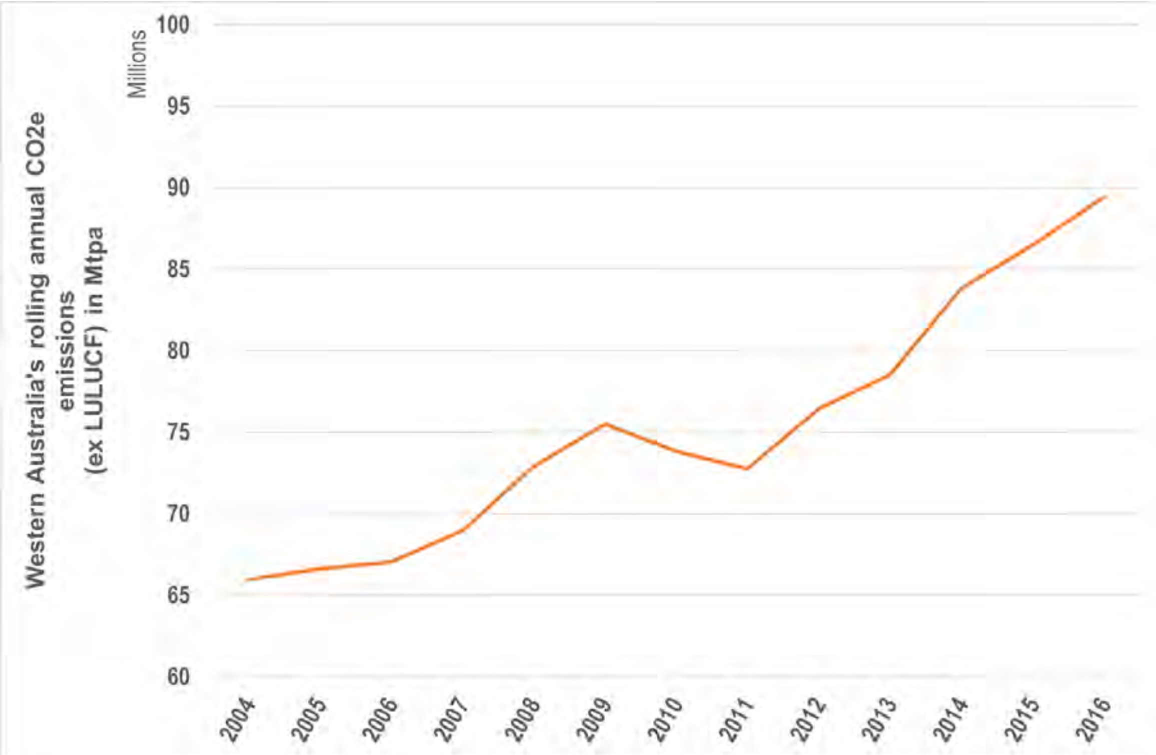


Figure 7: Western Australia's Recent Annual GHG emissions

Notably WA's GHG emissions are on a continual increase. The change from 2015 to 2016 at represents an increase of 3.44% being the 5th highest over the reported years. The years 2017-2019 represent the period over which the Gorgon project starts its latest LNG line, and Wheatstone was commissioned. These two projects add an additional 10 Mtpa to this key indicator.

Western Australia is the fourth highest contributor, moving from 11.29% of Australian emissions in 2005 to 15.7% in 2016. More importantly it is the only state to increase its emissions between 2005 and 2016 by 20.5%. Others with increases are smaller reporting entities were the Northern Territory (representing 3.2% of overall emissions with a 27.9% increase) the ACT (0.32%, 21.4%) and Other External Territories (0.01%, 228.6%).

Further research is necessary to confirm that "Other External Territories" figures include those for the FLNG facilities operating in Federal waters, Prelude at this stage, though there are a handful of NGL and oil extraction operators also in Federal waters, and trending towards more in the future.

Project Emissions

Project emissions of GHG have a number of critical dimensions. In our data collection and analysis, we have focused on the following:

In many analyses, the relevant green house measure is an efficiency term for example grams of CO2e per kW.hr of electricity produced, that is from the "use" point of view. However in this analysis we are concerned about gross emissions from an original thermal energy source and thus report emissions as a ratio of either original energy embodied in the natural gas or the same embodied in the LNG.

Life Cycle Accounting for emissions from an individual project has a few other dimensions to consider. There are two life cycles to consider.

The first is the lifecycle of the natural gas as it journeys from its natural reservoir underground to its final destination and use, generally for combustion for to produce electricity or thermal heat. Generally, these are termed supply chain emissions, and within the industry are generally broken into “upstream” and “downstream” emissions. These definitions are dependent on where the focus is within each analysis, in this case revolving around the actual process of LNG manufacture. Thus, upstream emissions are those occurring in the process of extraction and transport to the LNG plant, and downstream are those involved in the transport and use of the product. Shipping is the mode of transport for LNG from Australian facilities. The gas is generally then re-gasified at port of destination and transported by pipeline to final use.

The second is the life cycle of the facility. Two aspects to consider is the life cycle of the actual plant, and the second is the lifecycle of the gas reservoir from which the plant will receive its gas.

In general, we have selected the proponents stated life as the benchmark for plant lifecycle. An example is where the NWS venture is nearing its current end of life as it will run out of natural gas reserves from its stated reservoirs. However, Woodside have announced a prospective project to bring Browse basin gas to the facility. Similarly, the Darwin LNG plant is now dependent on finding new gas feeds.

The FLNG facilities however have a nominated life cycle entirely related to the gas field capacities. The life cycle in this case is nominated at the field life cycle not the FLNG facility life.

Global GHG Inventory Impact

The global total GHG emissions added to the carbon budget for the Australian LNG facilities has been estimated by combining these two life cycles. Attachment abvd summarises the per project and totals for the current production facilities lifecycle.

The Australian facilities in their current configuration will produce natural gas which will contribute 10.8 billion tonnes CO_2e globally. Should the facilities be expanded under current maximum expectations, this figure grows to 22.5 billion tonnes. By considering the 20-year rather than to 100 year methane impact, these emission will have the same impact as 26.7 billion tonnes CO_2e.

The following chart entitled “Figure 8: Comparisons of Australian project global emissions over the lifecycle of each project, indicating current and maximum scale as well as 20-year methane impacts at maximum scale" indicates each project's outcome for the global GHG budget.

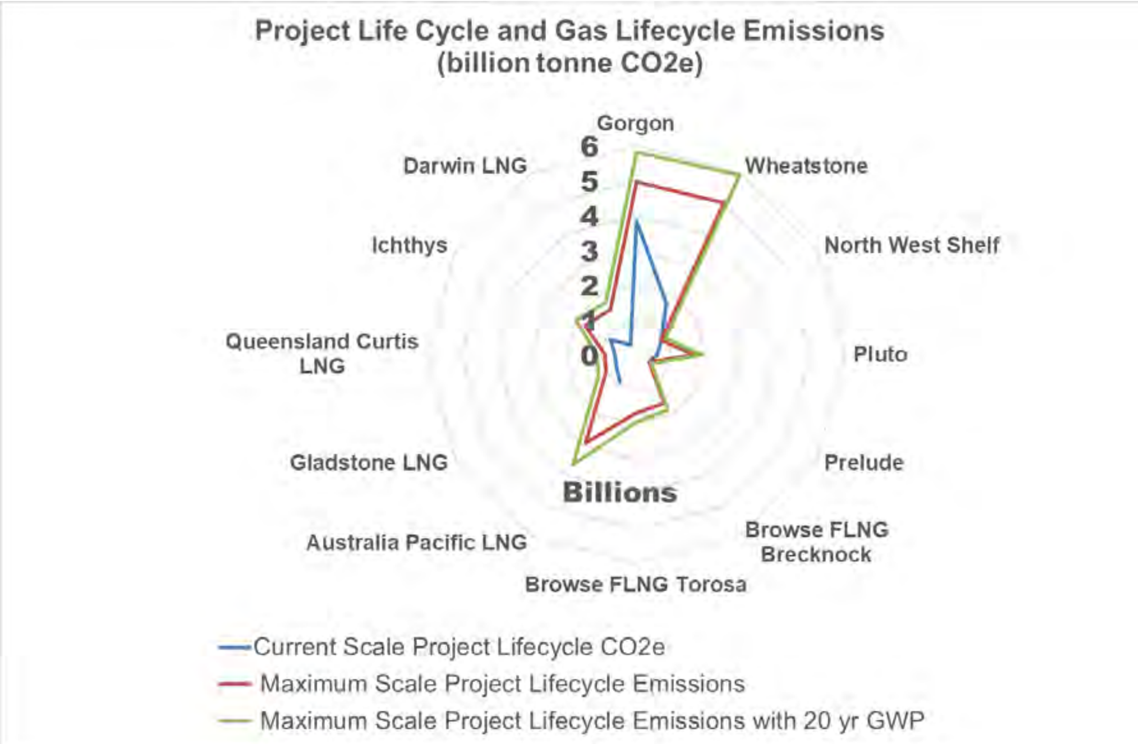


Figure 8: Comparisons of Australian project global emissions over the lifecycle of each project, indicating current and maximum scale as well as 20-year methane impacts at maximum scale

Both the NWSV and Darwin LNG facilities may soon be constrained by access to gas. This is particularly noticeable in the graphs where the NWSV figures indicate it will have minimal impact. This is entirely due to field exhaustion. Should they find further gas or utilise the Browse fields as signalled, the impact will change.

Both included Browse FLNG projects are not currently operating, nor are they expected to do so, hence the lack of data representation on the graphs for current operations. They are included as possible expansions. Woodside has signified the field development may be linked to its NWSV facilities. Either through FLNG technology of the NWSV facilities these fields seem to be the catalyst for the next major expansion or facility life extension, hence their inclusion.

There are some clear omissions from the report estimates, including construction emissions and indirect operational activities such as logistics maintenance and personal management.

Similarly, emissions from N_20 have not been included due to uncertainty in estimations and lack of data in the research community. The latter is the most impactful as it may represent more than the standard benchmark of 3% of total emissions. Note only a few EIS's acknowledge this pollutant in their GHG calculations.

Our benchmark against which all issues are measured is termed the “author estimate” of current emissions. Author Estimate is a benchmark selected which includes all upstream emissions, a reasonable fugitive emissions estimate and modelling to identify process mass flows determined from data generally provided in each proponents Environmental Impact Statement.

The following figure entitled “Figure 9: Scenario Comparison of annual Gas Lifecycle GHG emissions for one proposal regarding a FLNG facility on the Brecknock Field off WA” graphically highlights the impact of various scenarios modelled as part of this work.

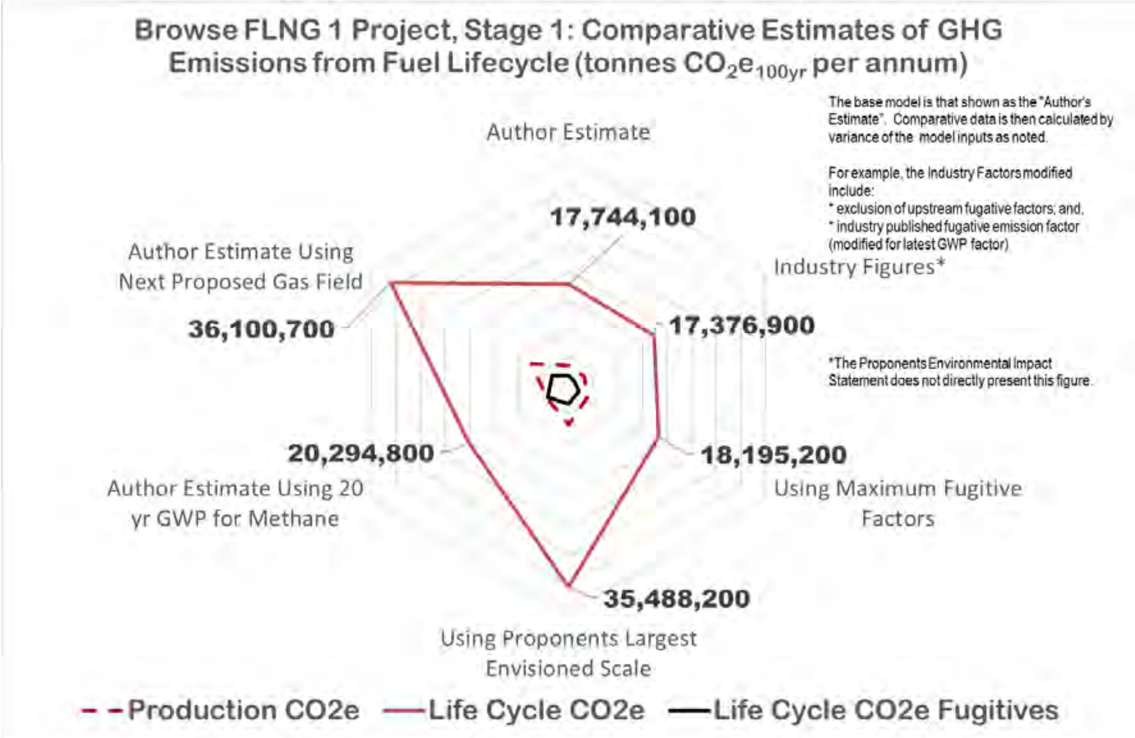


Figure 9: Scenario Comparison of annual Gas Lifecycle GHG emissions for one proposal regarding a FLNG facility on the Brecknock Field off WA coast

The next scenario standardised and modelled is the worst-case, derived from industry submissions which includes clear omissions. Such omissions include:

- Fugitive reporting, which has been a point of conflict between the industry and researchers, with some researchers identifying a maximum potential including not only production emissions, but emissions along the whole supply chain, approaching 6% of the gas resource. On the other hand, the industry claims in many cases the upstream and production facilities emit less than 0.1%. Our modelling is includes a multilevel approach to identifying reasonable and conservative estimates, which include component factors for production, piped transmission, and LNG facility emissions. A simple factor for fugitive emissions for the downstream supply chain is included to estimate gas lifecycle emissions on top of production emissions;

- Often the upstream emissions are excluded or made somewhat obscure in reading the EIS, so we model all plant for worst case no upstream emissions; and
- The models all use either a methane GWP of 21 or 25, when the current best scientific estimate is 36. Industry figures have been adjusted to reflect the best estimate, because this is partially a Federal Government responsibility to ensure best practise;

The overall difference in global emissions between the author estimates and the industry estimates is calculated to be around 2.1%. This 2.1% under estimation by industry is all due to production estimate variance, as no downstream fugitive emission rate differences were modelled. On a global scale this would appear to be minor, however later the much larger impact on Australian inventories is demonstrated.

The third scenario models the impact of a significantly large fugitive emission rate during production which whilst not in the order of 6% previously stated is at the upper range of a variety of research papers conclusions for the industry. The impact is clear, adding 4.5% to the industry estimates.

The fourth scenario models the facility at the largest size anticipated in each EIS. In the case above, Browse proponents expected to double the production with an additional FLNG facility at the gas field, and the subsequent doubling of emissions is clear.

The fifth scenario modelled is the impact of the short-term fugitive methane emissions, with a 20-year horizon rather than the standard 100 year one. The uplift in global equivalent emissions is also clear. The missions uplift by 16.8% for the Browse FLNG facility.

The final scenario modelled is not applicable to all proposals, but in this case models the introduction of the Torosa gas field, in GHG terms a higher embodied CO_2 field. An effective 1.7% increase in gas lifecycle emissions is noticeable. Like methane fugitive emissions, this is not a huge uplift globally but when examined later for the Australian inventory, the impact is relatively larger.

Australian GHG Inventory Impact

Within these lifecycles, Australian inventory rules concentrate solely on the emissions caused by the activities of the industry in Australia. Herein these are termed “production emissions”.

The Australian LNG facilities in their current configuration will contribute 1.6 billion tonnes CO_2e to the Australian Inventory during their nominated lives. Should the facilities be expanded under current maximum expectations, this figure grows to 3.45 billion tonnes. By considering the 20-year, rather than to 100-year methane impact, these emissions will have the same impact as 5.2 billion tonnes of CO_2e.

The following chart entitled “Figure 10: Comparisons of Australian production emissions over the lifecycle of each project, indicating for current and maximum scale, as well as for 20-year methane impacts at maximum scale ” indicates totals for each project’s life cycle of production emissions attributable to Australia’s future GHG Inventory.

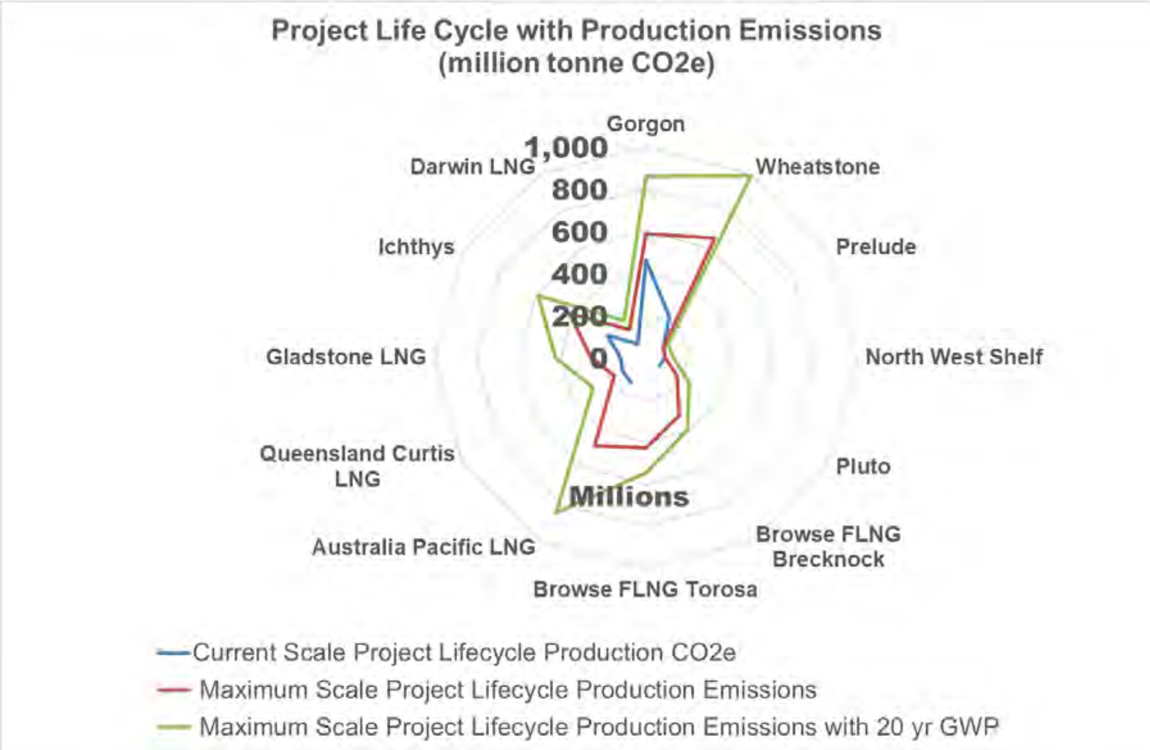


Figure 10: Comparisons of Australian production emissions over the lifecycle of each project, indicating for current and maximum scale, as well as for 20-year methane impacts at maximum scale

The Gorgon project at current scale is clearly the largest producer of production life cycle GHG’s at 0.46 billion tonnes primarily due to its proposed longevity, followed closely by the Wheatstone project at 0.22 billion, for the same reason. The equivalent emissions for envisaged maximum scale expansion show that Wheatstone is set to become the countries largest emitter at 0.65 billion tonnes, then Gorgon at 0.486 billion. If considering the impact of short term 20 year methane impacts Wheatstone will contribute nearly 1 billion tonnes gross, whilst Gorgon and Australia Pacific LNG emit about the same at about 0.620 billion tonnes. The impact of fugitives from the harder to manage coal seam gas field is evident by the relatively larger increase due to 20 year methane horizons.

Full statistics for this data may be viewed in Attachment ;akfj.

Again our benchmark against which all issues are measured is termed the “author estimate” of current emissions. Author Estimate is a benchmark selected which includes all upstream emissions, a reasonable fugitive emissions estimate and modelling to identify process mass flows determined from data generally provided in each proponents Environmental Impact Statement.

The following figure entitled “Figure 11: Scenario Comparison of annual Gas Production GHG emissions for one proposal regarding a FLNG facility on the Brecknock Field off WA coast

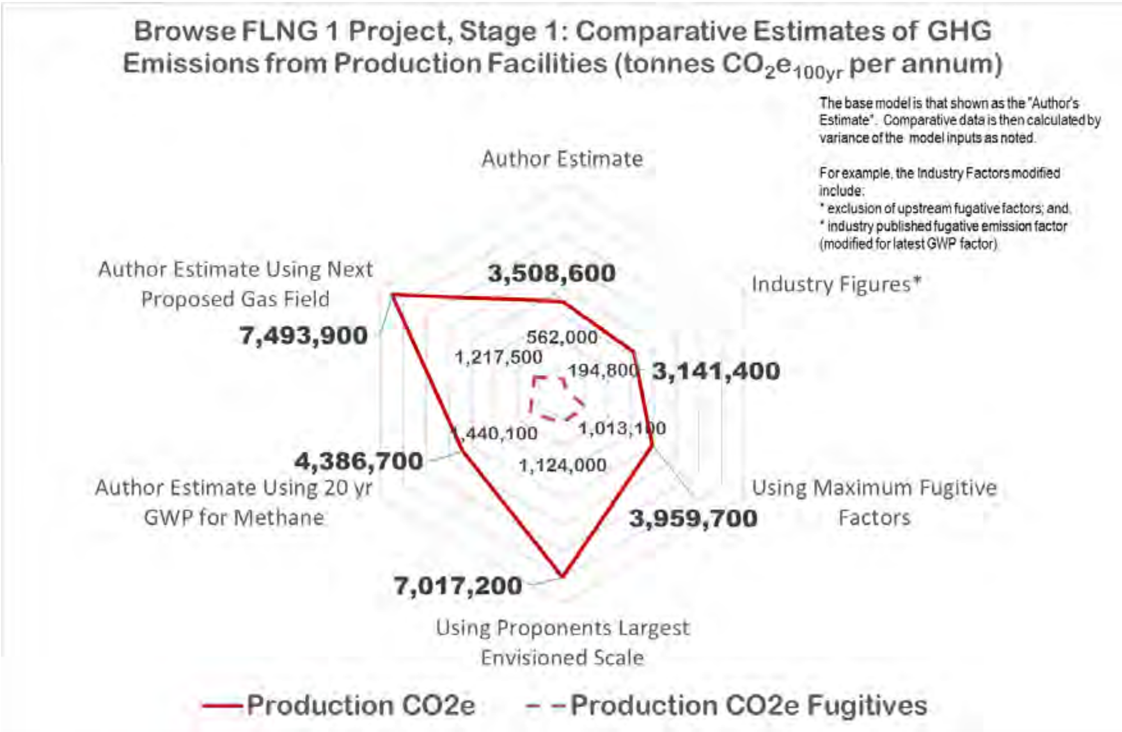


Figure 11: Scenario Comparison of annual Gas Production GHG emissions for one proposal regarding a FLNG facility on the Brecknock Field off WA coast

As for the Project and Gas Life cycle results, the next scenario for the Project and production emissions which was standardised and modelled, is the worst-case reporting from the industry which accounts for the three proponent omissions previously discussed: fugitive reporting. At the production level our modelling is based on a multilevel approach which includes component factors for production, piped transmission, and LNG facility emissions. No factor for fugitive emissions for the downstream supply chain was used; we model all plant for worst case no upstream emissions; and industry figures have been adjusted to reflect the best GWP methane estimate.

Contrary to the difference of 2.1% for global emissions the overall difference in Australian based production emission estimates between the author estimates and the industry estimates is calculated to be up to 9%. This is a significant divergence. It may have been addressed with a change in inventory reporting methodology for LNG industry fugitive emissions in 2015.

The lack of primary Australian or global independent research into the actual LNG industry fugitive emissions is a significant gap in our understanding. In some spaces, such as coal seam methane fugitive emissions, studies presented to date have some fundamental procedural flaws. Similarly, newer techniques of monitoring fugitive emissions are not being deployed to validate voluntary reporting by industry.

The third scenario models the impact of a significantly large fugitive emission rate during production. The impact is clear, adding 26% above the industry estimates, also reflecting the need for tightened monitoring and better baseline data from which to work.

Also as noted previously, the fourth scenario models the facility at the largest size anticipated in each EIS. In the case above, Browse proponents expected to double the production with an additional FLNG facility at the gas field, and the subsequent doubling of emissions is clear.

The fifth scenario modelled is the impact of the short-term fugitive methane emissions, with a 20-year horizon rather than the standard 100 year one. The uplift in global equivalent emissions is also clear. The missions uplift is 25% for the Browse FLNG facility.

The final scenario modelled is not applicable to all proposals, but in this case models the introduction of the Torosa gas field, in GHG terms a higher embodied CO_2 field. An effective 6.8% increase in gas production emissions is noticeable. Like methane fugitive emissions, this is a significant uplift for the Australian inventory.

This last modelling clearly identifies the impact of resource quality on Australia's emissions in significant direct emissions as well as indirect ones due to the energy requirements to remove this waste steam from the ultimate product.

This may bring into question how quickly the existing reserves of Australian natural gas will become untenable due to both the production economics and the escalating emissions intensities.

Conclusions relating to Both Global and Australian Inventory Impacts

Conclusions from this analysis include:

Fugitive emissions of methane from natural gas have the potential to damage the environment to a greater extent than either of the other two fossil energy sources of oil and coal.

More data around American shale gas experience in comparison to conventional gas, indicates that the fugitive emissions will only increase with poorer quality reserves as they are brought to production, requiring more treatment, and collection and transmission in ever expanding piped networks.

Fugitive emission rate data from all industry and academic papers range wildly for the general natural gas industry. The LNG industry is even worse served with no recent practical and independent advice taken from real measurement. It is possible that the emissions are at the levels claimed by industry at around 0.01%, but it is equally possible that they can reach the upper estimates converging on 6%. More and more research points toward the upper limits for piped gas. No-one really knows the extent of emissions along the LNG supply chain in the Australian Jurisdictions. Self-reporting and monitoring by industry is therefore suspect.

Australia and the industry need to address the issue of fugitive emissions in LNG supply with overwhelming research and independent monitoring regimes to ensure the industry can retain social license, let alone expand their operations.

Standardised benchmarking for the LNG Industry

Australia's emissions intensive trade exposed industries use benchmarking to justify mitigation requirements for each of their projects. Later discussion will note the weak downward pressures exerted through the Australian system, which obviate against concerted downward pressure on these benchmarks.

The best comparison to standardise emissions and the one quoted most regularly is entitled "kg CO2e per kg LNG (production)". These figures reflect the emissions which should be included in the national inventory. Similar figures for gas lifecycle, which include emissions from the consumption of the gas offshore show a similar variance.

Our figures indicate that the lowest benchmark figure is achieved by the longest operating facility, being the North West Shelf Venture. As noted previously this project has access to the best quality natural gas and achieves a standardised benchmark of 0.37 kg/kg. The next best is the Gorgon figures including sequestration at 0.41 (approximately 0.59 without sequestration). The highest estimated rate is reported for Ichthys at 0.98 as it represents the project with the highest carbon dioxide embodied in the extracted resource and transports the gas over the longest distance. It is also expected to be the last of the current developments, so should reflect the industries best practises.

The Northern Territory projects emit at the highest intensity, averaging 0.93, whilst the Western Australian projects emit the least at average 0.50 kg/kg. The outlier in the Western Australian projects is Shells Prelude project, a FLNG. Its emissions high intensity, at 0.84, is due to a combination of high embodied carbon and (probably) simplified process due to the compact nature of a floating LNG facility.

Most of the industry uses very similar processes and equipment so the major driver of intensities is the underlying quality of the gas resource. This is driven by the quantity of embodied inert gases, CO_2 and N_2: the higher these quantities the greater the process emissions. Being waste products, these inerts are both emitted directly to the atmosphere and have two secondary effects: the first of being that they are energy intensive to remove, and secondly economically difficult to remove without some "carry-over" products being captured in the waste stream, such as methane, which themselves are then emitted.

An interesting sidebar relates to the Queensland gas fields as they provide a salutary lesson on extraction of unconventional gases such as their coal seam gas, and the Northern Territories shale gas: Extraction is energy intensive and more fugitives prone. These two factors drive their benchmark emissions quantifiably higher than conventional gases.

There is little incentive and even less evidence that benchmarking by and for the industry is driving change. For the industry to achieve any semblance of social license, this must change.

As gas quality is reduced, in either closely related or exhausted fields or new greenfield operations, these benchmark figures will continue to inflate.

Which Entities are Responsible for these Emissions?

Clearly the states have a significant responsibility regarding emissions from the LNG industry. However, all project proponents are not equally culpable.

Whilst there are 27 corporations which participate in the Australian LNG through direct project equity controlling interests tell a slightly skewed version.

The following graphic, Figure 12: Attribution of Production GHG Emissions to Ultimate Corporate Equity Partner, attributes the project emissions to ultimate corporate responsibility.

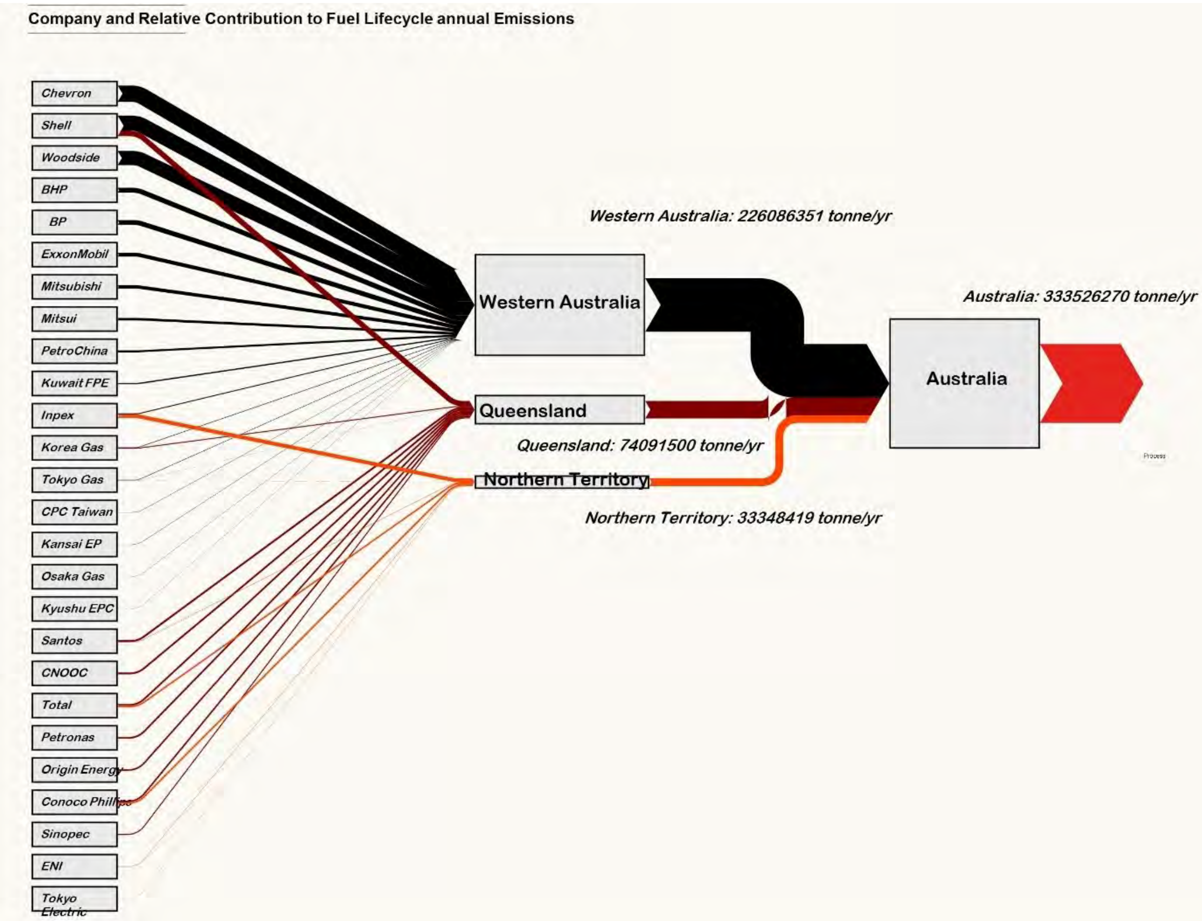


Figure 12: Attribution of Production GHG Emissions to Ultimate Corporate Equity Partner

Clearly three of the corporations, Chevron Shell and Woodside, have responsibility for the greater quantities of emissions from the industry in Australia. All three contribute the majority of this in the region of Western Australia, with Shell also the largest contributor in Queensland. Whilst not as large a contributor overall Inpex clearly dominates the emissions emanating from the Northern Territory.

Further, 13 of the project partners feature in the top 1500 global private companies by revenue. These top companies self-reported emitting in aggregate an average and minimum of 3.036 billion tonnes per annum for the years 2011, 2012 and 2013. Fifty-four (54) companies identified as being in the hydrocarbons business within this grouping and also in aggregate are estimated to contribute a minimum of 1-1.1 billion tonnes per annum of CO_2e to the atmosphere through the reported years. The figures are a minimum as some companies didn't report their contributions, including some on the project partners list.

The 13 project partners featuring alongside the 54 similar companies and being only 25% of the company count, reported they emitted between 44 and 50% of the hydrocarbon industries approximately 1 billion tonnes each year. Similarly these project partners, being just 0.9% of the complete company count emitted just under 17% of the total emissions.

Influencing the behaviour of these project partners in Australia will ultimately ripple out across the globe.

Australian Policies

The primary policies which dictate the behaviour of these companies are in part under review.

The LNG Industry is an Emissions Intensive Trade Exposed Industry

Emissions Intensive Trade Exposed Industry of which the LNG industry is one of the foremost, has been exempted from and/or compensated for imposts around every policy (Guglyuvatyy & Stoianoff, 2016). Guglyuvatyy et al conclude:

> *"…. demonstrates … the significance of political influence on the development of policy and design of market-based instruments in the quest to deal with the issue of climate change. Whether the motivation is to placate the business and industry sectors, as did the Howard, Rudd and Abbott governments, or to ensure the Gillard government remained in power by placating parliamentary power brokers who hold the balance of power, it is clear that actually dealing with climate change has been a secondary consideration….. The important feature of the* (current) *Direct Action Plan is its voluntary nature."*

Why is this an issue (Pan et al., 2017)

Current Federal GHG Enforcement Issues: Major Emitter Benchmarking

At the same time as it was reporting the poor state of Australia's emissions targets, the Federal Government released a discussion paper (*Emissions Reduction Fund: Safeguard Mechanism Consultation paper*, 2018) linked to the management of the "safeguard mechanism" a device to establish baselines above which major emitters in Australia must purchase domestic carbon offsets. The oil and gas industry is one of these industries.

The baseline is a mechanism with which to manage facility expansion without economic penalty. The fundamental premise is that major emitters are required to meet some kind of standard and by some logic this will help reduce emissions. Currently the baseline relies on emissions rates rather than actual overall emissions quantities. It also relies on the baseline being set at "industry best practise". The Australian Government amongst some other issues proposes annual setting of benchmarks to ensure market expansion is not penalised by the costs of meeting GHG emission commitments, thus delivering unfettered growth of Australia's emissions in line with economic prosperity.

Effectively the baseline standard is set by the industry itself, without any requirement to reduce the baseline nor have it audited nor with any enforceability. The outcome, unless other economic drivers or a sense of culpability within the industry, force change, there is no imperative for industrial change to the threat of Climate Change ("Choose your own baseline – Industrial emissions and the Safeguard Mechanism," 2018).

The aggregate LNG Industry Environmental Impact Statements reflect poorly on Benchmarking

The LNG industry is a clear example of this. Even before the introduction of the safeguard mechanism, the those responsible for environmental approval required proponents to identify and benchmark against industry best practise. A qualitative assessment after examination of the 13 different EIS's indicates that the industry is not motivated to take direct action, as the same actions are continuously repeated as being innovative compared with a low benchmark.

The EIS's mostly represent their discretionary GHG mitigation policies much in the style of a car sales person "throwing in for free" modern emissions technology which have been around for 30 years, or claiming the inclusion of rubber tyres are an innovation for wheels provided out of the kindness of the supplier's hearts.

The one exception has been the Gorgon EIS which proposed geo-sequestration for 80% of its embodied CO_2. In early 2018 Chevron notified relevant authorities of a facility failure which would delay sequestration by up to 12 months. This is discussed separately in a later chapter.

Further the projects directed solely to the Australian Government environmental approval process lack much detail that the States' and Territories demand.

Lastly, the justification on environmental grounds for project development invariably rest on emissions comparison to coal and claim the LNG as coal replacement. This has been challenged, most recently by speculation that only now is China switching to natural gas instead of coal, due entirely to a national health issue related to emissions of local NO_x's, SO_x's and particulates.

Generally the development of unconventional gas in the US and its displacement of coal is quoted by many to justify the industry position. Much research indicates that this was an economic displacement in the local markets, and the subsequent increase in US export of coal actually on balance ensured the world's nett emissions increased (Afsah & Salcito, 2012; Broderick & Anderson, 2012; Lu, Salovaara, & McElroy, 2012)(Peters and Hertwich, 2008; Barrett et al., 2013)

According to US EPA statistics

- Fuel switching decreased US emissions by "up to 50%" of 8.6% reported in the electricity production sector (i.e. <4.3%)

- Other work shows about 35-50% of this was due to price effects which may be unsustainable;

- Renewables and nuclear expansion account for about an uptake equivalent to 2/3 of the unconventional gas uptake. By inference gas fuel switching thus impacted about 2.6% of emissions reduction in the electricity sector of the US, only 30% of emissions reductions claimed

The Australian experience is also exemplary, as little fuel swapping has occurred until the closure of older more expensive coal facilities in recent times.

The uncritical view of this claim in each project by the various State and Federal Environmental watchdogs is startling.

Current Federal GHG Enforcement Issues: National Energy Guarantee (NEG)

In August 2017 COAG Energy Council established the Energy Security Board (ESB) and has been tasked with implementing reform of the National Electricity Market. A key plank of this is the Australian Governments National Energy Guarantee (NEG).

"*The proposed National Energy Guarantee aims to support the provision of reliable, secure and affordable electricity with a focus on ensuring:*

- *the reliability of the system is maintained*
- *electricity sector emissions reductions needed to meet Australia's international commitments are achieved*
- *the above objectives are met at the lowest overall costs.*

The board undertook a two-month consultation process. On the 20th of April 2018 it presented a "high-level" design of the Guarantee to the COAG Energy Council (*Initial design of the Guarantee*, 2018).

Several of the key design components relates to the LNG industry:

The first is the Federal Government's intention to exempt energy intensive trade exposed industries (such as the LNG industry) activities (supply of electricity) which would otherwise be caught under the Guarantee. The proposal is to institute a framework similar to that operating with the existing Renewable Energy (Electricity) Act 2000.

Given the ever-increasing impact of these trade exposed industries, and the possibility of moving the energy requirements away from unmetered natural gas towards renewable electricity on an industrial scale, a clear policy shift is required.

Currently the Australian LNG industry has the potential to outsource around 9 GW of electricity production should it wish decarbonise its process energy, which would grow to 20.5 GW. In doing so it would reduce demand for initially 14% of Australia's thermal energy demand growing to potentially 32% should the industry expand. This equates to adding between 31% and 70% to the Australia's electrical consumption.

Should this be exempt from any energy guarantee program, it would obscenely skew the national energy market dynamics and emissions reduction requirements.

For comparative purposes, the Aluminium industry received the equivalent of 2.9 GW of exemptions in 2016, as the biggest purchaser of electricity in emission intensive trade exposed industries (*Exemption approved for each EITE activity for 2016*, 2017). This represented 61.7% of all such exemptions.

This policy type is a form of protectionism in that it protects the Australian industry from the realities of the Global commons and the damage done by them. It may add unfair competitive advantage to the Australian industry in comparison to industry operating within countries who are moving towards containing GHG emissions from their own industry.

As market leaders and owners of such natural resource, Australia has the chance to design a system which ensures these industries act responsibly and remain competitive. One such future is explored in Volume 2 of this report.

We recommend that the instruments subsidising emissions intensive trade exposed industry (at the expense of domestic industry impositions) be examined to determine alternative policy settings.

The second relates to the notion of offsets. The proposed design identifies offsets as a legitimate way industry to offset their excessive emissions from electricity production and consumption. Much of the debate is around the probability for some international emissions offset credits to be the equivalent to “junk”. Interestingly some Australian commentators are identifying some of the Australian equivalent similarly ("Outlook for ACCU supply and offset prices in Australia through to 2030," 2017).

Key consideration of all offsets for emissions in Australia include: quality of offset; opportunities to leverage domestic industry development; and the threat of large unscrupulous industry players to repatriate profitability with yet another mechanism (and/or for them to develop clean industry in a favourably aligned foreign location).

Estimates of Australian Carbon Credit Units (ACCU) range from junk status at AUD5 per tonne through to AUD 35 per tonne ("Outlook for ACCU supply and offset prices in Australia through to 2030," 2017).

The last Australian Government auction results for ACCU’s indicated an average price of AUD 13.08 per tonne.

Should large scale requirements such as the LNG industry and other similar emissions intensive trade exposed industries enter the market then the domestic cost of offsets will probably be higher.

International carbon markets are expanding, with the largest being based in the European Union. The current price there is in the order of EUR (AUD 21) 13 per tonne, via EUR 20-30 (AUD 32-48) within three years to EUR 45-55 (AUD 72-89) in the next decade (Lewis, 2018). The World Bank tracks national initiatives for carbon pricing, globally. It notes that in 2017, 47 initiatives, of which Australia is one covered 8 billion tonnes of CO_2e valued at USD 52.2 billion, which represents 14.6% of global emissions ("Carbon Pricing Dashboard," 2017)

A recent report to the Queensland Government (Holt & Cook, 2017) identifies that Australia’s key export markets are implementing carbon pricing mechanisms with a real 2030 price expected to reflect an average AUD 29 per tonne CO_2e cost.

Whilst international markets for carbon offsets is expanding, the shear scale of the industry and its carbon emissions ensures that Australian LNG industry may to foster an Australian based carbon offset economy which can be internationally traded.

Major Technical Contributors to GHG Emissions in the Process of LNG Production

The major gaseous components which contribute to the GHG emissions from a LNG facility include:

Embodied Carbon Dioxide (CO_2)

Embodied carbon dioxide is that which comes with the hydrocarbons from the gas fields. The amount of this constituent ranges from less than 1% by volume in

Queensland's coal seam gas to nearly 16% in some of the proposed producing fields in North West Australia.

In terms of total emissions from production of LNG, the least of these emissions come from coal seam gas with at most 3.3% of production emissions being due to embodied carbon, and the most from high carbon fields associated with Prelude and Browse Torosa gas fields constituting around 30% of total production emissions.

This product is incompatible with LNG and must be removed from the gas stream down to levels counted in parts per million. It is also an "inert", a gas which doesn't add to the energy carrying capacity of gas so along with nitrogen is also carefully managed with maximum allowable quantities in domestic and export gas.

It, as a long term atmospheric residential and reference gas, has a GWP_{100} of 1.

Produced Carbon Dioxide (CO_2)

Carbon Dioxide is also produced through the combustion of either resource natural gas or some related produce streams, such as the methane rich nitrogen and acid gas effluents, previously described. Produced CO_2 represents most of the production GHG emissions: between 68 and 99%, depending on a few factors.

It, as a long term atmospheric residential and reference gas, has a GWP_{100} of 1.

The least of these emissions come the NWSV which has the best quality gas, requiring the least processing and transport, and perhaps some economies of scale with 0.31 kg/kg LNG. The maximum produced gas appears from the facilities in the Northern territory with high carbon fields associated with Prelude and Browse Torosa gas fields, and some significant transport energy requirements, constituting around 0.70 kg/kg.

Methane (CH_4)

Methane is embodied in the hydrocarbons which come from the gas fields, and is the major hydrocarbon sought for liquefaction as LNG. It generally represents between 70 and 95% by volume of commercial natural gas fields.

This gas is a shorter term atmospheric resident and has a reference GWP_{100} which has steadily increased from original estimates of 21, still used by industry and most legislative programs, including Australia's, to now 36, ensuring it a very potent GHG. Its GWP_{20} is 87, highlighting its shorter-term potency.

It is a major source of emissions from LNG production facilities either in:

- Acid gas product waste streams
- Nitrogen waste streams'
- Trace quantities from combustion of hydrocarbons in the process and
- process leakage, generally referred to as a fugitive;

Fugitive emission rates are also a hotly debated topic within the industry, even when facts don't support the argument, as fugitive management makes a significant difference to the GHG impact of natural gas, and hence its claim to be a transition fuel.

These seemingly small fugitive emissions can have a magnifying impact on overall GHG loading, especially as industry continues to adhere to a GWP_{100} for methane at 21 or less often at 25, rather than the current benchmark figure of 36, an increase of nearly 70%. Thus, most fugitives emissions are under reported as well as use an insufficient multiplier in calculation of its GHG impact within the LNG industry.

Nitrous Oxide (N_2O)

In the case for LNG, the combustion of hydrocarbons in the presence of nitrogen a major constituent of air, produces a variety of nitrogen oxides, commonly referenced as NO_x's, a small proportion of these is laughing gas, N_2O. itself is a large contributor to regional pollution and along with other similar emissions cause health effects to the general population. This well-known phenomenon has caused for example natural gas-powered turbine manufacturers to quantify and publish the performance of their equipment with respect to NO_x.

N_2O has a very high GWP_{100} of 298, originally thought to be 310. Its potency is thus more than significant than most GHG's. However, only trace elements are emitted within an LNG plant. These trace elements subsequently add approximately 3% to the GHG impact at both production emissions and probably at a higher rate for life cycle emissions.

It's formation maybe controlled through either removing the need to combust hydrocarbons in nitrogen, designing equipment to reduce the combustion temperatures which cause its production, or post combustion treatment of the flue emissions to catalyse it. None of the projects discuss this in detail, and few highlight its impact.

High nitrogen content streams are often used as fuel gas to power the turbines and heaters within the LNG process, and thus will produce more N_2O in comparison to using standard natural gas for combustion.

Gorgon and its Sequestration Issues

A qualitative assessment after examination of the 13 different EIS's indicates that the industry is not motivated to take direct action. The one exception has been the Gorgon EIS which proposes geo-sequestration for 80% of its embodied CO_2.

An estimate of annual mass flows through the Gorgon project is presented in the following "Figure 13: Estimate of Annual GHG Mass Flows through the Gorgon Project, including sequestration".

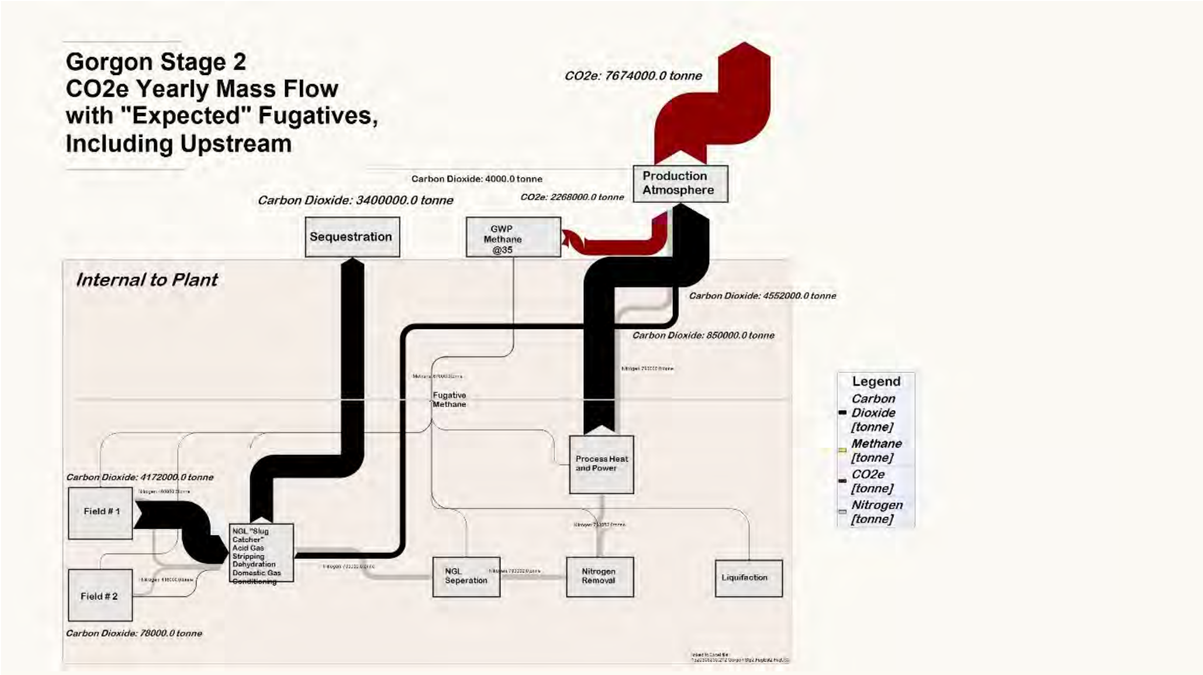


Figure 13: Estimate of Annual GHG Mass Flows through the Gorgon Project, including sequestration

The project proposes to sequester up to 3.4 Mtpa of CO2. In absolute terms this is significant and a successful outcome will clearly identify the economic and technical capacity to limit emissions. However, this is only part of the emissions the plant will emit. We estimate the process will emit a further 7.6 Mtpa within the Australian responsibility.

Further and globally the plant will be responsible for a product that will ultimately contribute an estimated 64 Mtpa of GHG's. This is graphically demonstrated in the following Figure 14: Estimate of Annual GHG Mass Flows through the Gorgon Project, including sequestration and downstream emissions.

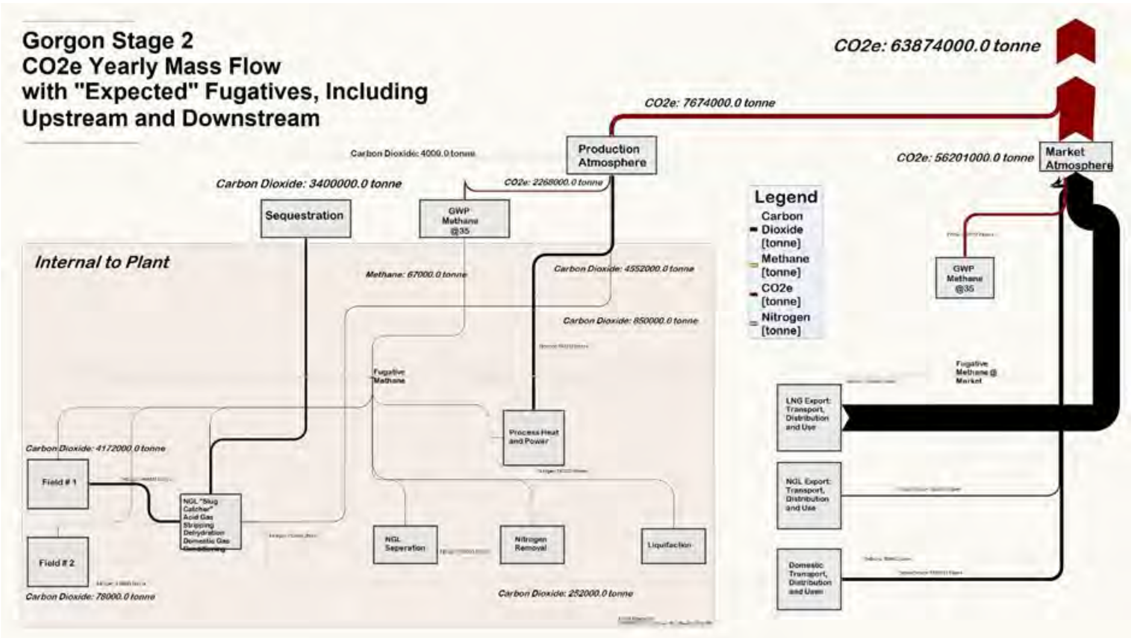


Figure 14: Estimate of Annual GHG Mass Flows through the Gorgon Project, including sequestration and downstream emissions

Whilst the sequestration project has positioned as being a relatively large and risky undertaking, no known technology associated with the “capture” components, nor the transmission systems is groundbreaking. Even the injection of the emissions underground is well heralded by other oil and gas industrial processes. Injecting CO_2 to help in hydrocarbon extraction (Verma, 2015), has been common since the 1980’s. Technically the only risk is either economic or geological, the latter referring to the likelihood of the gas remaining sequested.

A report (Milne, 2017) from Chevron to the Western Australian Government’s Department of Water and Environmental Regulation and released on the 18th Dec 2017, identified “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” delaying initial sequestration until at earliest December 2018 and reportedly more likely before mid-2019. Up to an estimated 5 million tonnes will subsequently not be sequestered.

However, the project is subject to the requirement to capture, with no apparent mechanism in place to penalise failure. As per valuations of offsets discussed later, this presents a failure costing, if conceptually monetised under Australian policy concepts, between AUD 25 and 175 million depending on the quality of Australian Carbon Credit Units, and paid for by the taxpayer.

Such a failure is questionable. Only a root cause analysis made public will enable a forensic attribution of cause, but until then it is possible to conclude at best there was a simple and negligent engineering failure, and at worst a corporate culture to create failure around a non-core issue. Such a culture may be motivated by industries’ desire to maintain a low benchmark to suit itself around current policy frameworks: Such a failure would signal that geo-sequestration is not an option for this industry, whilst success will create a future additional cost of production which as an industry best practise would flow throughout the industry.

The later postulation is reinforced considering the networked connections of the major participants through joint participation in a variety of Australian projects.

The following graphic, entitled “Figure 15: Chevrons Formal Industry Linkages through Project Participation” graphically illustrates the linkages.

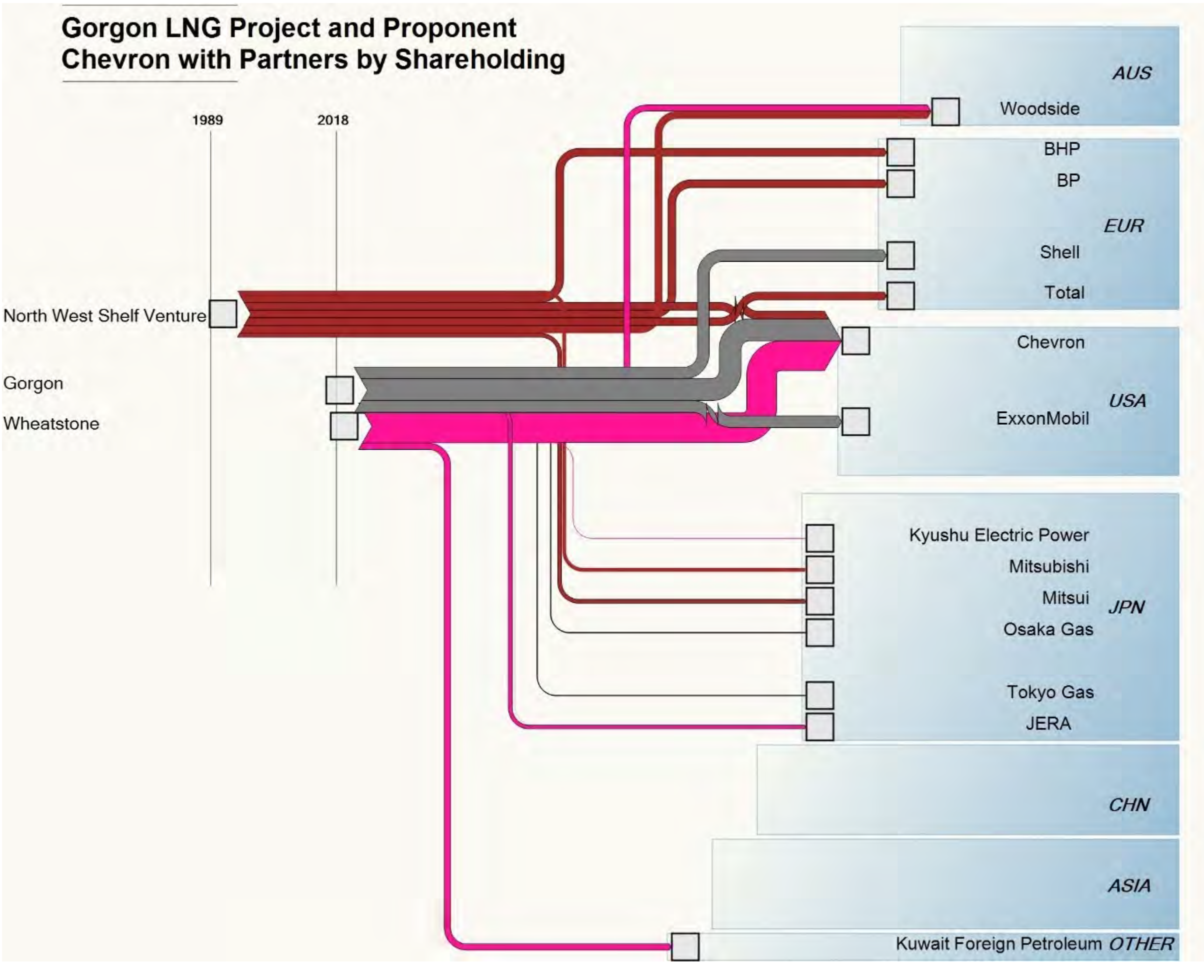


Figure 15: Chevrons Formal Industry Linkages through Project Participation

Gorgons project manager, Chevron, is clearly and formally linked with the other two major industry participants, Woodside and Shell, through this web of cross project participation. BHP, BP Total and ExxonMobil are international giants of the industry and whilst not major participants in the project, their association is important. Australian industry participants not directly linked will also aware through the industry association, APPEA.

The outcomes of any action by the Regulatory Authorities will be closely monitored by all in the industry. It provides an opening for the State Government to properly and carefully indicate that this is not without firm and indicative consequences.

Policy options include:

- forgiveness of a notional debt to society;
- ensure delay of project to avoid consequent emissions;
- extract an offset guarantee which the company puts forward, preferably in the domestic market, and of high quality
- extract a monetised offset equivalent “toll” for the state to disburse as it sees fit;
- extract a commitment to jointly work with and pay for research into, and subsequent initiation of a joint State and industry plan with the goal to

achieve complete amelioration of production emissions and to similarly plan and implement associated agglomeration benefits to the state of operating in the state, all to an equivalent offset cost; or

- a combination of all of the above.

Wheatstone and Chevron's Arbitrage of Politics

Initial conception of the Wheatstone project considered seriously the ability of Chevron to include sequestration of some of the embodied CO_2, as per the agreement on the Gorgon project. Wheatstone gas fields, Iago and Wheatstone, are reported to have comparatively low embodied CO_2, just under 3 % (Gorgon 14.5% , NWSV's North Rankin with 3.31%), such that using the sequestration embodiment rate used with the Gorgon project of 80%, the expectation was to sequester just over .8 Mtpa. The proposed sequestration would have reduced overall current facilities production emissions by about 20%, from 4.95 to 4.14 Mtpa. At the maximum envisioned scale, the emissions may have been reduced from 14.5 to 12.12 Mtpa.

From a gas lifecycle perspective, sequestration reduced the overall emissions by 2.2%, a small but significant reduction, but one which through omission has created a carbon debt currently indirectly being funded through the taxpayer.

Modelled production emission data is presented in Attachment "l..lm.m.mm".

However, Chevron and project partners were forgiven the subsequent carbon debt through a series of State and Federal Government policies changes, to an extent that there are little GHG restrictions on this project.

The Gillard Labour Government legislated the Clean Energy Act in 2011 which came into effect on 1 July 2012, which mandated a carbon price be paid by proponents on emissions from projects such as the Wheatstone LNG project.

In January 2013, the Western Australian Coalition State Minister for the Environment Minister Marmion, waived all of his department advice regarding GHG's, as he did with the Browse Project when it was proposed for James Price Point, north of Broome (Mercer, 2013), stating that management of GHG's were a federal matter. Commentators noted at the time that the EPA had advised the minister that its recommendations were complimentary to the Federal Clean Energy Act.

By September 2013, the Labour Government had been replaced by the Abbott Coalition Government. By July 2014 the Clean Energy Act was repealed.

Subsequently this project has no requirements or conditions regarding GHG's. It subsequently is not required directly to maintain world's best GHG emissions practises, including the sequestration of its embodied gas.

Commentators have opined that the election was a foregone conclusion (*Abbott's Gambit The 2013 Australian Federal Election*, 2015), thus it is possible to conclude that this outcome was foreseeable.

Chevron and its project partners have created an GHG emissions debt, which was otherwise avoidable with known technology of the time: geo-sequestration. This debt is estimated to be up to 3.526 billion dollars in present value terms. Under current policies this debt will be paid for by the taxpayer.

Alternatively, this debt may have been avoided with geo-sequestration alongside the Gorgon project for an estimated capital outlay of AUD 530 million[3] and incremental operating costs over the life of the project.

Policy implications are expanded upon in the following section.

The GHG Impacts of Subsea Infrastructure Failure is rarely reported

From the early hours of 21 August 2009, and for a period of just over 10 weeks, oil and gas flowed unabated into the Timor Sea, approximately 250 kilometres off the northwest coast of Australia. A subsequent enquiry (*Montara Commission of Inquiry*, 2009) found:

"*The volume of oil spilt from the Montara WHP makes the Blowout Australia's third largest oil spill after the Kirki oil tanker in 1991 and the Princess Anne Marie oil tanker in 1975. However, the Blowout is the worst of its kind in Australia's offshore petroleum industry history"*

This enquiry lead to the formation of the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA). What is evident is that the Inquiry had no conception of the damage to the environment caused by the gaseous emissions, instead focusing on the damage to the marine environment caused by the fugitive liquid hydrocarbons.

The Inquiry did however introduce the concept of user pays for environmental damage and remediation. A further line of research may be warranted into the NPSEMA powers to enforce the polluter pays concept and further extend this to GHG emissions.

Incidents involving fugitive hydrocarbons continue to occur in Australia.

[3] Authors very rough estimate based on quoted capital costs of the Gorgon equivalent.

The Externalised Cost of GHG Emissions in the LNG Industry

As noted earlier the Australian Government has shifted the cost of balancing Australia's GHG commitments away from the LNG industry through exemptions, to the domestic market. Thus 9.7% (with the potential to grow to 19.2%) of the current Australian GHG budget is exempt from actions demanded of the domestic economy. The current policy to facilitate cost externalisation of LNG GHG emissions, and to impose these costs onto the domestic market is bold.

The industry continues to advocate and lobby for this imbalance. An example includes a indicative comment in Woodsides submission to the Energy Security Boards National Energy Guarantee (NEG) Consultation Paper in March 2018, also resubmitted to the Federal Standing Committee on Economics Inquiry into Impediments to Business Investment in Australia as late as May 2018, both of which state:

"Recent cost reductions in wind and solar PV likely provide the (domestic) electricity sector with more opportunities for low cost abatement than many other sectors. Woodside would therefore encourage the Energy Security Board to consider a sectoral 2030 target that is higher than 28% to ensure Australia achieves least cost abatement across the economy as a whole"

Further, the taxpayer is being required to subsidise these industries by paying local industry, willing to volunteer, to do all the "heavy lifting". If offsets under schemes such as the ACCU concept of the current Government were extended to ameliorate all LNG industry emissions in Australia, our research estimates the project life time production emission amelioration costs would range from 0.56% to 8.49% of project lifecycle revenues, based on a spread of ACCU values. At current ACCU prices, the current deferred mitigation cost estimate is AUD 17 billion rising to 36.5 AUD billion if the industry were to reach maximum modelled scale.

Using published risk premiums for the export LNG industry (Hartley & Medlock, 2005), an appropriate real weighted average cost of capital (WACC) for present value calculations was selected at 6.48%. In the Australian context, country risk was assumed to be the same as the USA.

The following "Table 2: Present Value of Absolute Project Lifecycle Production emissions offset costs, and as a proportion of the PV of Project Revenues for Current and Maximum Industry Size" summarises the variables and outcomes when estimating the complete present value cost of offsetting all project life cycles for both production-based component and the complete gas lifecycle. The table includes these figures and indicates what percentage they are of the present value of gross revenue received by producers for the product.

Total Industry and Total Project Lifecycle Production Emission Present Value of Amelioration Costs, and Ratios to Present Value of Gross Industry Revenue				Minimum (junk) ACCU price	Current ACCU price	Maximum ACCU price
ACCU Price				AUD 5/tonne	AUD 13.08/tonne	AUD 35/tonne
ACCU Discount Rate	GHG Scale	Project Revenue PV @ Industry Discount Rate of 6.48% real (AUD billions)	Current Industry Size	561.762		
			Maximum Industry Size	1152.397		
Industry, 6.48% real	Australian	Current Scale	Present Value (AUD billions)	3.173	8.301	22.213
			Ratio to Project life revenue	***0.56%***	***1.48%***	***3.95%***
		Maximum Scale	Present Value (AUD billions)	6.959	18.203	48.71
			Ratio to Project life revenue	***0.60%***	***1.58%***	***4.23%***
	Global	Current Scale	Present Value (AUD billions)	20.713	54.186	144.993
			Ratio to Project life revenue	***3.69%***	***9.65%***	***25.81%***
		Maximum Scale	Present Value (AUD billions)	43.918	114.889	307.426
			Ratio to Project life revenue	***3.81%***	***9.97%***	***26.68%***
Australian Government 10 Year 1.13% real	Australian	Current Scale	Present Value (AUD billions)	6.53	17.083	45.712
			Ratio to Project life revenue	***1.16%***	***3.04%***	***8.14%***
		Maximum Scale	Present Value (AUD billions)	13.969	36.543	97.783
			Ratio to Project life revenue	***1.21%***	***3.17%***	***8.49%***
	Global	Current Scale	Present Value (AUD billions)	43.337	113.37	303.361
			Ratio to Project life revenue	***7.71%***	***20.18%***	***54.00%***
		Maximum Scale	Present Value (AUD billions)	89.949	235.306	629.642
			Ratio to Project life revenue	***7.81%***	***20.42%***	***54.64%***

Table 2: Present Value of Absolute Project Lifecycle Production emissions offset costs, and as a proportion of the PV of Project Revenues for Current and Maximum Industry Size

Several key points arise from these figures.

With business as usual, the increased costs of managing poorer quality gas for offsets will also is reflected in other operational costs, reflecting some of the resource economics symptoms outlined by economists (Hotelling, 1931a), where depletion of the quality of resources may reduce margins for both proponent and State over time, even as scarcity increases price.

These decreased margins are likely to be exacerbated by current policy settings which also externalise rising GHG mitigation costs to society.

Reduced margins due to reducing quality of gas resource over time may have a significant repercussion for sovereign returns through HRRT mechanisms, which backload these returns, perhaps to a period when resource quality significantly reduces returns anyway. The PRRT presupposes that margins remain static or improve over time under scarcity conditions, and thus remove sovereign benefits in time, and further discounts the any ultimate benefit through the concept of the "time value" of money.

These factors indicate the need for significant research into the value of the PRRT for Australia's natural gas assets.

Secondly, the currently externalised offset cost as a proportion of net profit, either to the project proponents to the Australian people or to customers is significant.

We have noted earlier the most likely costs for offsets of a scale to ameliorate these projects has a lower bound at the current highest proposed figure of AUD 35 per tonne. The following discussion focusses on this for comparative purposes.

The offset costs can be paid for by either:

- the Australian people through schemes such as the current RET and auction scheme, where the taxpayer funds the lot;
- The project proponents absorbing the costs as a cost of production. The industry indicates clearly that a unilateral move to increase costs of production by Australia will remove current incentives for future investment. This is the scheme that the Northern Territory expert panel on shale gas propose; or,
- customers through price increases, which the default position by industry and Government within Australia is that these are trade exposed and thus cause vulnerability to lost market share.

The previously presented analysis of project partners' tax affairs indicated that overall, the Australian people received 1.4% of gross revenue as mundane corporate tax, and 0.9% in PRRT, the later directly valuing the gas resource for Australians.

The data shows that only under conditions of "junk" offsets utilisation does the value extracted from this industry for the Australian people exceed the cost imposed.

Through the ACCU auctions these costs are already being paid by the taxpayer. This burden will only grow.

Under current policy settings, Australians will subsidise the production emissions for the LNG industry, using "junk" offset costs, at minimum around AUD 3.2 billion in present value terms. At current production rates and at the bottom bound of AUD35 per tonne offset, and using industry WACC rates, this rises to AUD 22.2 billion dollars present value.

At maximum industry scale and at the expected bottom bound value for offsets, this subsidy increases to AUD 48.7 billion dollars present value. Further any other assistance to extract and exploit the resources, such as "free" gas, accelerated time shifted offsets for exploration etc will remain unredeemed.

Should the discount rate match government bond rates (eg.15 year yield of 3.03%, less inflation at 1.9% thus real rate being 1.13%), rather than the more commercial rate of 6.48%, the subsidy at maximum industry scale increases to AUD 97.8 billion present value.

The data demonstrates that the future price of mitigation is perceived as less onerous to the industry. Thus industry is more willing to defer direct costs in comparison to a Sovereign Government, under the normative view of financial calculation and its core principal of the "time cost of money", given the relative difference in cost of capital.

Tax data indicates that project partners receive approximately 5.6% of gross revenue as net profit, albeit there is a probability that this is significantly understated. Some calculation within this analysis has addressed the proportional value to financiers, and shows that up to around 35%[4] of gross revenue may necessary to service debt.

This data also indicates that offset costs will effectively negate reported profitability for the project proponents if internalised to the project, negating the value of the industry unless international prices start reflecting true costs.

Note that royalties due from the NWSV are a relatively small proportion due to the nearness of its end of life and subsequently has been ignored in this calculation.

Using similar logic as for the Australian production emissions the project and gas lifecycle emissions global amelioration costs necessarily attributable to the Australian LNG industry amount to, at maximum industry size and at the lower bound offset pricing at least AUD 307 billion dollars present value at industry discount rate and AUD 629 billion using Australian Government Bond Rates. They represent an indicative increase in price necessary to internalise the costs of emissions along the supply chain to end user of between 26% and 55% of gross revenue for exported LNG.

Whilst the overall GHG impact and costs of amelioration for Australian sourced LNG are significant at a global level, the international rule of law does not require source nation responsibility, such as was envisioned with EU and German regulations for end of life disposal of motor vehicles, or even an global additive impost (similar to GST in Australia) which ensures the cost is embodied within the direct costs of goods sold.

Notwithstanding this, the Australian peoples’ responsibility currently lies with addressing the emissions produced through the production of the LNG. The data indicates the heavy financial and competitive toll that such imposts place on the industry should the current policy setting for domestic GHG management be extended to emissions intensive and trade exposed industries such as the LNG industry.

It is also clear that the current policy settings place no moral or legal obligations on these industries to address even the economic damage. Unfettered as they are these industries are doing effectively nothing to address this major threat to the economics social wellbeing of their hosts and environment of the world Australians and themselves.

Australia receives no value, and indeed subsidise, the extraction of it’s natural gas assets.

New approaches to addressing this looming and almost overwhelming issue of GHG emissions in the LNG industry need to change, and all actors within and

[4] 180422.Aus GHG Quarterly Inventory.xlsx

around the industry need to act to ensure that their activities remain morally legally economically socially and environmentally positive.

Looking Forward: Economics of Australian LNG in a Carbon Constrained World

The primary and now obvious market failure of humanities overuse of fossil fuels is our inability to initially recognise and then internalise (to the market "rent seekers") the cost to all humanity of its impact on the global system, at the time of its creation. Belatedly our civilisations are now reacting through science and an appearance of urgency to address them.

As noted by the IPCC 1.5º report (IPCC, 2018b) Australia is both subject to the economic costs of fossil fuel exploitation and a significant beneficiary of the economic value to the world of its natural gas resources exported to the world as LNG.

However, as the global drive to mitigate the impacts of fossil fuel on Climate Change accelerates, major science based institutions are now researching modelling and publicising the costs of various pathways we collectively can take. These pathways are grouped by these institutions into "Scenarios" for modelling possible outcomes in the future.

The IPCC say (IPCC, 2018c):

"scenarios are comprehensive, plausible, integrated descriptions of possible futures based on specified, internally consistent underlying assumptions, with pathways often used to describe the clear temporal evolution of specific scenario aspects or goal-oriented scenarios"

The IEA (International Energy Agency, 2019b) states that they:

"present projections for different core scenarios that are differentiated primarily by their underlying assumptions about the evolution of energy-related government policies"

Scenarios

These two institutions are however seemingly converging on three broad scenarios with which to examine energy production transport and consumption, both globally and for individual political entities. A brief description of pertinent scenarios follows:

Current Policies

Particularly the IEA state that this scenario and related pathways analysed is a useful one as it identifies what by others may be termed business as usual, and reflects the consequences of existing laws and regulations which govern the energy marketplace. This scenario sets policy at the beginning of the timeframe in question, and then enables the outcomes to evolve.

Stated Policies

Like the Current Policies Scenarios, the Stated Policies Scenario (previously called the "New Policies Scenario" or NPS for short, by the IEA) reflects stated policy ambitions, all of which are not yet reflected in law and regulation. This is, for example, what Woodside define as their central case (McConnell & Grant, 2019b). It too is used to see where the outcomes devolve to, as a response to input policies.

Sustainable Development Policies

The IEA has developed this scenario for the first time in its latest publication of the World Energy Outlook (International Energy Agency, 2019c). This IEA scenario addresses global desire for sustainable development for all. It is different to the previous scenarios in that it sets outcomes and explores policy options to determine success.

The Sustainable Development Goals (United Nations) are:

" … the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including those related to poverty, inequality, climate change, environmental degradation, peace and justice. The 17 Goals are all interconnected …"

The SDG's are all fundamentally impacted by of fossil and renewable energy sources and thus provides one framework for energy production distribution and consumption, based on need.

Further, our understanding is that pursuit of these goals are accepted as bipartisan policy for most Australian Federal and State political institutions.

Carbon Constraint Policies

As an alternative perspective, the International Panel on Climate Change also sets outcomes and explores policy options to determine success. More than this it has consistently refined the economic social cultural and environmental costs of not following carbon limiting policies aground climate change. Its latest report examines the imperative and impacts of limiting GHG impacts to 1.5º (IPCC, 2018b):

"Climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth are projected to increase with global warming of 1.5°C and increase further with 2°C."

The Paris agreements are capable of meeting this imperative, if taken holistically to include initial promises and then increasingly more ambitious policies over time especially for economies which are capable of managing the inevitable disruption this will require, namely developed countries such as Australia.

Demand

The resultant Scenarios analyses derived by each of the major institutions include data on the expected demand for global natural gas.

The aforementioned scenarios outcomes are plotted on the following graphic, entitled “Figure 16: Various Demand Projections for Global Natural Gas Supply”. The figure uses 2025 as a base case and examines the increase or decrease in projection for natural gas. The demand includes for domestic and international consumption and includes transmission through either pipeline or from liquefaction as LNG.

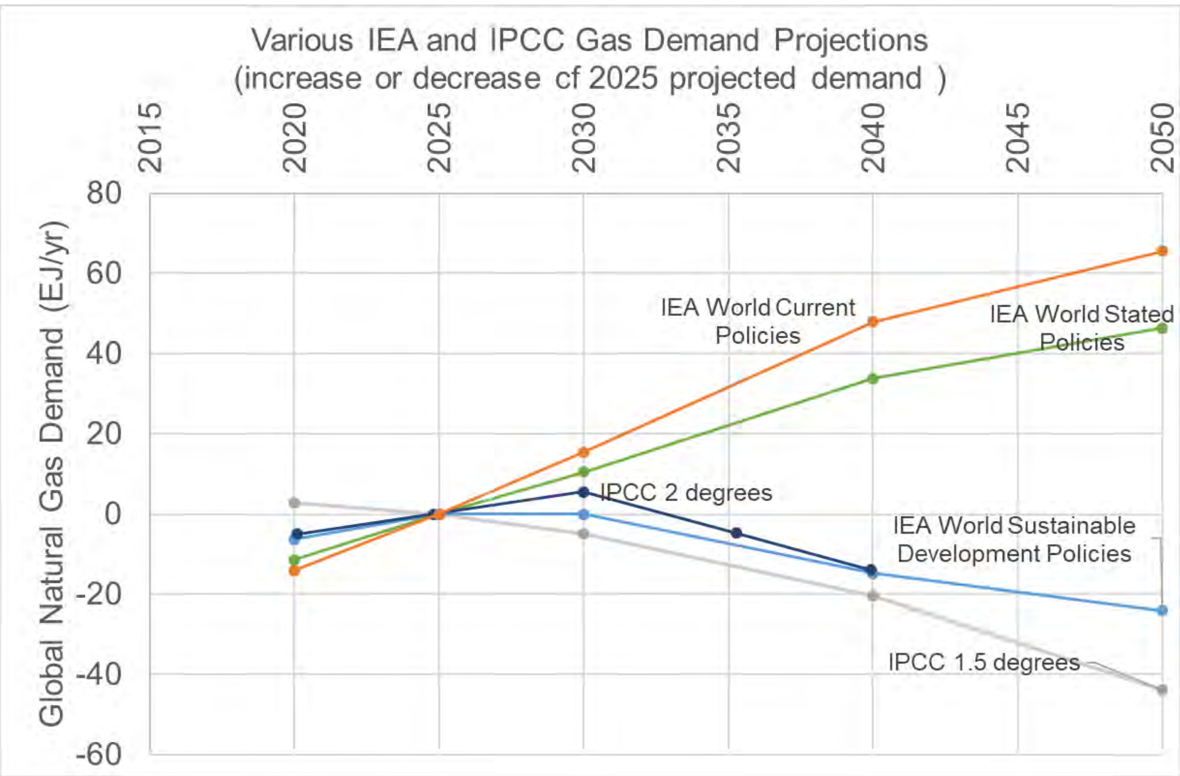


Figure 16: Various Demand Projections for Global Natural Gas Supply

For the first time the IEA has clearly indicated the differences between a laissez faire approach to natural gas supply as indicated by “free trade” expectations championed by the natural gas supply companies, and the “macroeconomic” approach indicated by constraints imposed by either sustainable development goals or carbon constraints to manage Climate Change.

The former align with growth expectations identified in the “The Production Gap: The discrepancy between countries’ planned fossil fuel production and global production levels consistent with limiting warming to 1.5°C or 2°C” (Stockholm Environment Institute, 2019) and the aforementioned IGU 2019 report

In a carbon constrained world the science shows that demand for natural gas will decrease, and at a rate that producing sovereign countries and gas proponents are not heeding.

Price

The resultant Scenarios analyses derived by each of the major institutions include data on the expected price for global natural gas.

The aforementioned scenarios price outcomes are plotted on the following graphic, entitled “Figure 17: Various Demand Projection for Global Natural Gas Price”. The price data is based on “landed terminal costs” and dose not include penalties for LNG such as the energy utilisation to degasify. Further, the price graphic has been modified in two ways from the original data in the IEA 2019 WEO report. These two modifications include:

1. For ease of comparison to other forms of energy such as coal and renewables the measure is reported in the universal measure of USD per MWhr, whereas the original was reported in “USD per billion cubic metres” (USD/bcm);
2. Similarly, to enable universal comparison the prices have been adjusted to reflect the efficiency of conversion of natural gas to electricity at a nominal efficiency of 60%;

The original report also notes that the Japanese pricing reflects regional LNG import as it has no domestic gas supply nor pipe gas options. This is relevant because we are considering Australia’s role as an LNG exporter.

Further the Chines pricing reflects that it has options for gas supply including its own conventional gas fields, potential shale gas supply of significant potential, and natural gas supply from Russian pipelines as well as an expanded suite of LNG suppliers. The aforementioned potential large scale African suppliers of LNG are of particular interest.

Also, of interest is the trajectory of the US gas price. In 2000, the USA was primarily constrained to conventional natural gas resources from domestic suppliers, with the beginnings of their own shale gas production cycle just emerging. In that year the IEA reports wholesale gas prices at 3 USD per MWhr(e). By the time that the US shale gas market was maturing in 2018, the price had almost halved to USD 1.6 per MWhr(e). This is an example of the price effect on gas in a significant oversupply situation, one potentially that Australian LNG faces.

Notably the US gas price doesn’t move much until under current policies in 2030 it starts to increase and by 2040 has increased substantially. There is no commentary in th report as to whether this is a price increase as the aforementioned export of LNG kicks in or the reduction in gas supply as shale gas progressively becomes harder to extract or both. Others have commentated this phenomenon in Australia’s Eastern Seaboard gas markets as the Queensland LNG facilities ramped up.

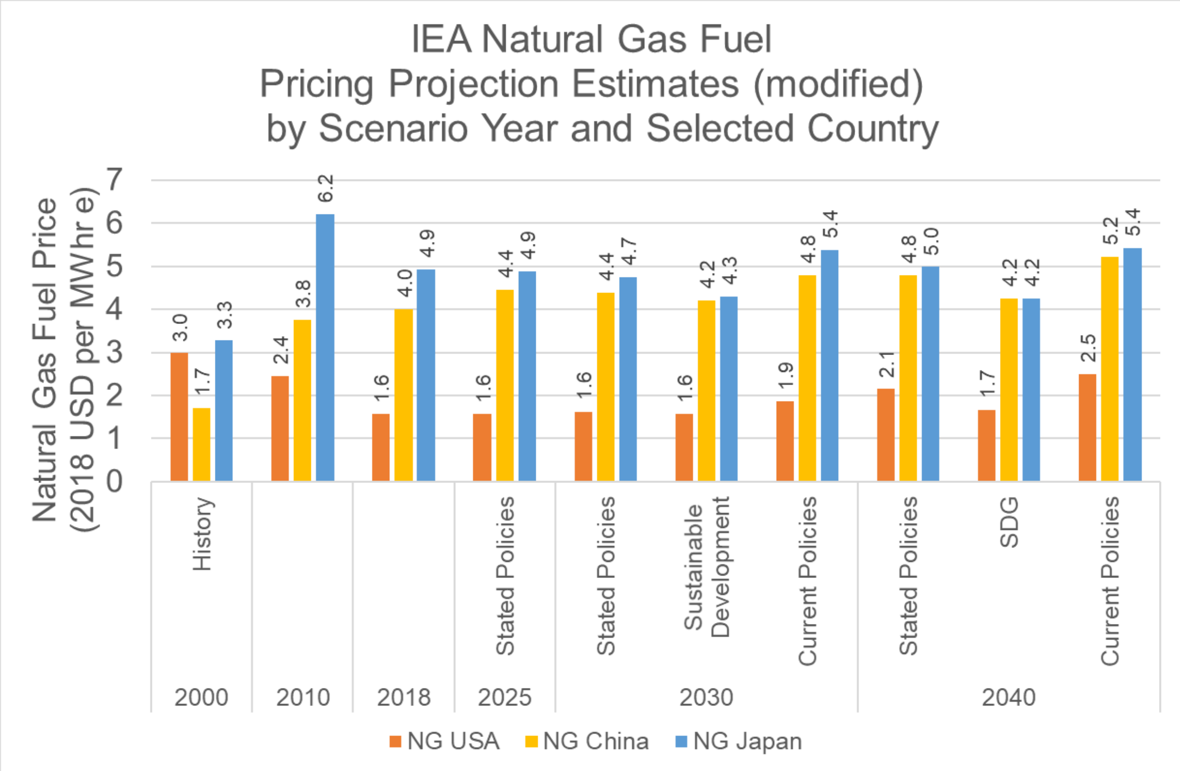


Figure 17: Various Demand Projection for Global Natural Gas Price

However the major conclusion that can be derived from this chart is that under a carbon constrained scenario as designed into the Sustainability Development Scenarios, prices for LNG are forecast to drop by 12% to 2030 and by nearly 15% by 2040.

Quality

Under any scenario, the increased costs of managing poorer quality gas for offsets will also is reflected in other operational costs, reflecting some of the resource economics symptoms outlined by economists (Hotelling, 1931a), where depletion of the quality of resources may reduce margins for both proponent and State over time, even as scarcity increases price.

For example, Woodside's (McConnell & Grant, 2019a) report shows that LNG produced from the Browse Basin, and intended to extend the life of the Burrup NWS Joint Venture plant, will have a local emissions intensity of around 26kg CO2 per Gigajoule. This is, as indicated in their own report, nearly twice the average for Australian LNG exports, making it one of the most polluting facilities in the country, and two and a half times that of the gas it replaces. Further it is over 30% more polluting than China's projected expected gas mix by the IEA. Any penalties associated with life cycle carbon equivalent polluting emissions will only increase as the quality decreases.

Further, in Woodside's case, the increased distance from the LNG plant and the depth of access to reservoirs all indicate an increased economic penalty, which may be broadly termed "quality" issues.

Some Big Reports in the Last 12 Months

What do these scenarios indicate for the Australian LNG export Industry?

Given the inability of Australian LNG to effectively contribute to the macroeconomic wellbeing of Australia under current policy settings, the increased competition for and subsequent reduction in demand and pricing forecast and the already apparent negative impact of decreasing quality of natural gas reservoirs, it is not feasible to foresee any macroeconomic improvement without significant policy resets.

In regards to its "Stated Policies Scenario" the International Energy Agency similarly makes a startling claim (International Energy Agency, 2019a)

"There is significant uncertainty as to the scale and durability of demand for imported LNG in developing markets around the world. LNG is a relatively high-cost fuel; investment in liquefaction, transportation and regasification adds a considerable premium to each delivered gas molecule. Competition from other fuels and technologies, whether in the form of coal or renewables, loom large in the backdrop of buyer sentiment and appetite to take volume or price risk."

Given that the comment reflects the situation for a market which under this scenario continues to grow, as noted in the next section, the implications for Australian LNG, for either a scenario based on Sustainable Development and/or Carbon Constraints is grim.

This is further reinforced by yet another similarly recent report which examines the gap between current Governments' global signal of development of fossil fuel capacity and the production Gap (Stockholm Environment Institute, 2019):

"Governments are planning to produce about 50% more fossil fuels by 2030 than would be consistent with a 2°C pathway and 120% more than would be consistent with a 1.5°C pathway."

We in Australia are particularly cognisant of the economic impacts of the collapse of a resource based or manufacturing industry on this scale due to gross over supply.

For the LNG industry in particular the International Gas Union's[5] latest report (International Gas Union, 2019) indicates that as of February 2019 the:

[5] The mission of the IGU is to advocate gas as an integral part of a sustainable global energy system, and to promote the political, technical and economic progress of the gas industry. The more than 160 members of IGU are associations and corporations of the gas industry representing over 95% of the global gas market. The working organisation of IGU covers the complete value of gas chain from

- Global nominal liquefaction capacity was 393 MTPA (21.5 EJ/yr), and
- Proposed liquefaction capacity was 843 MTPA (46 EJ/yr)

This forcast increase at over 200% of current installed capacity is occurring at a time when constrained scenarios particularly for the Sustainable Development Policies of the IEA and the IPCC 1.5 Scenarios are calling for a reduction from 2025 onward and with a reduction of between 24 and 44 EJ per year by 2040, not the business as usual 46 EJ per year indicative increase just for one element, LNG.

The report notes that of the proposed projects, the majority are targeted for the United States and Canada. Further, projects based on massive resource bases have continued to sign offtake agreements or attract new partners which will help reach FID, as is the case in Mozambique and Russia. Qatar has also proposed expanding capacity in the 2020s to ensure it is the largest liquefaction capacity holder in the world. These expansions are targeting the mid-2020s as the next period in which to bring new liquefaction capacity online.

The report also notes that despite “increased optimism” in future LNG demand growth, much proposed liquefaction capacity will be challenged by fierce competition for LNG buyers, project financing, and available engineering, procurement, and construction (EPC) contractors.

The Future for LNG in Australia

We conclude that current and aspirational policies signalled by both the Australian LNG industry and most tiers of Australian government are at odds with clear and present existential economic and environmental threats to the Australian future quality of life though anthropomorphic climate change, primarily from fossil fuel consumption.

These critical participants are literally banking Australia’s LNG export economy and to a lessor degree Australia’s economy on the hope that the world is unable to limit the unfolding damage induced by Climate Change, through constraining carbon emissions.

The evidence is clear: industry experts and groups such as the IPCC now produce the evidence that the consumption of natural gas must reduce globally, and that high cost and heavily polluting LNG is a risky option especially for developing countries such as China and India.

Many others will be able to differentiate the poor long-term economic benefits, and some of the similarly unprecedented costs to domestic consumers of gas, that Australia has reaped from its LNG and natural gas industry in comparison to most. The two standouts in all of this include Norway who have swapped one sovereign

exploration and production, transmission via pipelines and liquefied natural gas (LNG) as well as distribution and combustion of gas at the point of use.

asset (natural gas etc) for others (sovereign funds and state owned industry), and China, who has leveraged a relatively resource poor country into a global superpower over several decades.

Australia's strategic and policy settings around LNG must be targeting a transition, not growth. The question is now "how can the LNG industry leave a legacy for all Australia", given its historical failure to remarkable improve the overall long term wellbeing of Australians under current political and economic settings.

Policy options include:

- Clear and current policies to retain untapped domestic natural gas resources as strategic energy and industrial reserves;
- Support the economic status quo for existing operators; and
- Leverage the scale and natural advantages of agglomeration opportunities around existing plant, especially where synergies in industrial and market opportunities exist such as in the North West and North East of Australia.

The last of these policy objectives is explored in the next section: providing a sustainable pathway. It outlines a clear strategy to support the LNG industry and for it in turn to leave a legacy which supports expanded energy exports, reattraction of trade exposed energy intensive industries currently fleeing Australia, and develops a raft of high technologies and associated manufacture, much as China has done with its long term strategic approach to development of its strengths and weaknesses.

What does this Future mean for Australian LNG: A Sustainable Pathway?

In the case as anticipated that the industry will face Intense competition slowing demand and weakening price a variety of policy option need exploration.

For example, is it time to plan for “value add” in Australia rather than export?

In the face of poor returns in recent years to the people of Australia and an intensifying competitive environment and shrinking market, the industry needs to develop an alternative approach to leave a lasting and useful legacy to the people of Australia. Australian LNG plants need:

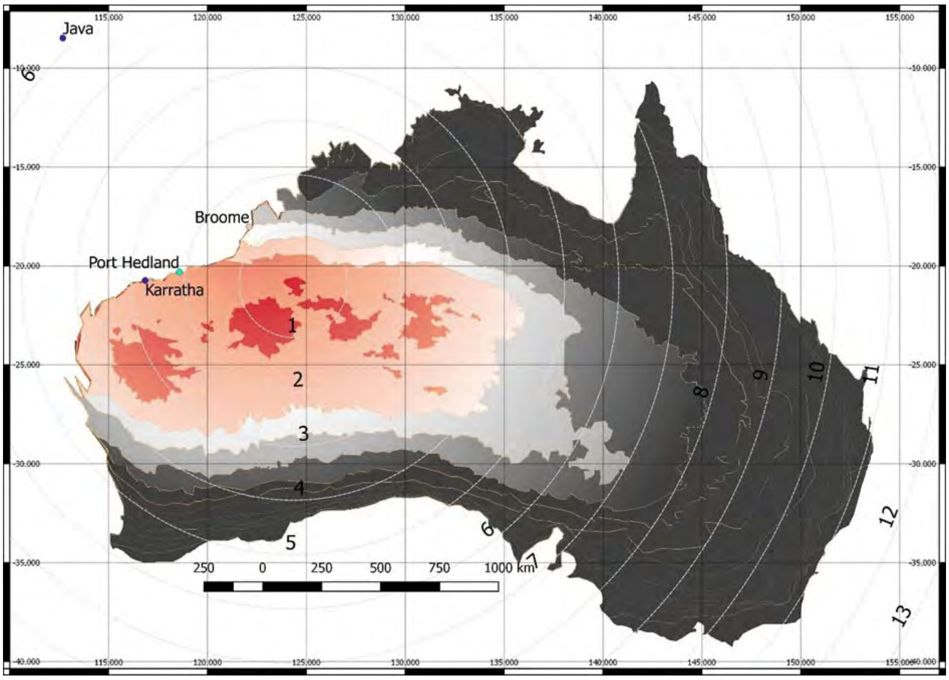
- to be powered by renewable energy much like Inpex have announced for their Darwin LNG facility
- Carbon Capture and Storage (CCS) as standard procedure, much as Chevron is attempting at the Gorgon LNG project, with attendant research to develop industries such as sustainable plastics LNG and natural gas and carbon uses such as graphene;
- Australian Offsets such as tree planting and renewable energy projects to be used to create thousands of new jobs for regional Australians, and
- It’s infrastructure to be given a longer life into an era where fossil fuels are removed from our economy, by creating green hydrogen for export

Australian Fossil LNG Leaving a Legacy

The key legacy which the LNG industry can leave is renewable power production and most importantly electrical transmission infrastructure of a quantity and quality sufficient to reverse Australia's industrial fortunes.

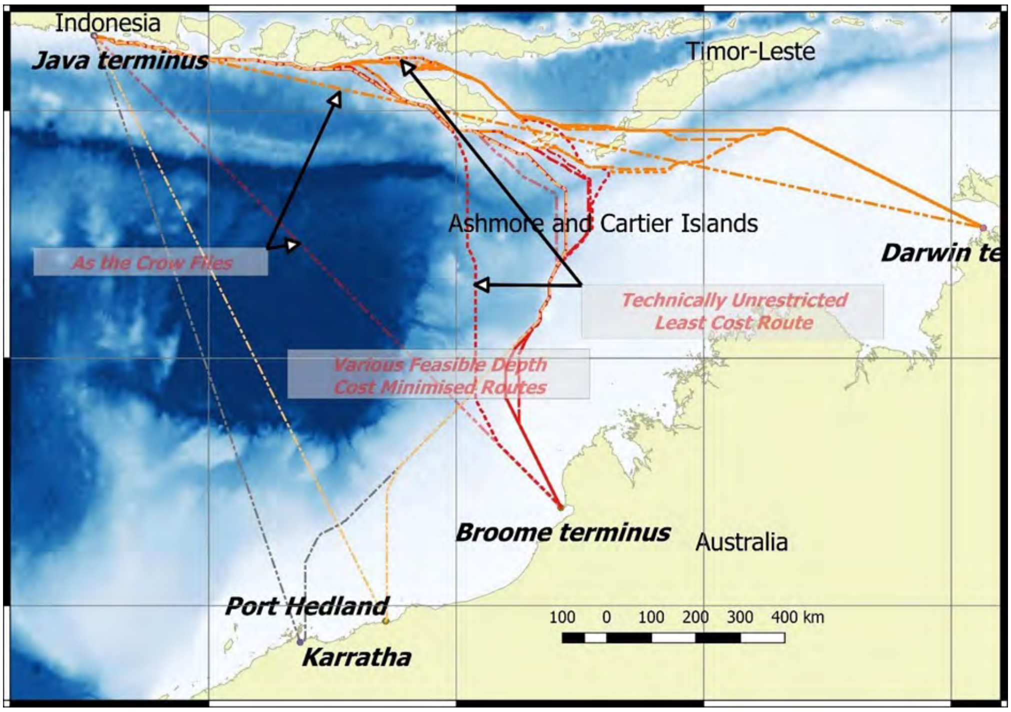
The vexed problem of our Pilbara carbon ghetto caused primarily by the LNG and iron ore industry is addressed enabling these producers to become carbonless and lower cost producers.

Australia has the opportunity to reconceive its industrial and energy strength, and leverage the third wave of large scale natural resource developments in the North of Western Australia: its world class solar insolation resources located not only in the Pilbara region but just to its North in the arid lands of the south/south west of the Kimberley region. Harnessing this power enables electrical power to channel north west across the coastline north of Derby to both Timor Leste and Indonesia, and **<u>south west to the large industrial complex of the iron ore and LNG industries</u>**.



The combination of all these markets will attract energy intensive high value add industries such as the aluminium smelting companies currently slowly exiting Australian shores to cheaper cleaner and more reliable energy suppliers elsewhere. The region has the potential to rival and surpass similarly emergent regions but based on renewable energy and local labour.

The attraction for Indonesia will be to emulate China's emergence based on low energy cost and relatively cheap labour costs to create an internationally competitive industrial complex based on the next generation of energy providers. Further, good policy development by WA and Australia may encourage a "free development zone" all around the Timor sea for these three regional neighbours to bolster regional and economic security, something which is valuable for all.



The attraction for East Timor is that it can do something similar, enable vision beyond that of fossil fuel exploitation: a resource which may find itself stranded with as the world trade decreases under global environmental concerns.

The attraction for Australia and particularly the Kimberley and Pilbara regions is to develop a completely new suit of technologies, based on a world class development, which not only enables the nation to leverage its natural resources into world class manufacture, but to revitalise its manufacturing prospects by: cornering several of the last renewable energy technologies and bringing them to the world; and providing a reason for very high technology energy intensive and high capital investment manufacturers to return to Australia rather than pack up and leave much as has happened over the last 20 years. Additionally, our estimates of the export market is about USD 20 billion plus per annum, eclipsing that for LNG and reaching toward our iron ore exports.

Key points are:

- Both Australia and Indonesia would like to attract new energy reliant heavy industries. This is hard to do today, as most companies are looking for the least expensive energy coast as well as large quantities with high reliability and most importantly are very happy if this can be achieved with carbonless energy supply. Australia has seen a nett loss of these industries over several decades;
- Similarly, there is a social responsibility to turn older and existing energy dependent industries away from carbon intensive fossil fuel reliance in both countries, but to do so without economic penalty;

- Both Australia and Indonesia are vulnerable to international natural gas pricing which is pricing domestic industry out of the market;
- Indonesia also has a need for new energy sources at least equalling all of Australia's current demand over the next decade should it wish to meet its social development policies
- Most energy policy is focused on residential commercial and less energy intensive industrial sectors due to the seemingly impossible ability to address energy intensive and heavy industry;
- Indonesia also has a population which can provide competitive skilled labour costs against competition from some of the major Asian Nations (India and China);
- Australia has the largest and world beating solar resource in the Kimberley and Pilbara regions without a large enough current demand to facilitate its development;

There is a (closing) time gap currently in a handful of emerging solar and power technologies which if deployed at scale and in a timely manner for this project will underwrite a new world class industrial base for the proponent states (Australia and Indonesia) therein developing their own manufacturing and science base to serve the world market

The proposal is to create a world scale industrial cluster around the Timor Sea targeting energy intensive resource value add (e.g. aluminium smelting) and manufacturing industries based on competitive labour coasts, low cost high volume and reliable low carbon electricity (approx. 97% reduction from equivalent in gas) supply, thus enabling access to established shipping routes and perhaps establishing some new ones.

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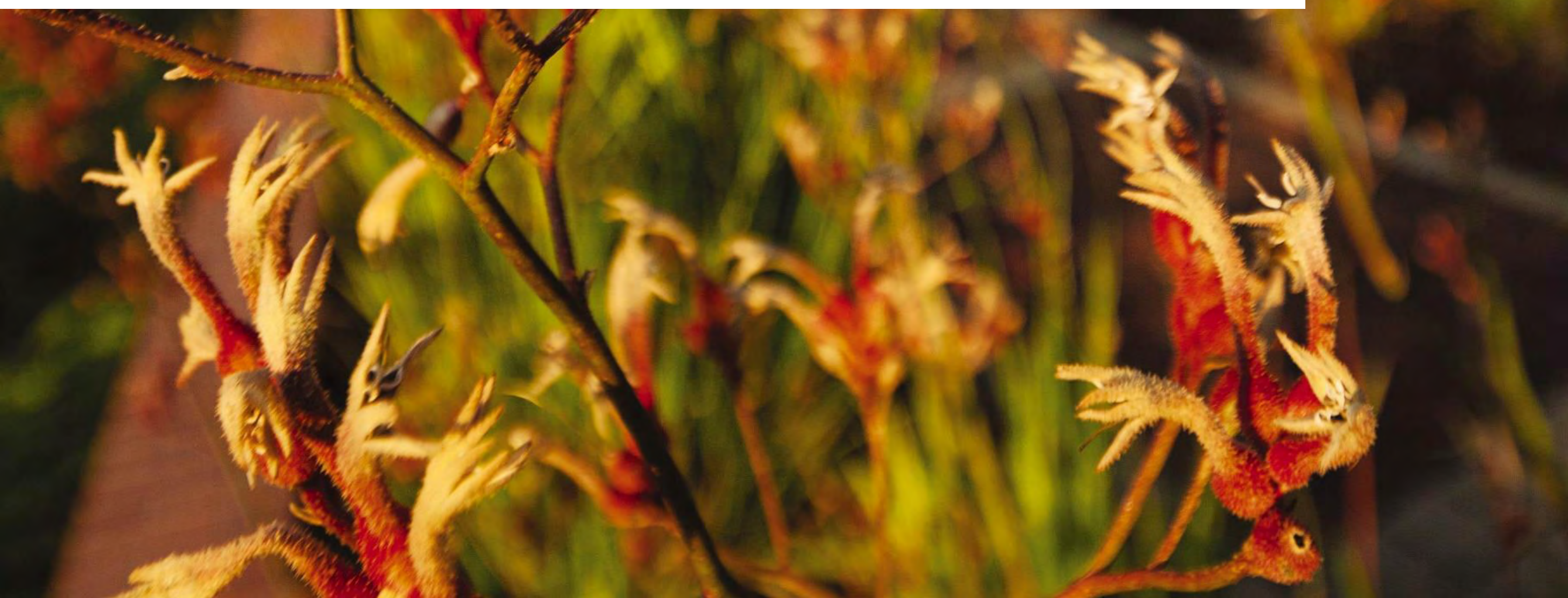
Curtin University

A Response to the EPA

In response to a Request for Input regarding the Question: *How should the WA EPA consider greenhouse gas emissions when assessing significant proposals in Western Australia?*



In response to

a Request for Input

regarding the Question:

How should the WA EPA consider greenhouse gas emissions when assessing significant proposals in Western Australia?

Authors:

Boyd Milligan BEng (Hons) MBA MIEAust

Adjunct Senior Research Fellow

Curtin University Sustainability Policy (CUSP) Institute

School of Design and the Built Environment

B,Milligan@curtin.edu.au

Professor Peter Newman AO

John Curtin Distinguished Professor of Sustainability

Curtin University Sustainability Policy (CUSP) Institute

School of Design and the Built Environment

P.Newman@curtin.edu.au

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Executive Summary

We show that humanity's response to the threat of climate change caused by anthropomorphic greenhouse gas emissions, primarily from fossil fuels, will create an existential threat to Western Australia's resources industries, particularly the incumbent LNG industry and its proposed hydrogen export industry based on fossil natural gas. This threat does not appear to be on the agenda of the companies involved but global focus is now shifting to reveal natural gas is as big a threat to global climate change as coal. It is likely that there will be a collapse in the market for natural gas from WA. Such a threat to these industries also threatens the social and economic wellbeing for all Western Australians, and to only a slightly lesser extent, all Australians. This submission sets out how WA can turn the threat into an opportunity.

The "call to reason" initiated on the release by the State's EPA this year of a Greenhouse Gas Guideline (currently withdrawn) for large projects in the State of Western Australia is also a significant recognition of the threat to our natural social and economic environment by Western Australian sourced GHG emissions**. The resulting response from the State Government whereby a commitment was made to a net zero carbon budget by 2050 is a welcome, timely and responsible act. This can be an important step in addressing the threat and beginning the transition in the state's economy.**

This report summarises our long-term analysis of the threat and puts forward conclusions and recommendations around the questions posed by the EPA's invitation for input in detail about how WA can respond to this existential crisis in a way that creates a new and highly productive economy on the global stage.

We offer a glimpse into at least one pathway of how the new climate-responsive global economy may be navigated through to a surprisingly optimistic global positioning for Western Australia as a renewables energy exporter of electricity and hydrogen and a variety of related manufactures, most importantly in conjunction with existing resource industries.

To achieve this requires swift, smart and cooperative macroeconomic efforts by the State and Federal Governments; holistically and strategically guiding and incubating the State's natural advantages, incumbent resources giants and new entrants in a targeted regional strategy.

Our research indicates Western Australia can achieve a Win/Win/Win for everyone. We have mapped one way which delivers hope of not only zero GHG emissions in the Pilbara but also:

- **A significant new export industry valued at about USD 25 billion per annum employing in the order of an additional 20,000 directly employed personnel;**
- **A catalyst for capture, development and exploitation of related "teenage" technology resulting in the deployment of about 15,000 direct manufacturing jobs;**
- **A catalyst for industrial revival of major value-added industries reattracting those currently fleeing, such as alumina and aluminium facilities and more;**
- **A catalyst for another investment and construction era greater than that of the recent one around LNG and Iron Ore, implying investment of USD 250 billion in industrial infrastructure over 20 years and a workforce of 30,000 direct construction jobs;**
- **Development of an Industrial Research culture around WA's tertiary institutions leading to around USD 10-30 billion in Research and Development activities over the next 10 years, and potentially a hub for tertiary education in the Pilbara and Kimberley regions;**
- **Regional engagement with the NT, Timor Leste and Indonesia for development trade and security value add where WA is at the centre of a major regional economic hub.**

Conclusions and Recommendations

We conclude that all jurisdictions must act in accordance with the combined Paris Agreement principles and targets identified by the recent IPCC report. We show that Western Australia is a globally significant contributor to the threat of climate change and therefore our society must act either unilaterally or in concert with the Federal policy setting, whichever best drives to achieve the global needs, but never abdicating our responsibility to take aggressive and escalating (progressive) action based on equity and sustainability principles for our jurisdiction to exceed the global average target of net zero emissions by 2050.

We conclude that this is not only an environmental necessity but an economic one too.

We recommend that the EPA consider, aggregate, update, enumerate, and continuously monitor current scientific understandings of the current and potential environmental harm to Western Australia due to GHG induced climate change, past present and emerging, using its identified Environmental Factors framework to adequately inform the process and participants. This forms the basis of a new economy growth phase just as California used environmental regulation to help lead the USA in its economic leap into the next digital and renewable electric economy.

Western Australian GHG emissions from resources extraction and use are significant at a Global Scale

We recommend that the State of Western Australia should develop a significant leadership role in managing the negative impacts of GHG emissions from LNG production, and by default other large-scale natural resources exploitative industries, such as the iron ore industry. First movers may gain a competitive economic advantage and develop a subsequent industry of global significance.

Our conclusion is that Australian gas exports are significant contributors to global GHG emissions and thus pose an existential threat to Western Australians through impacts of climate change and the global response to the LNG industry. As a host to the pre-eminent exporters of LNG in Australia, Western Australia has the capacity and means to further the Paris Agreement objectives rather than be seen as a major barrier to reaching them. It can do this by undertaking a lead role for equitable, sustainable and ambitious plans to eliminate environmental threats posed by LNG GHG emissions, and potentially develop associated subsidiary industry in a new era for the Pilbara as a resource hub for the future economy in the Indian Ocean/Asian region.

We conclude that potential exists for significant tension to develop over economic imperatives and damages consequent on this region's contribution

to GHG emissions, between and within both the State and private sectors. Our research indicates that collaborative innovative and willing cooperation and contribution by both these actors and others can achieve ongoing economic prosperity and meet recently stated emissions reductions in a timely manner. This may be considered an opportunity rather than a threat if managed well.

Our conclusion is that Australia, amongst the world's 195 sovereign states (and to an even greater extent, Western Australia), not only contributes more to climate change than most, but also has wealth and national income relatively greater than almost all nations. Australia thus has one of the best capacities to aggressively, equitably and sustainably advance our contribution to this global challenge, even beyond the political commitments to date.

The Paris agreement foreshadows the imperative for countries in this position to accelerate transition to a decarbonized economy.

We conclude that if a democratic and wealthy nation such as Australia, and subsequently a democratic and wealthy state such as Western Australia, cannot accelerate their commitments beyond the minimum, then there is little hope for the global response to be successful. It is time for WA to take further steps in leadership in this rapidly growing arena of political and economic change as it transitions to a new economy. This is our opportunity.

What is the information that should be required by the EPA for Environmental Impact Assessment?

We recommend that the EPA look internally at its own procedures and capacities to more fully explore all claims made within an EIS regarding GHGs and assist in providing balanced advice. In this regard full life cycle analysis of GHG must become a regular part of all LNG proposals.

We recommend the following principles be encouraged in the development, presentation and examination of the GHG emissions in projects examined by the EPA in WA:

- **We recommend that proponents are encouraged to undertake their best endeavours to transparently and holistically report on the GHG impact of their proposals and how they can contribute to the transition to the net zero emissions economy.**
- **We further and specifically recommend that proponents are required to transparently and holistically report on the speciation of the hydrocarbon extracted from any reservoir for use in any way in the process of producing commercial grade natural gas or other fossil fuel for either domestic markets or for export.**
- **We recommend that proponents submit as part of their EIS a holistic statement and justification regarding the sustainability for current and**

future residents of Western Australia overall, and particularly as a consequence of the GHG footprint of their proposal and how it meets the global, Australian and Western Australian net emissions targets.

- **We recommend that the EPA also present to the Minister a separate macroeconomic statement and justification of their recommendations based on sustainability principles. Although on the surface this would be seen to go beyond the environmental remit of the EPA, it is essential in understanding why choices are being made by the industry which have significant environmental implications.**

We recommend that industry bodies, proponents, state and federal jurisdictions, and academic institutions, jointly develop standardised reporting protocols which conform with these principles, robust enough to articulate into relevant global standards, and financial and regulatory instruments being considered at all statutory levels.

We recommend the development of a Technical Advisory Committee in the EPA to provide local coordinated and well-resourced independent functional advice to extend industry best practice around 'GHG emission factor' presentation. This also facilitates a requirement for community trust and oversight, as well as regulatory audit and verification.

We recommend that the concept of "free" natural gas fuel be examined in the context of its perversion of the goals of GHG mitigation in the LNG industry, and appropriate regulatory steps be taken to remove this impact. Further we recommend that the concept of "best practice" mitigation efforts be reinforced as being a functional concept to help lead industry into contributing to the transition away from fossil fuels, not limited by current industry practice.

How emissions associated with a proposal should be considered by the EPA

Our conclusion is that:

- **all the elements of GHG, both embodied in the original gas and produced in its processing, whether it's released in Western Australia or elsewhere, is significant and the environmental harms so produced should be considered;**
- **indirect (scope 3) emissions form a part of the life cycle of all products and are therefore relevant and in context with State Responsibilities;**
- **the natural gas industry implies awareness of scope 3 emissions when they state that gas is substituting for coal;**
- **the relationships for Western Australia as a state within a Federation, to Federal targets and regulations, need not, indeed should not, be binary nor subsidiary. The State is right to implement its own policies especially if they require greater GHG responses. However economic equalisation**

will be an ongoing issue given the vulnerability of the resources industries in Western Australia to GHG action and the wider economic benefits of hosting such industry;

- **all these elements can be conflated with the environmental harms in Western Australia, and therefore all such emissions related to the lifecycle of the product so produced, including both upstream and downstream scope 3 emissions fall under the auspices of the EPA through its responsibilities outlined in detail in its enabling act It is required to consider the environmental harm caused by a proposal brought before it;**
- **Only by including scope 3 emissions will proponents be able to participate fully in the transition to the new economy.**

We recommend that a project proponent be required to report on the lifecycle assessment of the GHG emissions under a standardised framework based on lifecycle analysis and undertaken to international standards such as that produced by the ISO. Such analysis should clearly delineate the proponent's specific internal responsibilities within their proposed processes and how the proposal fits into the broader transition to a net zero emissions economy.

Gas substitution for coal

We conclude, based on statistical analysis of energy trends worldwide, that contrary to oft quoted substitution of coal for natural gas, globally and in the jurisdiction of the USA, Australia and China, natural gas is at best a partial substitute for coal (US) or otherwise only indirectly substitutable. The more substantial finding is that substitution for coal is identified to be caused by the increasing penetration of renewables particularly wind energy. Roof-top solar is a more recent phenomenon that is considered now to be more cost-effective than all other energy sources. Roof-top solar energy is not part of the analysis as national data sources rarely include it because its behind the meter. Natural gas is shown in general to compliment coal in providing energy in jurisdictions with growing economies and populations. It in general is found to supplement the penetration of wind power in adopting jurisdictions.

We further conclude that natural gas, and therefore LNG as a specialised and more complex, subsidiary product, in general is not a "transition fuel" but an "agnostic complimentary" energy source for more primary energy sources. We find this agnosticism creates dangers for the Western Australian climate and industry if not regulated to reduce or halt facilitation of unsustainable primary fuel sources. We also find that it opens opportunities for natural gas to find its niche as a much higher value "facilitative" fuel and security asset in the transition to a new economy.

Our recommendation, in light of the probable inaccuracy of previous claims by the industry, that the EPA must require of proponents for proposed energy projects, or for that matter any project with significant scope 3 emissions, to cause:

- **scope 3 emissions be considered analysed and identified in detail;**
- **substitution claims for GHG credits by proponents be specifically attributable, quantified and exhaustively substantiated beyond a reasonable doubt;**
- **no project be granted environmental approvals unless able to demonstrate a firm and committed pathway to the net zero economy.**

We conclude that globally coal consumption from 1965 to 2017 continually grew, that it was most proportionally influenced by renewables and economic growth, but to only a slightly lesser extent influenced by the growth of nuclear and fossil fuel consumption as well as population growth. By corollary we conclude that gas has been shown to have no broad substitutionality with coal at a global level.

We conclude that on a world stage, solar and wind energy are a broad substitute for gas, or compete with gas, in its market and taking into account the conversion efficiency of gas to electricity it is a direct competitor to these renewables, or at least may simply be assisting renewables through grid stabilization before other storage mechanisms are introduced.

Our early findings from statistical analysis of global data trends in energy point to:

- **the role of the burgeoning shale gas industry in the US may be considered to be relatively facilitative regarding GHG emissions overall, playing some direct role in the decline of coal, but is by no means the whole story in this decline. It also appears to be facilitating the introduction of wind energy but may be serving as a barrier to wider implementation of solar energy in the US.**
- **the role of the burgeoning coal seam gas industry in Australia may be considered to be only indirectly facilitative regarding GHG emissions overall. In aggregate across Australia, gas seems to have played little direct role in the obvious decline of coal consumption. It also appears to be facilitating the introduction of wind energy and perhaps more recently solar.**
- **the role of importation of LNG into the PRC may be considered to be only indirectly facilitative regarding GHG emissions overall. In aggregate and historically, gas seems to have played little direct role in the obvious decline of coal consumption across China. It also appears to be facilitating the introduction of wind energy.**

We recommend exploration and implementation of bilateral mechanisms with approved trade partners to equitably share the economic benefits and costs associated with the lifecycle of scope 1, 2, and 3 intensive emitting products. These include benefits of substitution and costs of carbon leakage upstream along the supply chain, based on the principle of equity in exploitation of societally beneficial finite natural resources Such resources are (in Australia at least) owned by the people in trust to their State and Federal governments.

We recommend that any offsets and value of carbon credits created be shared equitably between all parties to the proposal including both host governments.

We recommend that Western Australia, Australia, and other sovereign states driven by equity and sustainability ethics should create a legally binding framework to drive bilateral agreements for export of product with potential significant offshore scope 3 impacts (e.g. fossil fuels like LNG) like those implemented for uranium export.

Our conclusion is that the implementation of whole product life cycle commitments in EISs will circumvent the opaque behaviour that is so evident at present.

The constraints on potential emissions mitigation conditions the EPA should recognise

We recommend that the EPA demand more transparency, greater focus and a broader interpretation of "best practice" when examining the mitigation strategies proposed by project proponents.

We recommend that industries and perhaps the Government strive to become leaders in best practice in GHG mitigation in key industries such as the iron ore and LNG industries. This is particularly pertinent where proponents participate in globally significant industries through localised research and development specifically targeting GHG mitigation.

We recommend that the conditions around mitigation include a nominated and aggressive downward trajectory for GHG emissions over the life of the projects which is in alignment with both Federal and State Government policies. We also recommend the formation of a system of annual review to ensure ongoing and dynamic downward pressure on implementation of avoidance and reduction strategies.

We recommend that the state investigate potential incentives for currently operating projects to enable them to implement strategies in line with the recently announced mitigation target of net zero by 2050. This may include preferred partnerships in any overarching industry development that facilitates transition to the new economy.

We note that Western Australia is in an ideal position to take advantage of bio sequestration methodologies as a primary offset mechanism, as nominated by the IPCC.

We recommend that offsets be used as a last resort, be local to ensure minimal economic leakage around currently externalised GHG emission liabilities to the state and meet both Australian and best practice international verification techniques.

We conclude that the incumbent Western Australian LNG producers can make a significant GHG reduction by applying technology proposed in producing Cyan Hydrogen (fossil natural gas processed using renewables) to existing LNG processes in the short term. To do so brings forward the potential Global GHG emission reductions of about 15% attributable to the industry, with less risk and without Carbon Leakage from Japan to Australia. The State Government should actively assist the industry to do so including to create economic conditions and infrastructure to facilitate implementation of 100% renewable energy supply to existing facilities, and market Cyan LNG, not Cyan ammonia-based hydrogen transport.

We recommend that the EPA investigate all proposed processes for lifecycle GHG emissions to identify:

- **technologies which can translate to reductions in current GHG emissions at existing facilities in the short term; and**
- **determine potential for Carbon Leakage in favour of client nations and at the expense of Australia's GHG burden.**

We conclude that in the long-term Cyan Hydrogen should be sidelined in favour of development of fully renewable technologies for energy export including "Green[1]" ammonia-based hydrogen transport and ultra-high voltage direct current subsea (UHVDC) technology for electricity transmission. This is the basis of the new economy in our region.

We recommend that during the transition period, the State Government actively participate in discouraging short term microeconomic gains to industry that cause subsidy of incumbents by the Australian community The Government should encourage new industry to maximise macroeconomic gains in the long term seeking to demonstrate these new technologies.

We conclude that the current externalised costs to the Australian people of hosting the LNG industry in Australia are unsustainable and unfair. However, should these costs be internalised to the industry, the incumbent industry may also be commercially compromised. Thus a transition strategy is needed.

Further, our estimate of the <u>global</u> GHG amelioration costs attributable to the Australian LNG industry will be at minimum between AUD 307 billion dollars and AUD 629 billion present value. They represent an indicative increase in supply

[1] Blue is widely identified as, and nominally the colour identified with fully fossil natural gas derivatives (e.g. blue Hydrogen) and renewable energy represented by green.

chain pricing necessary to internalise the costs of emissions of between 26% and 55% of gross revenue for exported LNG.

Summarizing One Pathway to Break the apparent Binary of Existential GHG related Climate Change with Western Australia's looming Economic Existential Threat

Finally, and just as importantly, the vexed problem of our 'carbon ghetto' caused by the LNG and iron ore industry in the Pilbara is addressed enabling these producers to become carbonless and lower cost producers in a new regional economic hub.

The proposal is to create a world scale industrial cluster around the Timor Sea targeting energy intensive resource value add (e.g. aluminium smelting) and manufacturing industries based on competitive labour costs, low cost high volume and reliable low carbon electricity supply (approx. 97% reduction from equivalent in gas), thus enabling access to established shipping routes and perhaps establishing some new ones.

This is only likely with close collaboration at a government to government level between Australia and Indonesia.

The first step is for the research community and the state government to:

- **Undertake a significantly more resourced due diligence analysis on the transition strategy to a net zero economy driven by new industries in the Pilbara;**
- **Work to build support at the intergovernmental (WA, Australia, Indonesia and Timor-Leste) level and regional and international infrastructure funds with the ultimate aim of sovereign funding of approximately USD 13 billion to build own and operate the first (of potentially nine) electrical energy links between Indonesia (IndoLink) and the Pilbara (PilbaraLink);**
- **Work with the Federal Government and other State Governments to understand the positive economics of transmitting electricity (TransNational link) rather than natural gas from the Pilbara and linking the region into the National Rail Network, perhaps even with electrically powered trains;**
- **Work to gather research and development resources on a scale which ensures Australian technological (and hence market) leadership for some direct and emerging technologies are both integral and subsidiary for the roll-out of this regional development program;**
- **Work to develop major industrial policies and programs to catalyse Australian and other participant nationals towards entrepreneurial opportunities in direct development of the technologies identified as being critical to the success of the precinct;**

- **Work to develop cultural, social, environmental, and economic policy programs and infrastructure in the regions to address local equity in the Pilbara and Kimberley (for example, a University, industrial support, and land management in the region);**
- **Work to gather a cluster of energy companies to invest an initial combined USD 7 billion to provide the renewable high-quality low cost and high-volume energy to the IndoLink and PilbaraLink transmission paths;**
- **Work to gather a cluster of energy intensive high value add manufacturers and resource developers who may invest in Australia and Indonesia over the longer term. It is imperative to include local industrial players in the LNG, Iron Ore and Alumina industries, to create the new net zero industrial hub in the Pilbara.**

Contents

Table of Figures

Introduction

This submission is prepared in response to a call for input from the Environmental Projection Authority of Western Australia ("Greenhouse gas emissions assessment guidance - consultation," 2019):

"The Environmental Protection Authority (EPA) is calling for input from the community and industry on how it should consider greenhouse gas emissions when assessing significant proposals in Western Australia.".

The submission is based on insights gained from an exhaustive and as yet unpublished study by the authors[2] of all Environmental Impact Statements submitted to the various State and Federal authorities including those to the Western Australian EPA, all relating to LNG export development. They start with Woodside's ground-breaking original proposals in the 1980's. The following diagram entitled "Figure 1: Projects and Project Partners identified in Research" indicates the various LNG projects and related partners subject to our prior studies.

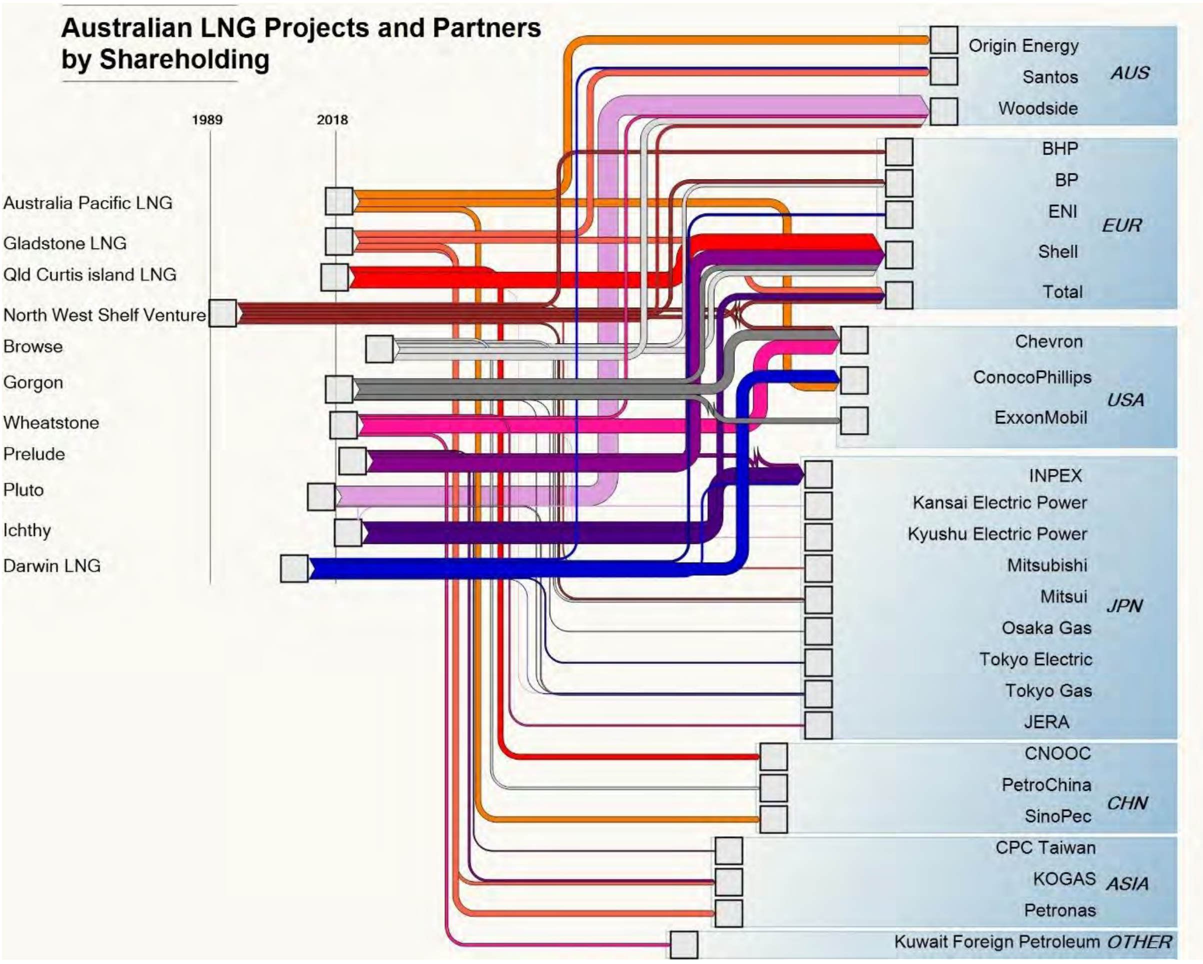

Figure 1: Projects and Project Partners identified in Research

[2] As yet unpublished

This enquiry is a critical examination of ethical and sustainability issues for a state like WA with its economy firmly rooted in the globally significant resources extraction industry, particularly energy extraction and, most of all the energy intensive and trade exposed fossil LNG industry.

A systematic failure by key decision makers to consider the social and environmental wellbeing of not only the Australian and Western Australian hosts of this industry, but the damage being caused to the global commons is evident. The global community will not any longer remain a silent partner on these issues as global climate change is now becoming dramatically more evident and democratic and wealthy places like WA will not be able to turn a blind eye to the threats being created daily by increased greenhouse gas emissions.

Western Australia has a significant responsibility in its stewardship of these resources, and thus for the consequent globally significant emissions.

Western Australia's contemplation of and action regarding its responsibilities must be considered as an early and urgent function of our body politic and business leaders.

What is the Enquiry Trying to Achieve?

Key questions posed by the EPA in asking for input include:

> *"….. the following are areas about which the EPA is particularly interested in receiving any views or information to improve the greenhouse gas emissions guidelines:*
>
> - *The information that should be required by the EPA for Environmental Impact Assessment*
>   - *information on greenhouse gas emissions and their mitigation which the EPA should expect and consider in making any advice on a proposal*
>   - *information the EPA should expect on how a proposal aligns with Australia's emissions reduction targets*
>   - *the need for, and any reasonable constraints on, transparency in emissions data and proposed mitigations*
> - *How emissions associated with a proposal should be considered by the EPA*
>   - *the scope of emissions to be considered*
>   - *the relevance and context for considering indirect (scope 3) emissions*
>   - *the relationship to national or state emissions targets and regulation*
>   - *consistency with the EPA's duty to use its best endeavours to protect the environment*
> - *The constraints on potential emissions mitigation conditions the EPA should recognise*
>   - *the appropriateness and practicability of measures to mitigate greenhouse gas emissions, including nature and level of planned reductions or offsets*
>   - *the timing of planned reductions or offsets*
>   - *the kinds or size of proposals to which the guidelines should apply*

- *Any other advice related to the assessment of greenhouse gas emissions by the EPA that would further clarify or improve the guidelines."*

Stakeholder Reference Group

The EPA has an established "Stakeholder Reference Group" which was consulted prior to initial publication of the now withdrawn Greenhouse Gas Guidelines. The EPA notes in its supporting documentation that there was some disagreement between participants of this reference group.

The agreements are stated to include the following points:

- greenhouse gas emissions should be treated as a unique factor (distinguished from air quality) and have its own assessment guidelines
- the mitigation hierarchy should apply
- emissions threshold(s) should be set to which the revised guidelines would usually apply
- the degree of any expected offsetting of emissions should be clear.

The EPA states that there was disagreement in the group on the following points:

- the need for any local (state) controls on emissions in addition to existing Commonwealth regulation
- the appropriateness or level of any offsetting.

The EPA's Supporting Information

To assist our response to this request, we have considered that the EPA is governed by the following acts and regulations:

- Environmental Protection Act 1986 ("Environmental Protection Act 1986," 1986)
- Environmental Protection Regulations 1987 ("Environmental Protection Regulations 1987," 1987)

Furthermore the following documents emanating from the EPA were considered:

- Statement of Environmental Principles, Factors and Objectives (*Statement of Environmental Principles, Factors and Objectives*, 2018)
- Background paper on greenhouse gas assessment guidance (*Background paper on greenhouse gas assessment guidance*, 2019)
- Environmental Factor Guideline: Greenhouse Gas Emissions (*Environmental Factor Guideline: Greenhouse Gas Emissions*, 2019)
- Technical Guidance: Mitigating Greenhouse Gas Emissions (*Technical Guidance: Mitigating Greenhouse Gas Emissions*, 2019)

Regulatory Regime

Whilst understanding that the requirements of the Environmental Protection Act are distributed between a variety of State Actors we note and endorse full implementation of principles outlined in the act including:

> *"§ 4A Object and Principles of Act*
>
> *The object of this Act is to protect the environment of the State, having regard to the following principles —*
>
> *Table*
>
> 1. *The precautionary principle*
>
>   *Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.*
>
>   *In the application of the precautionary principle, decisions should be guided by —*
>
>   *(a) careful evaluation to avoid, where practicable, serious or irreversible damage to the environment; and*
>   *(b) an assessment of the risk-weighted consequences of various options.*
>
> 2. *The principle of intergenerational equity*
>
>   *The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.*
>
> 3. *The principle of the conservation of biological diversity and ecological integrity*
>
>   *Conservation of biological diversity and ecological integrity should be a fundamental consideration.*
>
> 4. *Principles relating to improved valuation, pricing and incentive mechanisms*
>   *(1) Environmental factors should be included in the valuation of assets and services.*
>   *(2) The polluter pays principle — those who generate pollution and waste should bear the cost of containment, avoidance or abatement.*
>   *(3) The users of goods and services should pay prices based on the full life cycle costs of providing goods and services, including the*

use of natural resources and assets and the ultimate disposal of any wastes.

(4) Environmental goals, having been established, should be pursued in the most cost-effective way, by establishing incentive structures, including market mechanisms, which enable those best placed to maximise benefits and/or minimise costs to develop their own solutions and responses to environmental problems.

5. The principle of waste minimisation

All reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment.

§ 5. Inconsistent laws

Whenever a provision of this Act or of an approved policy is inconsistent with a provision contained in, or ratified or approved by, any other written law, the provision of this Act or the approved policy, as the case requires, prevails."

Setting the Backdrop to this Submission

The authors believe that there is little creditable opposition to the science around Climate Change and its consequences. More recently there is an accelerating urgency to protect the global environment affected by climate change. IPCC[3] reporting continues to provide the very best understanding of the current status and associated current and future impacts on the global environment and by corollary the Western Australian environment.

One of the latest curated publications to illustrate this is the document "Global warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty" (IPCC, 2018). In part it concludes:

> *"Climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth are projected to increase with global warming of 1.5°C and increase further with 2°C"*

Further it concludes:

> *"… pathways with no or limited overshoot of 1.5°C, global net anthropogenic CO_2 emissions decline by about 45% from 2010 levels by 2030 … reaching net zero around 2050 …. For limiting global warming to below 2°C11 CO_2 emissions are projected to decline by about 25% by 2030 in most pathways … and reach net zero around 2070 …. Non-CO_2 emissions in pathways that limit global warming to 1.5°C show deep reductions that are similar to those in pathways limiting warming to 2°C."*

The Australian Federal Government committed to reduce emissions by 26-28% from 2005 levels by 2030 at the Paris climate change conference[4]. Despite the above-mentioned risks and call to arms for urgent action beyond current Paris conference targets and timeframes, independent reports (Malos, Meyer, & Skarbek, 2018) are now emerging indicating that Australia is unlikely to even meet this commitment with current Federal policy settings.

The 2015 Paris Agreement ("Paris Agreement," 2015) whilst a brief document and not a legally binding one, includes several important points including:

- section 3 which asks contributors to undertake ambitious effort, and
- section 4.1 which calls for action based on equity and sustainability

[3] The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change.
[4] Australian Government Department of the Environment and Energy Fact Sheet

- section 4.3 that asks successive contributions should represent a progression beyond current commitments.

The recent release by the Western Australian McGowan Government statement on Greenhouse Gas Emissions Policy for Major Projects calling for net zero emissions by 2050 is a welcome acknowledgement of the responsibility of Western Australians to be ambitious and progressive whilst recognising our capacity to lead based on equity and sustainability, as stated in the Paris Agreement.

We conclude that all jurisdictions must act in accordance with the combined Paris Agreement principles and targets identified by the recent IPCC report. We show that Western Australia is a globally significant contributor to the threat of climate change and therefore our society must act either unilaterally or in concert with the Federal policy setting, whichever best drives to achieve the global needs, but never abdicating our responsibility to take aggressive and escalating (progressive) action based on equity and sustainability principles for our jurisdiction to exceed the global average target of net zero emissions by 2050.

We conclude that this is not only an environmental necessity but an economic one too.

The Questions this Section is Answering

The following subsections explore the past present and future impacts caused by Western Australian LNG and other less significant industries, addressing specifically the following questions:

- What is the extent of the environmental damage caused by GHGs in WA?
- Are the GHGs emitted by Australia, Western Australia and Western Australian resources industry, in particular those of the LNG Industry, globally significant?
- Are Australia's historical GHG emissions relevant to the question of equity highlighted in the Paris Agreement?

Greenhouse Gases and Related Climate Change Cause Significant Harm

Contemporary scientific understanding provides the legal basis for the EPA to consider that Greenhouse Gases create significant environmental harm to Western Australia in all sixteen of its Environmental Factors and related objectives as follows (Figure 2: Table of EPA's Environmental Factors impacted by Climate Change due to Greenhouse Gas Emissions):

Factor	**Objective**
Benthic Communities and Habitats	To protect benthic communities and habitats so that biological diversity and ecological integrity are maintained.
Coastal Processes	To maintain the geophysical processes that shape coastal morphology so that the environmental values of the coast are protected.
Marine Environmental Quality	To maintain the quality of water, sediment and biota so that environmental values are protected.
Marine Fauna	To protect marine fauna so that biological diversity and ecological integrity are maintained.
Flora and Vegetation	To protect flora and vegetation so that biological diversity and ecological integrity are maintained.
Landforms	To maintain the variety and integrity of significant physical landforms so that environmental values are protected.
Subterranean Fauna	To protect subterranean fauna so that biological diversity and ecological integrity are maintained.
Terrestrial Environmental Quality	To maintain the quality of land and soils so that environmental values are protected.
Terrestrial Fauna	To protect terrestrial fauna so that biological diversity and ecological integrity are maintained.
Inland Waters	To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.
Air Quality	To maintain air quality and minimise emissions so that environmental values are protected.
Social Surroundings	To protect social surroundings from significant harm.
Human Health	To protect human health from significant harm

Figure 2: Table of EPA's Environmental Factors impacted by Climate Change due to Greenhouse Gas Emissions

Whilst significant bodies of work indicate that harm at a global scale is caused through climate change to all these environmental factors, and some analysis has devolved to consider the harms at a national level, there remains a significant gap in the EPA's understanding of the harms already caused and in train due to the global average 1ºC increase in atmospheric temperature above preindustrial levels to date. A similar gap exists for the potential for further harms as the average temperature increases further in an unmitigated world.

We recommend that the EPA consider, aggregate, update, enumerate, and continuously monitor current scientific understandings of the current and potential environmental harm to Western Australia due to GHG induced climate change, past present and emerging, using its identified Environmental Factors framework to adequately inform the process and participants. This forms the basis of a new economy growth phase just as California used environmental regulation to help lead the USA in its economic leap into the next digital and renewable electric economy.

Western Australian GHG emissions from resources extraction and use are significant at a Global Scale

Western Australia is a part of the Australian Federation, which in turn is one of 195[5] independent States in the World. The EPA also recognises that the Western Australia population carries the second highest per capita emissions within Australia.

Significantly the LNG industry is preeminent and comparatively overwhelming in its production of GHG emissions in Western Australia. Whilst it is not the only industry operating in this state with significant emissions, this document uses this industry as a benchmark for our recommendations and conclusions relevant to the questions the EPA asks.

Western Australia's unique current GHG footprint

The Western Australian GHG footprint is significantly inflated by our industries, principally iron ore and LNG production. Whilst the iron ore industry is a large emitter, the LNG dwarfs it with its Scope 1 and 2 emissions, and contemplation of the impact of its scope 3 emissions is globally significant, as demonstrated later in this section.

The numbers indicate that the Australian LNG industry is a significant contributor. When the current projects are fully commissioned (planned by 2019) our estimates indicate they will contribute 53.2 Mtpa[6] of CO2e. This equates to 9.7% of Australia's 2016 reported inventory.

[5] US Bureau of Intelligence and Research Fact Sheet: Independent States in the World, dated March 27, 2019.
[6] Including a 3% overhead on our own figures to account for N_2O emissions.

Most importantly, these emissions are virtually uncontrolled by Federal legislation. The LNG industry appears to be a protected industry and the safeguards are being tilted towards industry development, directly at the expense of the global atmospheric commons.

Further, should the industry undertake expansion in both greenfield and brownfield developments as contemplated in the various EISs, the burden will nearly double to 105 Mtpa, representing an unregulated 19.2% of Australia's 2016 emissions.

Current Australian LNG operations are projected to contribute, over their lifetime, a total 11 billion tonnes of CO2e to the global commons, and with further expansions, a total potential of 23 billion tonnes. This current contribution is in the order of 1.5% of the remaining global carbon budget and when the recognised greenfield additions and brownfield expansions are included this expands to 3.1% of the remaining global budget.

The following figure entitled "Figure 3: LNG Project Participants and their relative global GHG contribution from Australian Resources" shows the 26 large multinational operators, their relative contributions to Australia's scope 1 2 and 3 annual emissions at maximum extent as notified in their various Environmental Impact Statements and how this plays out at a state level and national level.

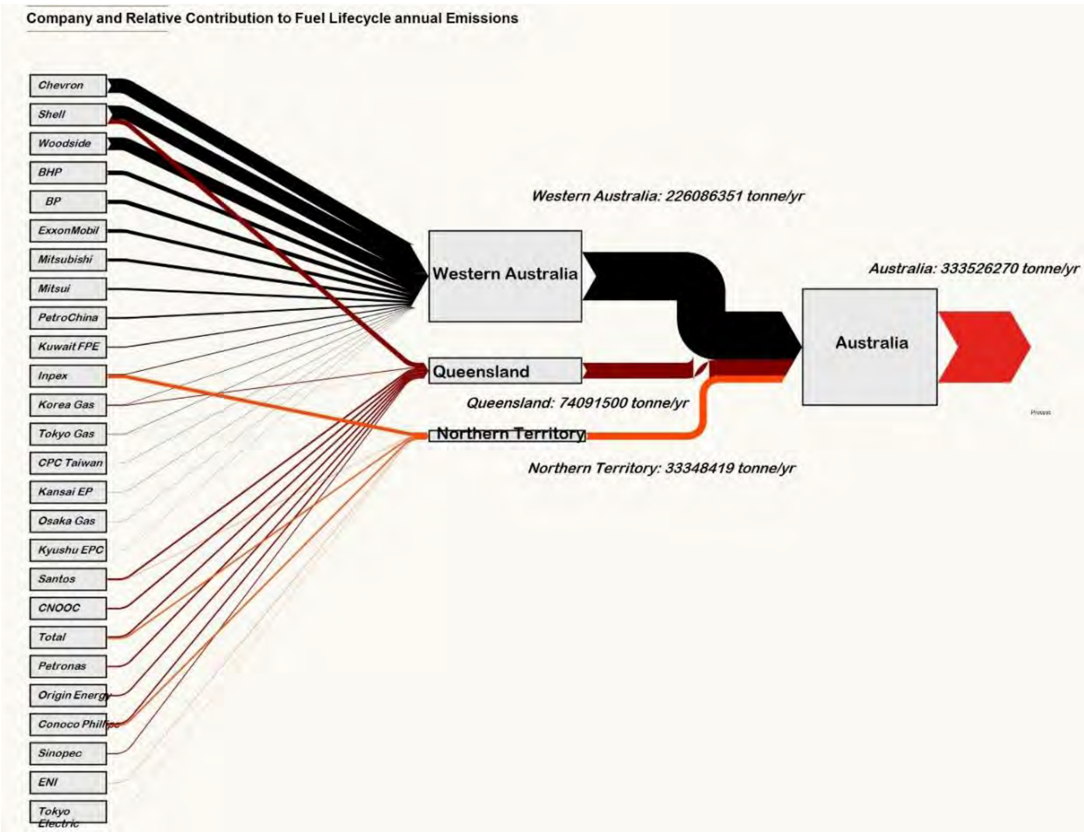

Figure 3: LNG Project Participants and their relative global GHG contribution from Australian Resources

Most notably:

- Australia has the approved capacity, given all currently contemplated facilities, to export 334 Mtpa GHG potential per annum through its LNG facilities, which equates to approximately 60% of Australia's annual contribution of GHG as measured by the current accounting system, AEGIS;
- of the 26 multinationals involved in the Australian LNG industry only 3 are majority Australian owned and based. This is an important issue in that without firm sovereign management, the major decisions are made in the boardrooms located well offshore; and,
- nearly 70% of these LNG related GHG emissions will come from the Western Australian region, the majority of which lies within the State Government's responsibilities for environmental protection.

The following Figure 4: Geographical Distribution and Representation of Individual project's current and potential future contributions to GHG Emissions, indicates the industries regional and relative contributions by project.

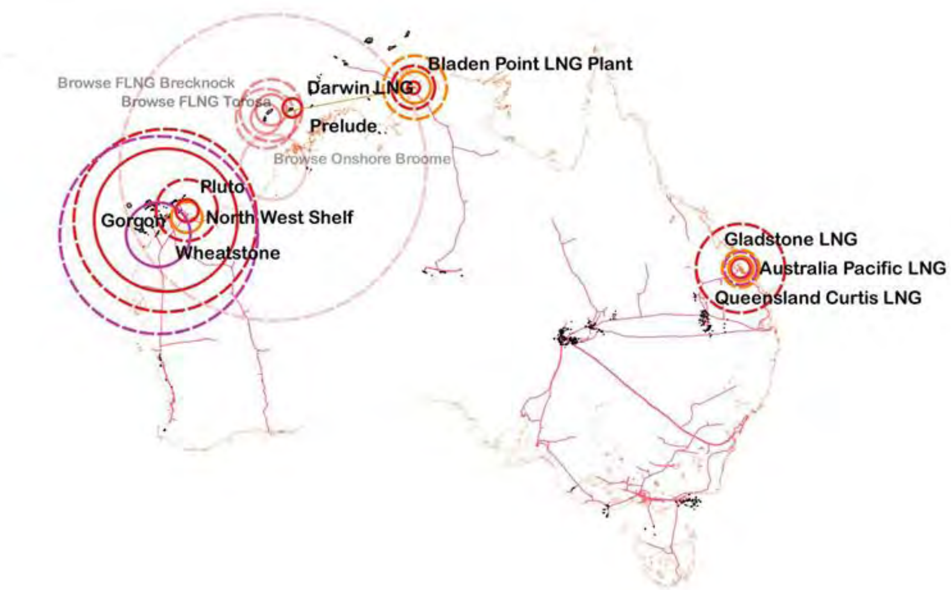

Figure 4: Geographical Distribution and Representation of Individual project's current and potential future contributions to GHG Emissions

Our estimates show that all Western Australian based LNG facilities for example at full capacity as reported in their EISs will currently be emitting scope 1 and 2 emissions at the rate of about 28 Mtpa CO2e per annum or just under 32% of the States total emissions. This will potentially rise to 40.3 Mtpa or nearly 80% of WA's remnant available emissions budget after meeting Paris agreement targets[7]. This kind of thinking means the rest of the WA society may need to reduce from a net 60.3 Mtpa to 10.6 Mtpa, an 82% reduction, just to counter the LNG industry, to only just achieve Paris commitments to which the Australian Government remain bound.

For Western Australia, should hydrogen from natural gas proceed the emissions figures just can't be balanced to net zero no matter what the rest of the state economy does.

Our analysis also shows that it's possible the industry is currently under reporting by 6.6 Mtpa (23.6%) and that detailed accounting for fugitives may add a further 6.1 Mtpa or 21.9% more. This is detailed in Attachment 1. Further, should the urgent nature of the challenge require accounting at a 20-year timeframe and not the current 100 year one for short stay gases such as methane, then we will need to add a further 12.1 Mtpa CO2e to our account due to methane emissions.

We conclude that this unique cluster of industries will need a lot of macroeconomic guidance and support from the greater community within which they operate to navigate the ever increasing pressure of the fossil fuel industry and to be relevant in a future world that is rapidly increasing the pace of decarbonizing the economy.

We recommend that the State of Western Australia should develop a significant leadership role in managing the negative impacts of GHG emissions from LNG production, and by default other large-scale natural resources exploitative industries, such as the iron ore industry. First movers may gain a competitive economic advantage and develop a subsequent industry of global significance.

How does this compare Globally?

Fossil fuels are known to be the largest drivers of anthropogenic GHG emissions and therefore the subject of the following commentary.

Our indicative analysis shows that Australia is ranked seventh for overall annual GHG potential of the fossil fuels *produced*, at about 1.5 billion tonnes per annum, and thus can be considered a significant contributor. In Attachment 2 we show how Australia is a globally significant contributor to GHG if historic consumption patterns are included.

The following graphic entitled "Figure 5: Ranking by top 20 Country for annual production of fossil fuel life cycle GHG emissions" shows the top 20 producing countries by rank.

[7] WA's 2005 emissions were 70.65 Mtpa which need to be reduced by 28% by 2030 to 50.86 Mtpa on an Australian pro rata basis

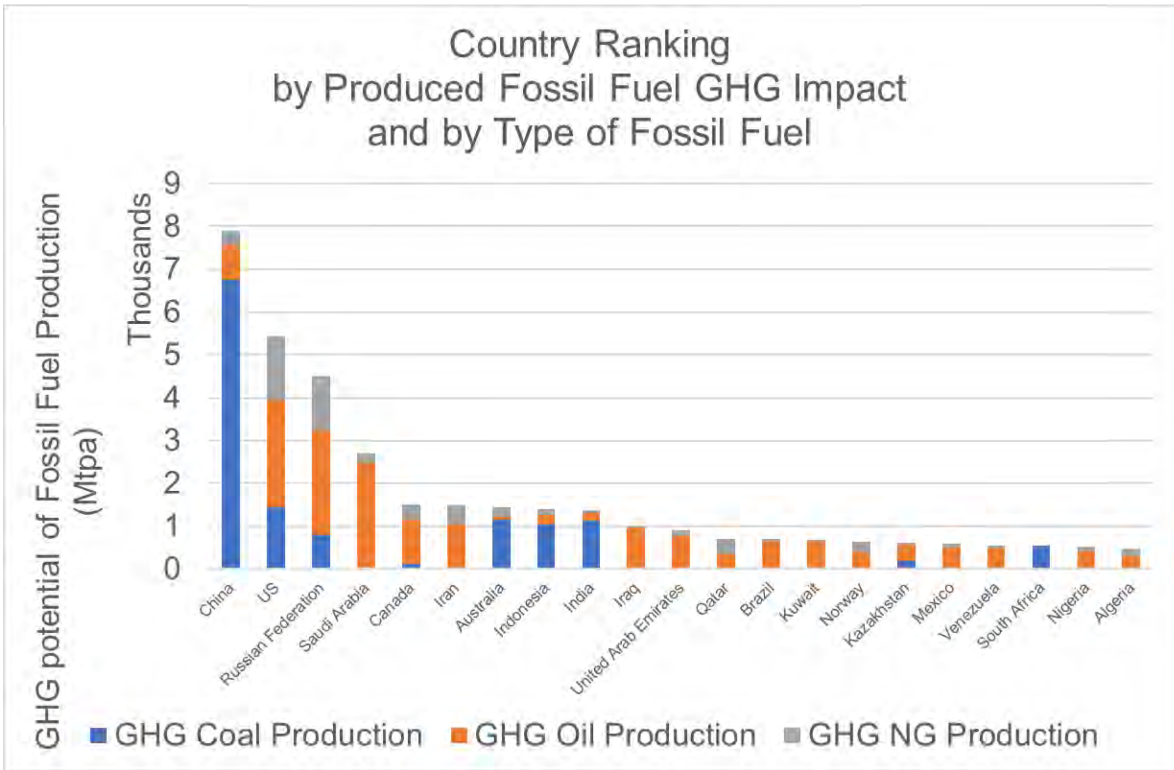

Figure 5: Ranking by top 20 Country for annual production of fossil fuel life cycle GHG emissions

It is clear from this alone that Australia "punches well above its weight" when it comes to GHG potential production. It compares directly with Canada, and is within the same ballpark as the US, to make a troika of industrialised nations with relatively wealthy and strong economies and high rankings in contribution to the environmental harm being wrought by GHG emissions.

Many of these countries utilise the majority of energy production domestically to ensure sustainability of their own economies and structures. Australia however is in the position to export large quantities for economic gain.

The following graphic entitled "Figure 6: Ranking by top 20 Country for annual export of fossil fuel life cycle GHG emissions" shows the ranking of the top energy exporting countries, by GHG potential of their exports.

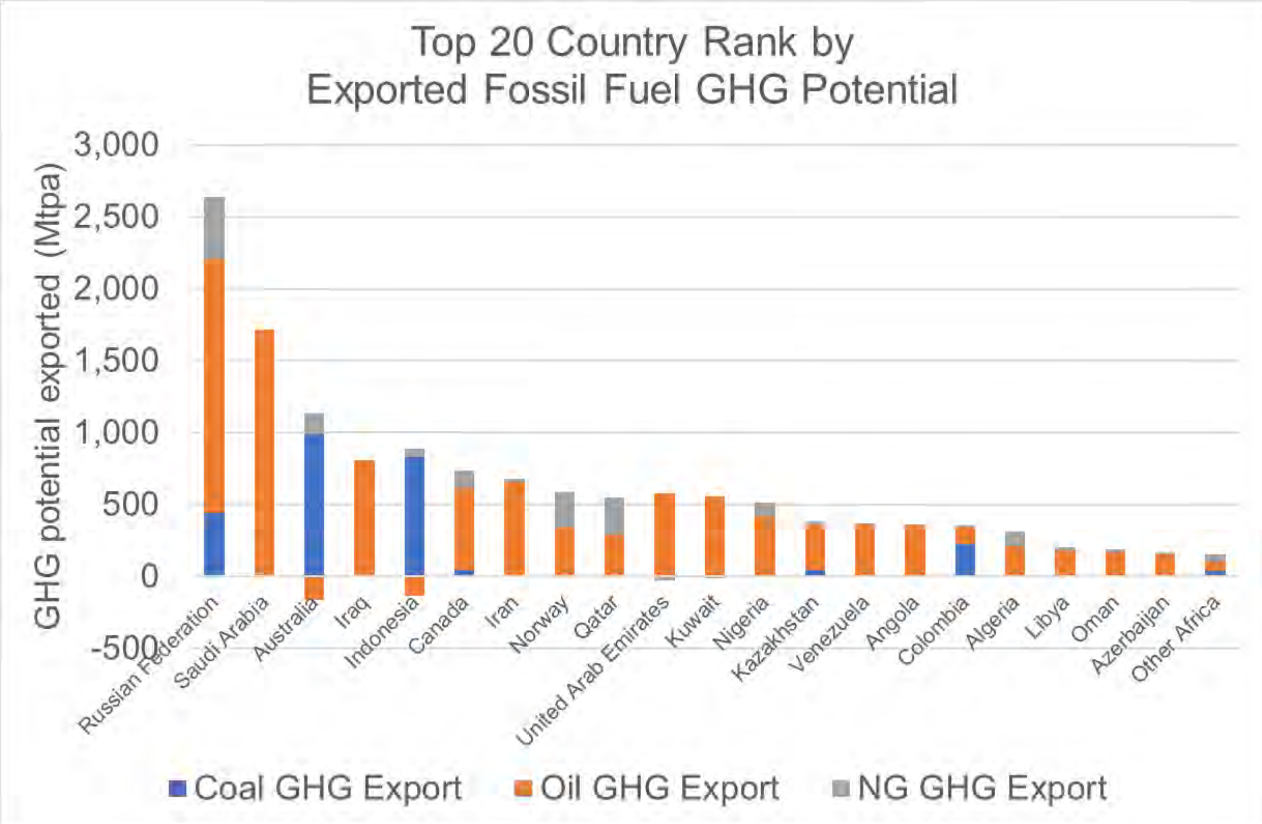

Figure 6: Ranking by top 20 Country for annual export of fossil fuel life cycle GHG emissions

Australia occupies a clear third place in export of GHG potential from fossil fuels, second only to Saudi Arabia and Russia.

However, it is also clear from the above two graphics that Australia's place in this ranking of GHG potential is driven primarily by coal, and is in unique company, with Indonesia having a very similar profile. Natural gas production is a significant but smaller contributor to Australia's positioning, as noted in the following graphic.

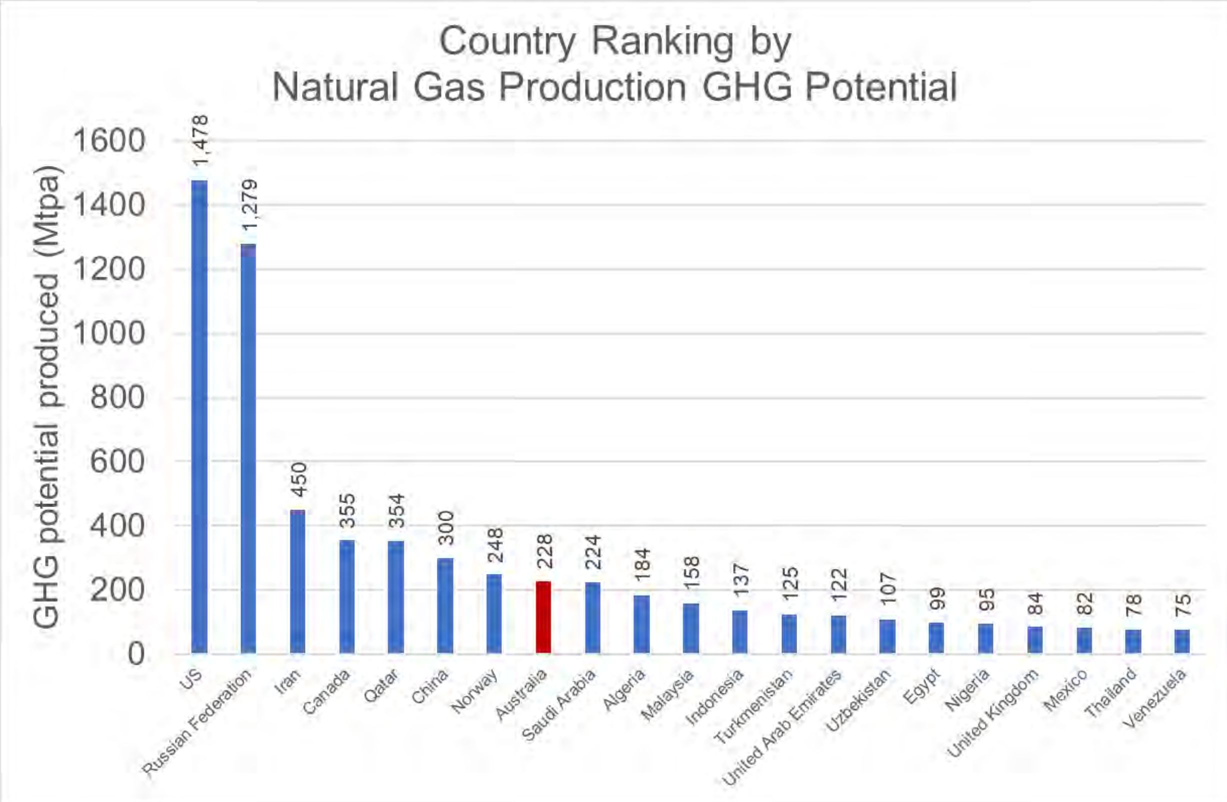

Figure 7: Ranking by top 20 Country for annual production of natural gas life cycle GHG emissions

Australia ranks as the eighth largest producer of natural gas, nestling in proximity to 7 of the top eight such producers including China. Clearly the larger producers by nearly a full magnitude are the US and Russia.

However once again much of this gas is for domestic consumption. In export terms Australia ranks as fourth largest exporter for economic gain of natural gas as shown in the following graphic entitled “Figure 8: Ranking by top 20 Country for annual export of natural gas life cycle GHG emissions”.

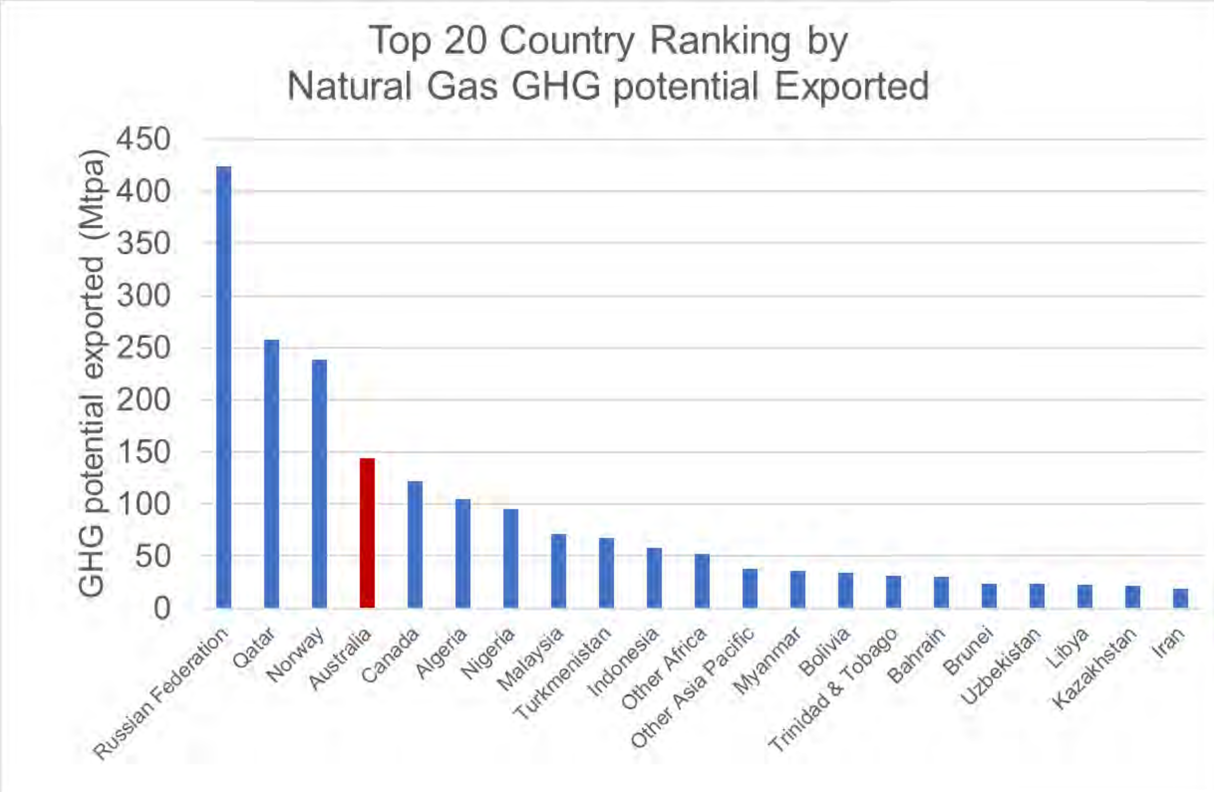

Figure 8: Ranking by top 20 Country for annual export of natural gas life cycle GHG emissions

Out of the top 3, Russia and Norway export natural gas primarily by pipeline, while Australia exports primarily by liquefaction and shipping. Qatar does both, but Australian exports of LNG are predicted to overtake those of Qatar imminently to take position as the world's largest LNG exporter. This is likely to make Australia the biggest emitter of GHG from natural gas exports due to the extra processing involved. As the attention of the world's climate scientists is moving now to natural gas it is more than likely that WA's LNG will be targeted for its climate change impacts. This will be a serious if not existential threat to an economy where LNG exports are a big component[8].

Our conclusion is that Australian gas exports are significant contributors to global GHG emissions and thus pose an existential threat to Western Australians through impacts of climate change and the global response to the LNG industry. As a host to the pre-eminent exporters of LNG in Australia,

[8] Incidental research shows that the net economic impact to the economy of LNG export over the last few years, even discounting the indirect effects of industry displacement with rising gas prices along the eastern seaboard, is negative when pricing in the implied costs of GHG emissions as indicated by the Federal Governments auctions. It has also been marginal without consideration of nominal costs of GHGs. Australian society appears to benefit little from its natural gas resources under current policy settings. Financiers project proponents and international customers appear to benefit from exploitation of these resources.

Western Australia has the capacity and means to further the Paris Agreement objectives rather than be seen as a major barrier to reaching them. It can do this by undertaking a lead role for equitable, sustainable and ambitious plans to eliminate environmental threats posed by LNG GHG emissions, and potentially develop associated subsidiary industry in a new era for the Pilbara as a resource hub for the future economy in the Indian Ocean/Asian region.

Capacity for Economy to manage Equitable and Sustainable Transition is Linked to Historical GHG Emissions

The Pilbara and Kimberley regions in Western Australia are significant engines for Australia's economy on the back of its iron ore and LNG resource developments. They are technically designated the statistical division of "Western Australian Outback (North)" with the Australia Bureau of Statistics.

The following graphic entitled "Figure 9: Geographical Distribution of Australia's Regional Product (2016)" indicates the distribution of regional product and relative contribution.

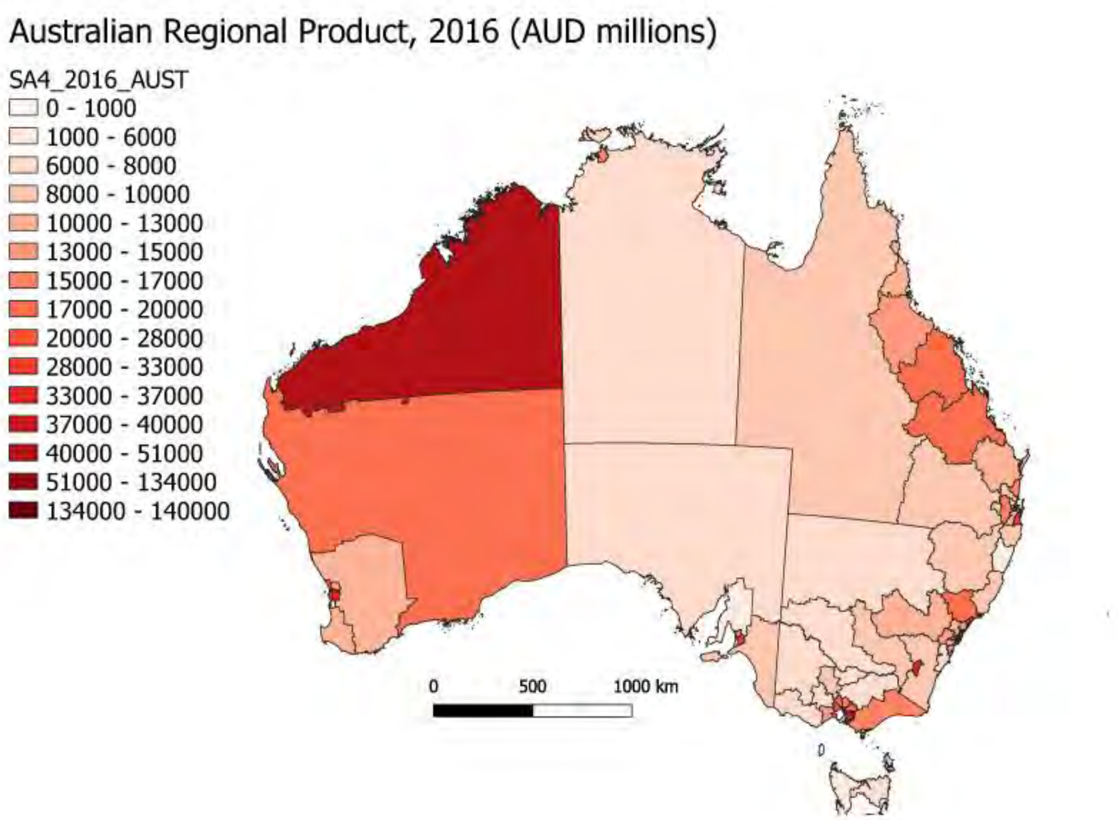

Figure 9: Geographical Distribution of Australia's Regional Product (2016)

The latest Australian data from 2016 shows that the statistical division of the Western Australian Outback (North) is the fifth most productive region in Australia, only eclipsed by Sydney, Melbourne, Brisbane and Perth CBDs. Further it is the only region outside cities in the top 10, the next region in this category is the Gold Coast. It is the only resources region in the top 23, the only other being WA's Outback (South) at rank 24, with Central Queensland at 27th.

The impact of GHG mitigation if poorly managed may be a potential threat to this prosperity of Australia's 5th largest economic region. The world is on a transition to decarbonize the economy and unless the Pilbara plays a large part in this the economic benefits that have been so significant in recent decades for Australia and for WA, will rapidly erode.

We conclude that potential exists for significant tension to develop over economic imperatives and damages consequent on this region's contribution to GHG emissions, between and within both the State and private sectors. Our research indicates that collaborative innovative and willing cooperation and contribution by both these actors and others can achieve ongoing economic prosperity and meet recently stated emissions reductions in a timely manner. This may be considered an opportunity rather than a threat if managed well.

Further, as a developed nation: which has emitted a high historical gross greenhouse gas quantum; which in turn has underwritten Australia's top ranking in median wealth per adult and 4th ranking in mean wealth per adult, we have the capacity to afford rapid transition.

The following graphic entitled "Figure 10: Comparison by Country of Mean Wealth per adult with Historical cumulative GHG emissions per capita" indicates Australia's unique positioning regarding mean wealth per adult (2017) and per capita historical GHG emissions.

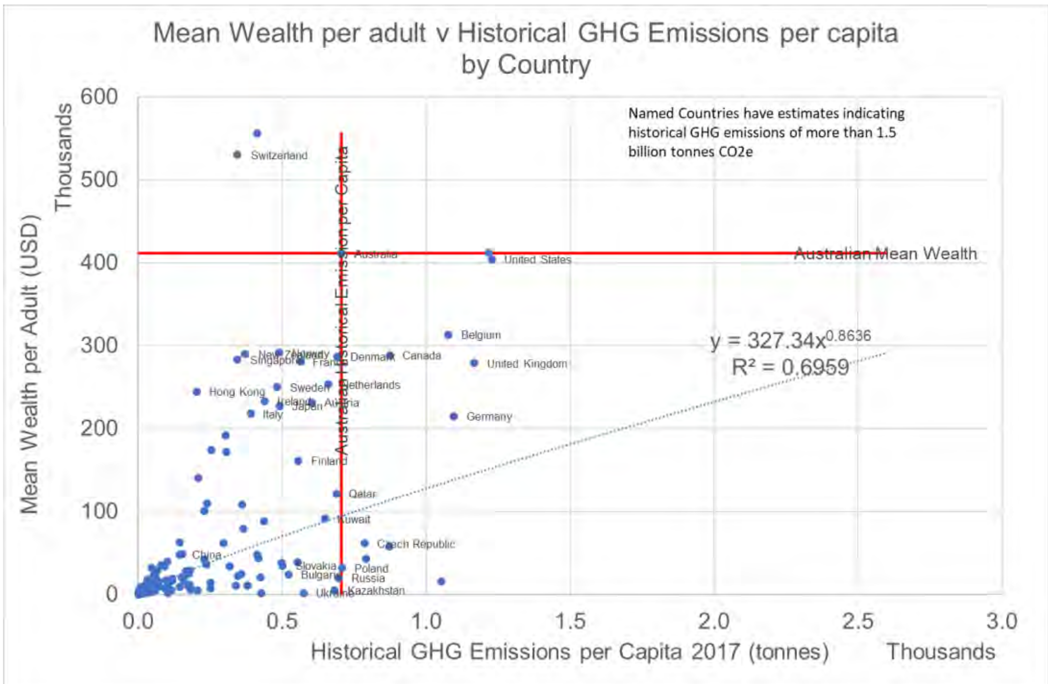

Figure 10: Comparison by Country of Mean Wealth per adult with Historical cumulative GHG emissions per capita

Clearly there is a broad trend in the data that indicates wealth is highly correlated to historical GHG emissions, and as the trendline indicates nearly 70% of current wealth is explained by historical emissions.

The data indicates that as a nation Australia is uniquely very wealthy and has a very high historical carbon footprint, only eclipsed by the USA in having a higher footprint amongst the bigger wealthier emitters (greater than 1.5 billion tonnes GHG).

The following graphic entitled "Figure 11: Comparison by Country of GNI per capita with current annual GHG emissions per capita" shows national placement regarding current annual emissions of GHGs against GNI, a proxy indicator of current income[9].

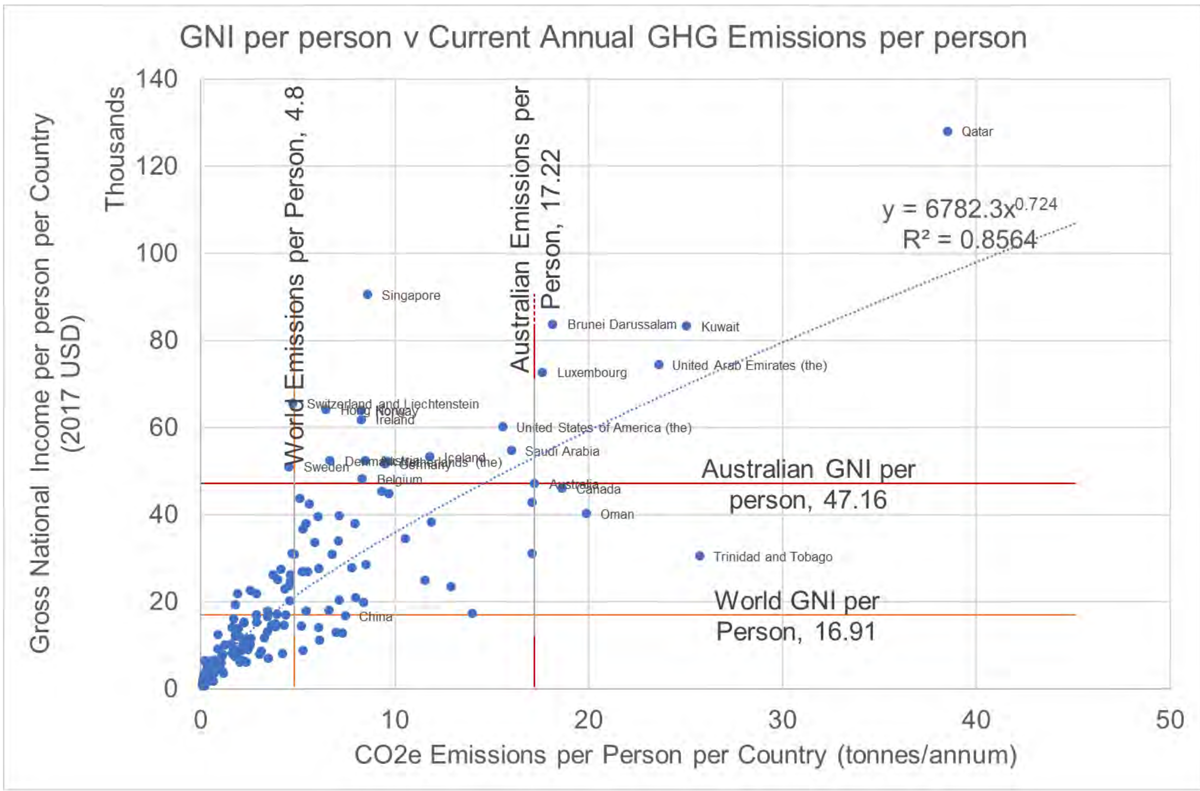

Figure 11: Comparison by Country of GNI per capita with current annual GHG emissions per capita

Similar to the data for overall wealth, economic output as measured by GNI is clearly highly and positively linked to a nation's rate of GHG emissions, with more than 85% of GNI being correlated with annual emissions.

Australia's place is such that along with the USA and Canada it is positioned within a high income, economically active, and high emitting group of fossil fuel producing nations, headlined by the extreme case of Qatar.

[9] A word of caution here is that GNI doesn't always connote spare economic capacity.

Conclusions from Scene Setting

Clearly the questions posed in the introduction of this chapter define the setting for this report. It is clear that:

- the GHGs emitted by Australia, Western Australia and life cycle emissions of Western Australian resources in particular those of the LNG Industry, are globally significant, and thus greatly add to the past present and future environmental harm impacting on Western Australia; and,
- Australia has few equals in its combined impressive wealth and national income and the correlation with historical and current rates of GHG emissions is proven. It has one of the best capacities to equitably and aggressively address its response to climate change based on GHG emissions.

Our conclusion is that Australia, amongst the world's 195 sovereign states (and to an even greater extent, Western Australia), not only contributes more to climate change than most, but also has wealth and national income relatively greater than almost all nations. Australia thus has one of the best capacities to aggressively, equitably and sustainably advance our contribution to this global challenge, even beyond the political commitments to date.

The Paris agreement foreshadows the imperative for countries in this position to accelerate transition to a decarbonized economy.

We conclude that if a democratic and wealthy nation such as Australia, and subsequently a democratic and wealthy state such as Western Australia, cannot accelerate their commitments beyond the minimum, then there is little hope for the global response to be successful. It is time for WA to take further steps in leadership in this rapidly growing arena of political and economic change as it transitions to a new economy. This is our opportunity.

Response to EPA Questions

The following sections outline our response to each of the key questions asked by the EPA, and in some parts include detailed supporting information.

What is the information that should be required by the EPA for Environmental Impact Assessment?

The request for comment highlights the following specific questions about information that should be required by the EPA for Environmental Impact Assessment:

- information on greenhouse gas emissions and their mitigation which the EPA should expect and consider in making any advice on a proposal;
- information the EPA should expect on how a proposal aligns with Australia's emissions reduction targets; and,
- the need for, and any reasonable constraints on, transparency in emissions data and proposed mitigations.

Our prior analysis of all the Australian LNG based EISs identified that much of what is presented around GHG emissions is minimalist to the extent that it may obfuscate the underlying issues. The poor quality of proposals and the shallow depth of justifications in no way match the rigorous and onerous standards demanded in many of our institutions such as the academic, financial, banking and legal industries. There are many factors underlying this current inadequate state of justification and we support the EPA's proposed requirements to improve this. It will begin a process whereby the industry can survive a potential existential threat to their existence.

The EISs we studied and their responses from regulators indicate an apparent imbalance in power and knowledge which may have traditionally worked to the proponents' favour. We note that the knowledge and skills necessary to undertake these forensic technical tasks are readily available. Further, the generic industry deployed by LNG technology is endemic and rarely a trade secret, so "commercial in confidence" arguments are mostly facetious in this important space. These claims by proponents may circumscribe capacities for scrutiny.

We recommend that the EPA look internally at its own procedures and capacities to more fully explore all claims made within an EIS regarding GHGs and assist in providing balanced advice. In this regard full life cycle analysis of GHG must become a regular part of all LNG proposals.

We recommend the following principles be encouraged in the development, presentation and examination of the GHG emissions in projects examined by the EPA in WA:

Principle 1: Transparency

Recent Royal Commissions have identified the corporate failings of some of our previously most trusted institutions (Brown, Vandekerckhove, & Dreyfus, 2014; Fisher, 2010; Goven, 2006), and it is almost a mantra (myth) of social governance that transparency creates trust. Trust is important when considering social license to operate, which should be of concern for proponents of projects likely to be of significance regarding their GHG footprint. Evidence of secrecy or obfuscation from previous submissions regarding GHGs creates the impression that there is something to hide, in turn impacting on trust and thus social license.

Transparency facilitates a requirement for community oversight, regulatory audit and verification.

An example is the publication of each gas well speciation or at least field average and standard deviation, something the industry is slowly but surely making hard if not impossible to find. It is possible that the shroud of secrecy is not targeted at competitive advantage but to reduce scrutiny of the GHG emissions' impact in progressively reducing gas quality input feed to the LNG plant. This single factor almost by itself dictates the GHG impact of producing LNG in any facility and must become much more transparent in GHG accounting.

We recommend that proponents are encouraged to undertake their best endeavours to transparently and holistically report on the GHG impact of their proposals and how they can contribute to the transition to the net zero emissions economy.

We further and specifically recommend that proponents are required to transparently and holistically report on the speciation of the hydrocarbon extracted from any reservoir for use in any way in the process of producing commercial grade natural gas or other fossil fuel for either domestic markets or for export.

Principle 2: Sustainability and Resilience

The concept of sustainability revolves around the integrated interdependence of Cultural Social Economic and Environmental measures of a society. Each is not able to be evaluated in isolation.

We recommend that proponents submit as part of their EIS a holistic statement and justification regarding the sustainability for current and future residents of Western Australia overall, and particularly as a consequence of the GHG footprint of their proposal and how it meets the global Australian and Western Australian net emissions targets.

We recommend that the EPA also present to the Minister a separate macroeconomic statement and justification of their recommendations based on sustainability principles. Although on the surface this would be seen to go

beyond the environmental remit of the EPA, it is essential in understanding why choices are being made by the industry which have significant environmental implications.

Principle 3: Standardisation

As part of transparency aspirations, comparability between like proposals is advantageous. Further, the science around GHG footprints, industrial processes of a scale requiring approvals and scrutiny, and product life cycle determination in almost all circumstances is deterministic and thus suitable for application of standardised reporting structures.

We recommend that industry bodies proponents state and federal jurisdictions and academic institutions jointly develop standardised reporting protocols which conform with these principles robust enough to articulate into relevant global standards (discussed elsewhere), and financial and regulatory instruments being considered at all statutory levels.

Standardisation facilitates a requirement for community oversight, regulatory audit, and verification.

Principle 4: Best Scientific Factors for Estimation of GHG Impact

Particularly in the LNG industry standard factors are often used in estimations of GHG factors, particularly for fugitives, mainly methane and probably nitrous oxides.

This particular measure is a hotly contested one between researchers and industry as some studies indicate that measured fugitive emissions from some natural gas production facilities and regions negate the GHG advantage of natural gas consumption over coal.

However, a recent internal paper, reproduced in this submission as "Attachment 1: A Briefing Paper regarding Fugitives and the State of Knowledge in the Natural Gas Industry" concludes that in many multinational industries self-reporting and regulation has failed on many fronts. The performance of Australian natural gas industry, and particularly the LNG industry is unknown. The regulatory regimes around environmental protection, particularly GHG control, are weak, with possible industry capture. Benchmarking can no longer be an industry internal function. It is clear that the concept of industry best practice within oligarchic industry is self-referential and thus self-defeating.

Theoretically the natural gas production transport and use supply chain is totally enclosed and thus zero fugitives are possible. At least one researcher indicates a feasible cap at 0.9% in comparison to indicative rates of more than double this. Australia is now a leading exporter of LNG in uniquely different environments and has a moral and legal imperative to reduce the climate change impact of its fugitive emissions. Notwithstanding this policy options may significantly contribute to reduction of Australia's actual fugitive and thus overall GHG footprint:

Emerging techniques are converging on a scientifically verifiable "air-shed" and "bottom up" capability to determine actual fugitive emissions. The reliance on US industry provided data is not sufficient. Western Australia should join lead and implement in this capability due to its heavy reliance on LNG export.

We recommend the development of a Technical Advisory Committee in the EPA to provide local coordinated and well-resourced independent functional advice to extend industry best practice around 'GHG emission factor' presentation.

This also facilitates a requirement for community trust and oversight, as well as regulatory audit and verification.

Principle 5: Expansive Justification

In terms of facts presented in the EISs, often a framing statement is made to indicate action when in reality a broader view paints a completely different picture. Expansive justification is necessary to ensure regulatory examiners are given a holistic picture.

The most obvious one relates to the requirement for "best practice" endeavours to reduce emissions. Too often this is narrowly framed as "what does this industry globally do as best practice to reduce emissions". When viewed as framed by an oligopolistic industry "practice" often operating in sovereign regimes with less regulatory scrutiny than ours, rather than scanning for global multi-industry best practice, the outcomes are limited.

The most obvious example is that almost all LNG EIS submissions contemplate that best practice for process power, which consumes up to 10% of the input gas and is responsible for most of the scope 1 GHG emissions in current practice, is often to use open cycle gas turbines. The best endeavours clause in this space is often assuaged by a discussion of the relative benefits of the difference between aero-derivative gas turbines and industrial gas turbines, the latter being typically less efficient and thus emitting more GHGs for the same task. On several occasions the dissertations led to a more advanced discussion of combined cycle gas turbines instead, which is even more efficient.

The narrowing of the conversation to this technical level refocusses analysis away from two major issues:

- the incentive to retain this regime is (perversely) that the LNG industry is most often not required to account for its consumption of the gas either through direct billing, through royalties or through the generally more prevalent resource rental regime operating for most projects. In Western Australia the industry is fuelled

by “free” natural gas, significantly reducing energy costs to a level that is impossible to compete with;
- this state of affairs means that there is a perverse economic incentive for operators not to focus on providing process energy from other less impactive and otherwise more economic sources, such as renewables. To undertake such a focus has the potential to virtually eliminate the majority of the GHG emissions from these projects.

We recommend that the concept of “free” natural gas fuel be examined in the context of its perversion of the goals of GHG mitigation in the LNG industry, and appropriate regulatory steps be taken to remove this impact. Further we recommend that the concept of “best practice” mitigation efforts be reinforced as being a functional concept to help industry into contributing to the transition away from fossil fuels, not limited by current industry practice.

How emissions associated with a proposal should be considered by the EPA?

The request for comment highlights the following specific questions about how to consider emissions associated with a proposal:

- the scope of emissions to be considered
- the relevance and context for considering indirect (scope 3) emissions
- the relationship to national or state emissions targets and regulation
- consistency with the EPA’s duty to use its best endeavours to protect the environment

Our conclusion based on this sectional analysis is that:

- **all the elements of GHG, both embodied in the original gas and produced in its processing, whether it’s released in Western Australia or elsewhere, is significant and the environmental harms so produced should be considered;**
- **indirect (scope 3) emissions form a part of the life cycle of all products and are therefore relevant and in context with State Responsibilities;**
- **the natural gas industry implies awareness of scope 3 emissions when they state that gas is substituting for coal;**
- **the relationships for Western Australia as a state within a Federation, to Federal targets and regulations, need not, indeed should not, be binary nor subsidiary. The State is right to implement its own policies especially if they require greater GHG responses. However economic equalisation will be an ongoing issue given the vulnerability of the resources industries in Western Australia to GHG action and the wider economic benefits of hosting such industry;**
- **all these elements can be conflated with the environmental harms in Western Australia, and therefore all such emissions related to the**

lifecycle of the product so produced, including both upstream and downstream scope 3 emissions fall under the auspices of the EPA through its responsibilities outlined in detail in its enabling act It is required to consider the environmental harm caused by a proposal brought before it;

- **Only by including scope 3 emissions will proponents be able to participate fully in the transition to the new economy.**

Defining and Analysing the Term "Scope 3"

In answering this question, we first define terms:

The GHG Protocol[10] Corporate Standard classifies a company's GHG emissions into three 'scopes':

> *"Scope 1 emissions are direct emissions from owned or controlled sources. Scope 2 emissions are indirect emissions from the generation of purchased energy. Scope 3 emissions are all indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions."*

The GHG Protocol is concerned with individual organisations reporting requirements for specifically standardising such reports. Whilst it has strong currency, it is focused on individual organisations' reporting requirements. A common refrain is that "our scope 3 emissions are someone else's scope 1 emissions". Clarity is essential in reporting systems so this approach may lead to "double counting" issues.

The GHG Protocol's focuses on "Scope" emissions, is not necessarily fit for regulatory oversight (Hertwich & Wood, 2018). Similarly, though well known the GHG Protocol is not an subject to global governance. Scope emissions can be complimentary to reporting life cycle emissions but by themselves create an opaque regulatory regime which may be exploited.

Product life cycle emissions are all the emissions associated with the production and use of a specific product, from cradle to grave, including emissions from raw materials, manufacture, transport, storage, sale, use and disposal. This pathway focuses on the holistic impact of the production and use of a product, rather than an organisation's particular "subset" activities.

Such analysis of the lifecycle of a product or service rather than focus on a stage of production (e.g. consideration of subsea work separate to header platform separate

[10] GHG Protocol establishes comprehensive global standardized frameworks to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, value chains and mitigation actions.
Building on a 20-year partnership between World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), GHG Protocol works with governments, industry associations, NGOs, businesses and other organizations.

to transmission separate to processing separate to sequestration etc) gives a better indication of the overall environmental impact a process from a societal perspective.

The Organisation Internationale de Normalisation, commonly referenced as the ISO is a globally accepted organisation with accepted methodologies for standards development. It also has developed "life cycle" based standards which may be more suitable for a macroeconomic view of GHGs within and between sovereign jurisdictions. Particularly relevant may be: International Standard ISO 14040 ("ISO 14040 Environmental management -- Life cycle assessment -- Principles and framework," 2006).

We recommend that a project proponent be required to report on the lifecycle assessment of the GHG emissions under a standardised framework based on lifecycle analysis and undertaken to international standards such as that produced by the ISO. Such analysis should clearly delineate the proponent's specific internal responsibilities within their proposed processes and how the proposal fits into the broader transition to a net zero emissions economy.

Industry Acknowledgement of the benefits of substitution of downstream Scope 3 Emissions is evident but unproven

A typical statement in every one of the studied LNG EISs submitted to authorities by proponents in Australia indicate that natural gas is good for the environment, and particularly for Climate Change mitigation, "because it replaces coal".

By these statements therefore and implicitly the LNG industry has always acknowledged, not only the role of downstream scope 3 emissions, but also the concept of substitution, as justification for continued exploitation of Australia's gas in the face of an emerging GHG threat. The legality of consideration of substitution and the impact of downstream scope 3 emissions in project approvals is addressed later in this submission.

Few Regulators challenge their statements and it appears that this sentiment has achieved the status of a social convention: it may or may not be fact but is treated as a truism. The issue must be debated as our data has shown.

The industry continues to support the mythology[11] that natural gas is a transition fuel away from coal.

The evidence increasingly indicates that gas substitution for coal is not supported by the facts

Our continuing research of the correlations between historic substitutability of alternate fuel sources is nearing completion. Preliminary results are emerging which challenge this assertion. The research examines to date Global, US Australian Western Australian and Chinese jurisdictions to understand the

[11] concepts, images, symbols, and narratives

- technical roles of the various fossil renewable and other fuel sources;
- the impact of policy decisions, and;
- the statistical time series evidence.

on substitutability or otherwise of the various fuel sources over varying time spans from 1965 to 2017. It will further examine South Korean and Japanese jurisdictions within the same frame.

The following subsections outline preliminary conclusions derived from ongoing research into the relationships between changing energy mixes in a variety of jurisdictions pertinent to Australian LNG export.

We conclude, based on statistical analysis of energy trends worldwide, that contrary to oft quoted substitution of coal for natural gas, globally and in the jurisdiction of the USA, Australia and China, natural gas is at best a partial substitute for coal (US) or otherwise only indirectly substitutable. The more substantial finding is that substitution for coal is identified to be caused by the increasing penetration of renewables particularly wind energy. Roof-top solar is a more recent phenomenon that is considered now to be more cost-effective than all other energy sources. Roof-top solar energy is not part of the analysis as national data sources rarely include it because its behind the meter. Natural gas is shown in general to compliment coal in providing energy in jurisdictions with growing economies and populations. It in general is found to supplement the penetration of wind power in adopting jurisdictions.

We further conclude that natural gas, and therefore LNG as a specialised and more complex, subsidiary product, in general is not a “transition fuel” but an “agnostic complimentary” energy source for more primary energy sources. We find this agnosticism creates dangers for the Western Australian climate and industry if not regulated to reduce or halt facilitation of unsustainable primary fuel sources. We also find that it also opens opportunities for natural gas to find its niche as a much higher value “facilitative” fuel and security asset in the transition to a new economy.

Our recommendation, in light of the probable inaccuracy of previous claims by the industry, that the EPA must require of proponents for proposed energy projects, or for that matter any project with significant scope 3 emissions, to cause:

- **scope 3 emissions be considered analysed and identified in detail;**
- **substitution claims for GHG credits by proponents be specifically attributable quantified and exhaustively substantiated beyond a reasonable doubt;**
- **no project be granted environmental approvals unless able to demonstrate a firm and committed pathway to net zero**

Supporting and preliminary analysis, conclusions and recommendations arising from our research follow:

Globally

A summary of the global correlation of coal as the dependent fuel source, and oil gas nuclear hydroelectricity solar wind geothermal biofuels other renewables population and GNI as independent variables, with an adjusted R^2 of 97.3% for the period from 1965 to 2017 indicates a high positive correlation with a greater than 95% significance between coal consumption and the two remnant independent variables of nuclear power and other renewables. A multicollinearity test indicates that the condition number at 1.83, well below the standard measure of 30 or more for an ill-conditioned regression matrix, whilst the variance inflation factors for each independent variable at 1.42 are also well under the standard measure of 5 of more for excessive collinearity. Both these indicators enable us to conclude that the independent variables for both nuclear power and other renewables represent an accurate indication of individual impact on coal consumption, in that an increase of 3.1 GJ coal is indicated for every GJ other renewables energy and 2.15 for nuclear.

A regression analysis of the independent variables also shows that nuclear power is most highly correlated with growth in oil gas and population. Similarly, other renewables are more closely correlated with solar wind geothermal and GNI growth.

An inspection of the data indicates that globally coal had not peaked by 2017, the end of the current dataset.

We conclude that globally coal consumption over this period continually grew, that it was most proportionally influenced by renewables and economic growth, but to only a slightly lesser extent influenced by the growth of nuclear and fossil fuel consumption as well as population growth. By corollary we conclude that gas has been shown to have no broad substitutionality with coal at a global level.

Similarly at a global scale and when analysing gas as the dependent variable we can conclude that gas consumption is driven by economic growth (or decline with economic decline) but that solar power (which over this dataset never seriously declines and is in primarily constant growth) and its very highly correlated energy source of wind is substitutable for gas with a reduction in gas consumption at a rate of 3.51 PJ per PJ of solar power.

We conclude that on a world stage, solar and wind energy are a broad substitute for gas, or compete with gas, in its market and taking into account the conversion efficiency of gas to electricity it is a direct competitor to these renewables, or at least may simply be assisting renewables through grid stabilization before other storage mechanisms are introduced.

The USA and Shale Gas

The incredible rise of shale gas in the US has created a mythology of its own regarding the decline of coal due to the very low gas price with oversupply. Our research reviews the facts.

The following graphic entitled “Figure 12: Time Series Representation of US Electrical Power Consumption referenced against Peak Coal in 2007,” for example shows the characteristics of the time series for the various energy sources measured in electrical output in the United States of America since peak coal in 2007.

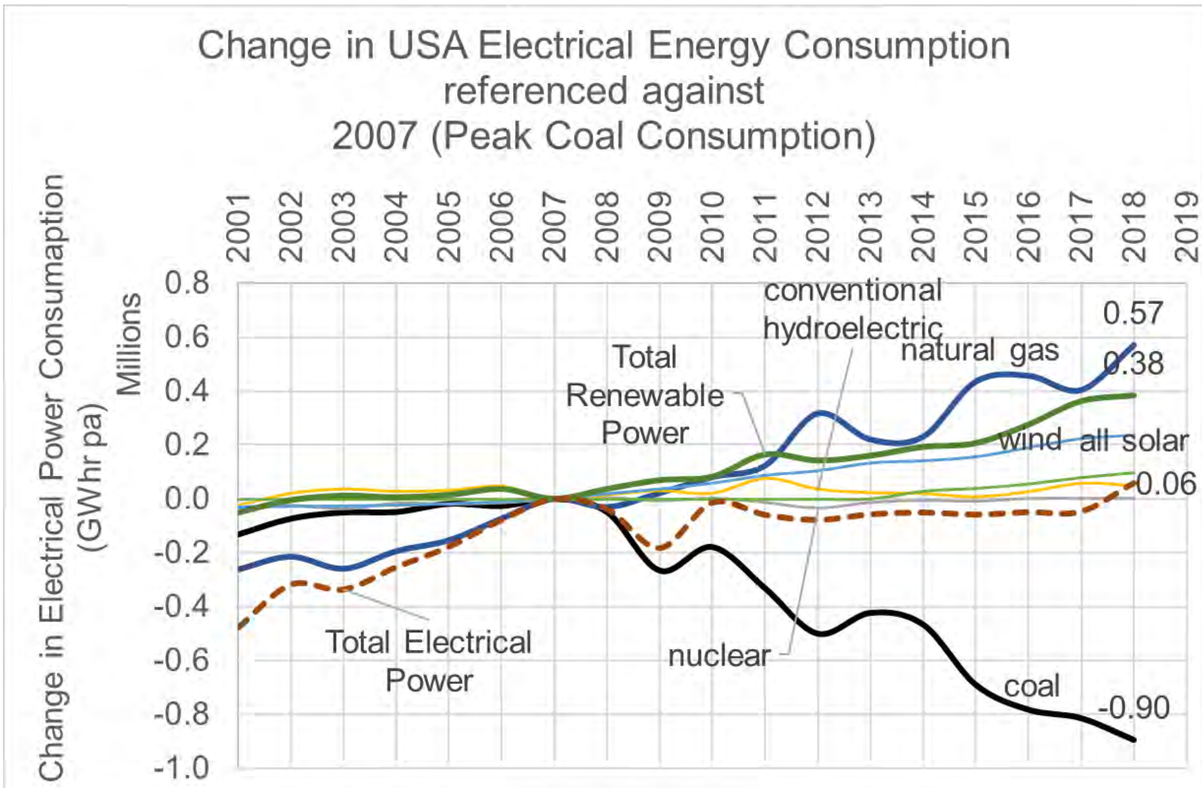

Figure 12: Time Series Representation of US Electrical Power Consumption referenced against Peak Coal in 2007

By inspection some conclusions may be drawn:

- total electricity supply by coal fuel has declined by 0.9 GWhr per annum since its peak in 2007, indicating a (slow) decoupling of coal from electricity supply; whilst
- total electricity supply has flatlined until 2018 when it finally increases by 0.06 GWhr per annum beyond its 2007 peak; and
- The gap is filled by 38% renewables, primarily wind energy, and 57% natural gas, mostly shale gas.

The data also indicates that a well-conditioned independent variable regression for coal against the other factors produces an adjusted R^2 factor of 97.3% at a 95% significance level, a matrix conditioning value of 3.8, well under the standard measure of 30, variance inflation factors for each independent variable well less than the standard measure of 5. This regression indicates the best fit is associated with a negative (substitution) correlation with wind (correlation coefficient of -2.9 GWhr/GWhr) and all solar sources (correlation coefficient of -2.2) and a positive correlation with nuclear energy (correlation coefficient of 4.1). The wind correlation coefficient, whilst indicating a best fit with wind resource development may also be interpreted as a proxy for the closely correlated variables of natural gas fuelled electricity supply, population, and economic growth.

A correlation matrix for the dependent variables identifies a strong correlation between wind natural gas population growth and economic growth and a similar lesser correlation between all solar source's natural gas population growth and economic growth.

By analysing gas as the dependent variable, we were able to meet all statistical parameters and to confidentially identify that the major indicator of gas growth has been the rise of wind power. A correlation analysis of the independent variable set indicates a strong correlation (regression coefficient of 3) between wind and by association population and economic growth. Yet again the relationship between solar and gas is found to be mostly competitive on a direct substitution basis (regression coefficient of -1) with far less association with other independent variables.

Our conclusion is that in the US the rise of very low-cost natural gas has had a significant but not matching inverse correlation with coal. The rise of renewables has also had a more closely linked significant but also not complete inverse correlation with coal. Gas increase has been correlated positively with the growth of wind energy resources population and economic growth and substitutionality with the introduction of solar resources

Overall, we conclude that even in a strongly price competitive market for natural gas such as the US, natural gas has only achieved partial substitution with coal, has growth significantly linked with the growth of wind resources, and is competitive as a substitute with solar energy.

Our early findings point to the fact that the role of the burgeoning shale gas industry in the US may be considered to be relatively facilitative regarding GHG emissions overall, playing some direct role in the decline of coal, but is by no means the whole story in this decline. It also appears to be facilitating the introduction of wind energy but may be serving as a barrier to wider implementation of solar energy in the US.

Australian Energy Markets

The following graphic entitled "Figure 13: Time Series Representation of Australian Electrical (equiv.) Power Consumption referenced against Peak Coal in 2008" shows the characteristics of the time series for the various energy sources measured in electrical equivalent output in Australia since peak coal in 2008.

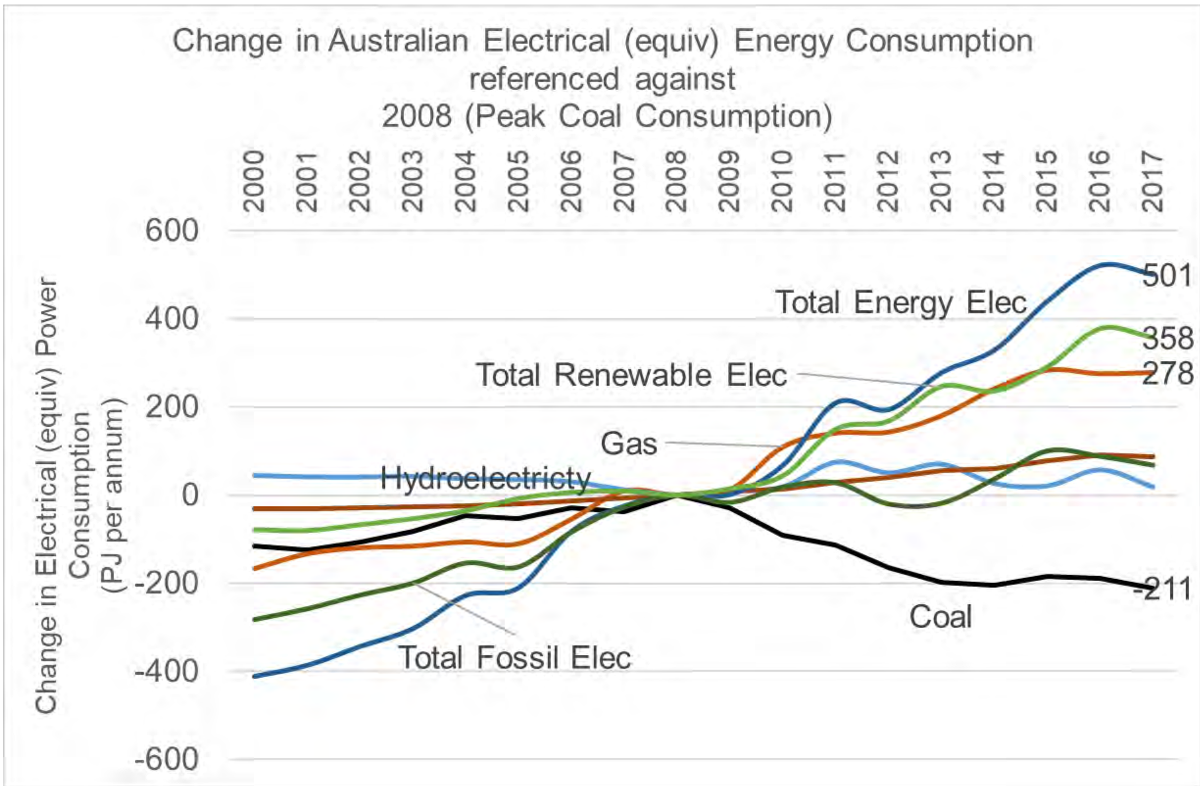

Figure 13: Time Series Representation of Australian Electrical (equiv.) Power Consumption referenced against Peak Coal in 2008

By inspection some conclusions may be drawn:

- total electricity supply sourced from coal fuel has declined by 211 PJ per annum since its peak in 2008, indicating a (slow) decoupling of coal from electricity supply. This is only a year later than the USA with its much vaunted shale gas revolution; whilst
- unlike the USA total electricity supply has not flatlined with Australia having continuous growth until 2016. Overall it has increased 501 PJ per annum since coal consumption peak in 2008 peak; and
- The reduction in coal fuelled electrical power supply equivalent by 211 PJ per annum is more than compensated for by an increase in renewable electrical supply of 358 PJ per annum, and to a lesser extent by gas with an increase of 278 PJ per annum.

The data also indicates that a well-conditioned independent variable regression for coal against the other factors produces an adjusted R_2 factor of 96.0% at a 95% significance level, a matrix conditioning value of 4.37, well under the standard measure of 30, variance inflation factors for each independent variable well less than the standard measure of 5. This regression indicates the best fit is associated with a negative correlation with wind (correlation coefficient of -13.28) and a positive correlation with natural gas derived electrical equivalent (correlation coefficient of 1.45). The wind correlation coefficient, whilst indicating a best fit with wind resource development may also be interpreted as a proxy for the closely correlated variables of solar and other renewable sources of energy supply. The natural gas correlation coefficient, whilst indicating a best fit may also be interpreted as a proxy for the closely correlated variables of population and economic growth.

By analysing gas as the dependent variable, we were able to meet all statistical parameters and to confidentially identify that the major indicator of gas growth has been the rise of wind power. A correlation analysis of the independent variable set indicates a strong correlation (regression coefficient of 7.3) between wind and gas and by a weak association with all other renewables. Natural gas is shown to have a direct and proportional relationship with coal (correlation coefficient of 0.6) which in turn has a reasonable correlation with population growth.

Our early conclusion is that in Australia the rise of coal seam natural gas has had a significant but not matching direct correlation with coal, with little evidence of substitution. The rise of renewables has also had a more closely linked significant inverse correlation with coal. Gas increase has been correlated positively with the growth of wind energy resources population and economic growth and to a lesser degree with coal.

Overall, we conclude that even in a strongly priced and competitive market for natural gas, overall natural gas has not achieved substitution with coal, and has growth significantly linked with the growth of wind resources. More recently the dramatic growth in roof-top solar suggests it has become the cheapest form of energy (Newman et al, 2017).

Our early findings point to the fact that the role of the burgeoning coal seam gas industry in Australia may be considered to be only indirectly facilitative regarding GHG emissions overall. In aggregate across Australia gas seems to have played little direct role in the obvious decline of coal consumption. It also appears to be facilitating the introduction of wind energy and perhaps more recently solar.

Peoples Republic of China's Energy Sources under the Spotlight

The following graphic entitled "Figure 14: Time Series Representation of the PRC Electrical (equiv.) Power Consumption referenced against Peak Coal in 2013" shows the characteristics of the time series for the various energy sources measured in electrical equivalent output in the People's Republic of China (PRC) since peak coal in 2013.

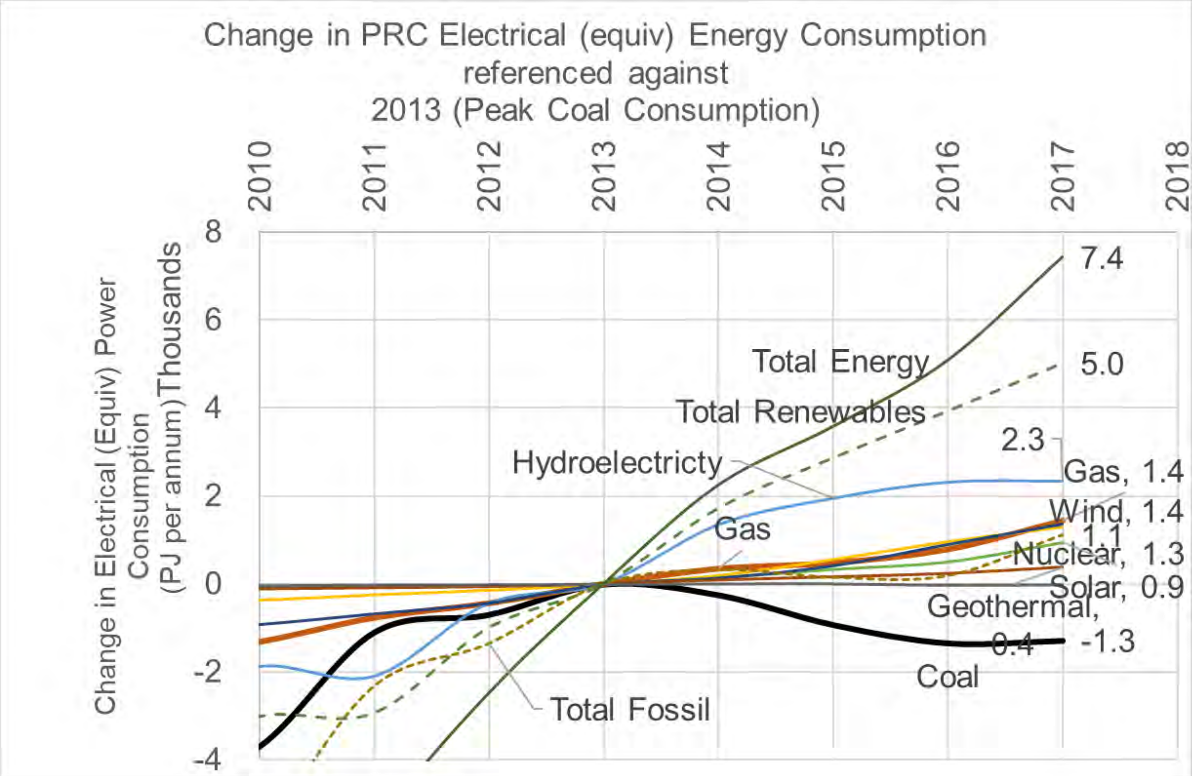

Figure 14: Time Series Representation of the PRC Electrical (equiv.) Power Consumption referenced against Peak Coal in 2013

By inspection some conclusions may be drawn:

- total electricity supply sourced from coal fuel has declined by 1,300 PJ per annum since its peak in 2013, which is six times greater than the decline in Australia, indicating a (slow) decoupling of coal from energy supply. This decline started later than the USA and Australia; whilst
- unlike the USA total electricity supply has not flatlined but similar to Australia the PRC has had continuous growth in all periods. Overall it has increased 7,400 PJ per annum since coal consumption peak in 2013 peak, some 13 times the growth in Australia, and with no signs of a reduction in rate; and
- The reduction in coal fuelled electrical power supply equivalent by 1,300 PJ per annum is more than compensated for by an increase in renewable electrical supply of 5,000 PJ per annum, and to a lesser extent by gas with an increase of 1,400 PJ per annum.

The data also indicates that a well-conditioned independent variable regression for coal against the other factors produces an adjusted R2 factor of 98.6.0% at a 95% significance level, a matrix conditioning value of 4.27, well under the standard measure of 30, variance inflation factors for each independent variable well less than the standard measure of 5. This regression indicates the best fit is associated with a negative correlation with solar power (correlation coefficient of -35.5) and a positive correlation with both GNI and population growth. The solar correlation coefficient, whilst indicating a best fit with solar resource development may also be interpreted as a proxy for the closely correlated variables of wind nuclear and geothermal energy supply. The GNI correlation coefficient, whilst indicating a best fit may also be interpreted as a proxy for the closely correlated variables of hydroelectricity, oil and gas. Population growth may also be interpreted as a proxy for the use of oil in the economy.

By analysing gas as the dependent variable, we were able to meet all statistical parameters and to confidentially identify that the major indicator of gas growth has again been the rise of wind power. There is a statistically significant but small positive correlation with coal (correlation coefficient of 0.04) and a significantly greater correlation with wind power (correlation coefficient of 2.22 PJ gas per PJ wind power. The correlation of gas with coal may been interpreted as a proxy for oil and GDP growth. The correlation of gas with wind may also be interpreted as a proxy for geothermal nuclear and solar energy sources as well.

Our early conclusion is that in the PRC natural gas has had an small direct correlation with coal, with little evidence of substitution. The rise of solar as a proxy for most renewables has also had a more closely linked and significant inverse correlation with coal, that is a substitution effect. Gas sourced power increases have been correlated positively with the growth of wind energy resources population and economic growth and to a far lesser degree with coal.

Overall, we conclude that in the PRC's energy mix, at a national level natural gas has not achieved substitution with coal, and has growth significantly associated with the growth of wind resources and the economy in general.

Our early findings point to a conclusion that the role of importation of LNG into the PRC may be considered to be only indirectly facilitative regarding GHG emissions overall. In aggregate and historically gas seems to have played little direct role in the obvious decline of coal consumption across China. It also appears to be facilitating the introduction of wind energy.

Other Jurisdictions to which Western Australian LNG may be exported

Our ongoing research also contemplates the other markets of Australian LNG which include Japan and South Korea. Whilst the analysis of these jurisdictions is at very early stages. Our research is indicating:

- Japanese proposals to increase demand for thermal coal for electricity supply after the Fukushima Daiichi nuclear disaster have been reversed in recent months with few of the new coal fired power stations likely to be built and operated, possibly after renewed confidence in its nuclear industry. Our research remains outstanding regarding the role of LNG in Japan's energy mix; and
- Analysis of the South Korean energy mix has yet to commence but is expected to be complete this year.

Economic Impact of International "Economic Rent Seeking" around the Costs and Benefits of GHG mitigation

Currently in Australia it remains the responsibility of the Sovereign State to both commit to and reach GHG reduction targets. In the Australian context trade-exposed energy-intensive industry is legislatively excluded from "paying for its emissions" thereby transferring mitigation costs necessary to meet Paris Agreement commitments to the State. This externalisation of these substantial costs amount to a cross subsidy to both the end user of the gas and the project proponents. This transference is termed “rent seeking”. Further by trading internationally, it is entirely feasible for a recipient nation to claim substitution benefits against their own commitments. This too is “rent seeking” at the expense of the Australian Tax Payer.

The LNG industry is a classic example of how its export from Australia has created the potential for asymmetric economic loss to Australia around the costs of Climate Change mitigation. Currently Australian trade exposed energy intensive industry such as LNG gets a free pass to emit GHGs. The broader Australian citizenry is then required to offset the overall national emissions footprint in total to meet its Paris Agreement commitments. The industry project owner itself contributes little if anything towards the economic cost of mitigating its GHG emissions from its own Australian footprint. The LNG is then consumed in a jurisdiction such as China with its plans to implement Carbon Trading, which gives an energy operator a financial incentive to substitute fuels.

Under current Australian regulatory settings and the current and proposed Chinese GHG regimes, the economic benefit is shared only initially between the Chinese energy operator and the international conglomerate who supplies the fuel to a greater or lesser extent, whilst Australian taxpayers pay for the significant emissions produced in Australia.

This is a clear example of possible international arbitrage or rent seeking in ill balanced international transactions and associated financial costs and benefits.

Should projects such as the Cyan Hydrogen supply to Japan (discussed later) proceed under these disjointed international arrangements, potential asymmetric economic loss to Australian taxpayers through rent seeking could be economically crippling.

We recommend exploration and implementation of bilateral mechanisms with approved trade partners to equitably share the economic benefits and costs associated with the lifecycle of scope 1, 2, and 3 intensive emitting products. These include benefits of substitution and costs of carbon leakage upstream along the supply chain, based on the principle of equity in exploitation of societally beneficial finite natural resources Such resources are (in Australia at least) owned by the people in trust to their State and Federal governments.

We recommend that any offsets and value of carbon credits created be shared equitably between all parties to the proposal including both host governments. For example, purchase of offsets produced in a 3rd party nation by a private project proponent circumvents sharing of such benefits with the producing and consuming host nations.

Legal Standing of Scope 3 emissions in Australia

The legal Status of Scope 3 emissions is coming under increasing scrutiny in many jurisdictions in Australia.

It is our understanding that other submissions will provide advice on the current legal standing of Scope 3 emissions in the evaluation of environmental impacts of resources proposals in Western Australia.

Private communications with legal counsel conversant with these issues appear to indicate that significant scope 3 emissions and analysis are arguably a primary legal requirement for Australian Environmental Protection Agencies' jurisdictional advice and Ministerial decision making.

International Legal Obligations

The Paris agreement and the pledges by signatories currently hold no internationally legal standing. In Australia each government (both State and Federal) are only bound by their policy commitments regarding exported scope 3 emission potential such as that found in coal and LNG.

The challenge for humanity to mitigate the impact of anthropomorphic Climate Change caused by GHG emissions, particularly of fossil fuels has been considered by many to be the greatest challenge humanity has faced to date, thus binding international commitments have a significant role to play.

An earlier example of how a similar existential threat was managed is regarding nuclear non-proliferation (Bunn, 2003). These treaties include sovereign bilateral safeguard mechanisms, which in part is to create conditions for only beneficial export of nuclear product, such as Australia's uranium for power production. Australia has an obligation to export its uranium to countries with which it has an appropriate safeguard mechanism. Such mechanisms enable verification that recipients do not make nuclear weapons from the uranium either directly or by substitution. The past present and future impacts of anthropogenic Climate Change are similarly unsustainable. Negligent or malicious exploitation of internationally trade potential pollutants causing increased inability to meet the world's need for GHG reduction may be avoided through similar mechanisms.

We recommend that Western Australia, Australia, and other sovereign states driven by equity and sustainability ethics should create a legally binding framework to drive bilateral agreements for export of product with potential significant offshore scope 3 impacts (e.g. fossil fuels like LNG) like those implemented for uranium export.

Miscellaneous Issues

It is obvious after our review of all Australian LNG Environmental Impact Statements, as the Global Climate Change impacts of GHG emissions become better known, the EISs evolved and shared some common characteristics:

- The speciation of the sour gas produced from the various gas reservoirs became harder and harder to identify.

This can be construed as an attempt to limit exposure to public (and academic) scrutiny. An example may be obfuscating the likelihood of greater GHG emissions as the lesser quality reservoirs (with for example more embodied free carbon dioxide entrained or higher nitrogen contents) are developed for commercial gain. It should be noted that the gas is a sovereign asset and such knowledge evasion impinges on transparency for the public;

- Fracturing of life cycle knowledge by multiple EISs across the one product life cycle

Use of multiple EIS linked with "Scope emissions" reporting enables obfuscation of emissions and environmental impacts, particularly GHGs.

Segmentation of EISs into stages of the lifecycle (e.g. exploration extraction pipeline transport processing loading facilities and territorial shipping) hide the true overall impacts: each segment should consider the scope 3 input and output impacts as a minimum for all state based emissions and with best practice in a complete life cycle analysis.

Current proposals to export hydrogen energy are similarly unsustainable due to Climate Impact, if framed as is LNG, that hydrogen production from natural gas, albeit with the use of renewable process energy, is a viable transition path. This submission contemplates this proposition and comments accordingly.

Our conclusion is that the implementation of whole product life cycle commitments in EISs will circumvent the opaque behaviour that is so evident at present.

The constraints on potential emissions mitigation conditions the EPA should recognise, the appropriateness and practicability of measures to mitigate greenhouse gas emissions, including nature and level of planned reductions or offsets

The request for comment highlights the following specific questions about the constraints on potential emissions mitigation conditions the EPA should recognise:

- the appropriateness and practicability of measures to mitigate greenhouse gas emissions, including nature and level of planned reductions or offsets
- the timing of planned reductions or offsets
- the kinds or size of proposals to which the guidelines should apply

Mitigation was explored in detail in the Report by the IPCC WG5 published in 2014 (Field et al., 2014; IPCC, 2014) and in this context defines mitigation as:

"Mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases".

The EPA has noted its mitigation hierarchy in descending order of merit in relation to environmental harm as:

1. Avoidance
2. Reduction, and

3. Offset

We understand that a State Climate Strategy is in preparation and that it will complement the EPA's mitigation hierarchy requirements in EISs. Notwithstanding this we add the following input.

The emphasis on a creditable mitigation strategy is now very important with a clear statement from the government on mitigation targets and our research which finds that natural gas and therefore LNG cannot be seen as a valuable GHG mitigation agent as it does not substitute for coal.

We have already addressed the key issues of what data should be presented in an EIS earlier in this submission. These principles also apply in regard to identifying strategies associated with the first two hierarchical mitigation techniques of avoidance and reduction.

Perhaps the key and yet unaddressed issue around mitigation hierarchies relates to timing. Under current practices once an EIS is approved there appears to be little effort by either the proponents or the regulators to aggressively monitor new information regarding avoidance and/or reduction capacities and strategies once the initial approvals are in place.

The Paris Agreement explicitly requires a ratcheting mechanism for efforts to mitigate GHG emissions. The mechanisms for how Western Australia achieves this effect may include a range of regulatory and market mechanisms as a key component of both State Strategy and EPA EIS requirements.

Given its current of a holistic State Strategy for GHG mitigation, the state may be in a position where it takes a more expansive view of research and development as a key component of a ratchet strategy proposed by a project proponent.

We recommend that an EIS should include the steps needed to ratchet toward net zero by 2050 and the research and development commitment in line with the strategy should be significant.

A key element for creating change within the mitigation hierarchy includes removal of market distorting subsidies, such as the previously mentioned "free" fuel inherent in the business of LNG production under current regimes.

A further element may be to implement direct monitoring of emissions on a continuous "airshed scale" particularly for fugitive methane, detailed and accurate self-reporting and subsequent independent auditing on a yearly basis linked to proposed initial mitigation strategies.

Post commissioning change is always difficult as the resource processes in Australia tend to be capitally intensive and subject to medium to long term constraints. Continuous improvement techniques tend to be vigorously minimalist and more focused on production efficacy.

Consequently, the same powers of the act may be used to negotiate with and commit proponents to an aggressive equitable and agreed trajectory for further legally enforceable and clear avoidance and reduction targets at the time of granting project approval. Such oversight should include regular (annual) statutory reviews interwoven with strategic scanning of opportunities to further accelerate mitigation rates. This may be facilitated by formation of industry specific technical advisory boards including members independent of both government and industry.

Cooperatively the Western Australian Government may wish to partner with proponents to undertake (local) research and development specifically to assist proponents to meet these goals and build up capacity to articulate findings into international technological trade. Benefits of such activity's consequent to the research and development should be shared between the partners.

We recommend that the EPA demand more transparency, greater focus and a broader interpretation of "best practice" when examining the mitigation strategies proposed by project proponents.

We recommend that industries and perhaps the Government strive to become leaders in best practice in GHG mitigation in key industries such as the iron ore and LNG industries. This is particularly pertinent where proponents participate in globally significant industries through localised research and development specifically targeting GHG mitigation.

We recommend that the conditions around mitigation include a nominated and aggressive downward trajectory for GHG emissions over the life of the projects which is in alignment with both Federal and State Government policies. We also recommend the formation of a system of annual review to ensure ongoing and dynamic downward pressure on implementation of avoidance and reduction strategies.

We recommend that the state investigate potential incentives for currently operating projects to enable them to implement strategies in line with the recently announced mitigation target of net zero by 2050. This may include preferred partnerships in any overarching industry development that facilitates transition to the new economy.

We note that Western Australia is in an ideal position to take advantage of bio sequestration methodologies as a primary offset mechanism, as nominated by the IPCC.

We recommend that offsets be used as a last resort, be local to ensure minimal economic leakage around currently externalised GHG emission liabilities to the state, and meet both Australian and best practice international verification techniques.

Carbon Leakage and Salutary Lessons from the Current Support for Fossil Fuel Derived Hydrogen Products, even if using Renewable Process Energy

Some LNG exporters advocate that a future exists where "Cyan[12]" hydrogen derived from fossil natural gas using renewable energy technologies to provide the process power. Our research (Baccanelli, Langé, Rocco, Pellegrini, & Colombo, 2016; Cardella, Decker, & Klein, 2017; "Chapter 4 - Energy and Exergy Analyses of Natural Gas Liquefaction Cycles," 2014; Kanoğlu, 2002; Kirova-Yordanova, 2004; Obara, 2019; Pedro Dinis & Pedro Dinho da, 2015; Rosen, 1996; Roszak & Chorowski, 2014; Valera-Medina, Xiao, Owen-Jones, David, & Bowen, 2018; Vatani, Mehrpooya, & Palizdar, 2014; Zarzo & Prats, 2018) into the lifecycle GHG impact of such technology does provide GHG emissions advantages in comparison to the current LNG processes commonly found in the Pilbara, which use "free" fossil natural gas to provide the process energy. Anecdotally the demand for this is driven by Japanese customers already working with LNG suppliers. The primary benefit for the Japanese is complete

[12] Cyan is the colour derived from mixing blue and green, hence adequately describes any energy product derived from fossil fuels but process power derived from renewables, i.e. a mix of the two. Blue is widely identified as, and nominally the colour identified with natural gas (e.g. blue Hydrogen) and renewable energy represented by green.

removal of GHG from their own scope 1 and 2 emissions when used to fuel fuel-cells for motoring, a particular strength of Japanese technology. The advantages for the current LNG suppliers is a potential added value revenue stream at a higher price and presumably margin than fossil LNG. The disadvantages for the Australian GHG commitments at Paris is that this Cyan hydrogen lifts Australian GHG emissions by more than 2 ½ times current LNG Scope 1 and 2 emissions, and under current Australian systems externalises the cost of the Australian supply and Japan's GHG commitments to the rest of the Australian economy. Globally the whole life cycle GHG emissions of Cyan hydrogen in comparison to current LNG practice reduces its footprint by around 16.7%: a small net benefit.

However, should LNG producers commit fully to Cyan LNG: i.e. using renewable electricity to power operations, the same measure provides an approximate 14.7% reduction. This is technology available now and doesn't require the development of a completely new technologically risky supply chain and does not incur a large "Carbon Leakage" from Japan to Australia. Such large-scale carbon leakage imposes a massive perhaps insurmountable burden on Australia to meet its Paris and beyond GHG reduction targets.

We conclude that the incumbent Western Australian LNG producers can make a significant GHG reduction by applying technology proposed in producing Cyan Hydrogen (fossil natural gas processed using renewables) to existing LNG processes in the short term. To do so brings forward the potential Global GHG emission reductions of about 15% attributable to the industry, with less risk and without Carbon Leakage from Japan to Australia. The State Government should actively assist the industry to do so including to create economic conditions and infrastructure to facilitate implementation of 100% renewable energy supply to existing facilities, and market Cyan LNG, not Cyan ammonia-based hydrogen transport.

We recommend that the EPA investigate all proposed processes for lifecycle GHG emissions to identify:

- **technologies which can translate to reductions in current GHG emissions at existing facilities in the short term; and**
- **determine potential for Carbon Leakage in favour of client nations and at the expense of Australia's GHG burden.**

Further, our research examines the lifecycle GHG emissions for direct (Green) renewable energy transmission though UHVDC electricity, liquid hydrogen and ammonia-based hydrogen transport. Our research indicates that direct electrical transmission for export is by far the most efficient energy transmission mechanism, and when coupled with solar thermal (Dubey, Sarvaiya, & Seshadri, 2013; Popovici, Hudişteanu, Mateescu, & Cherecheş, 2016; Srilakshmi, Ramaswamy, & Thirumalai, 2016) or wind energy technology's is 2.3 times the efficiency of either of the hydrogen transmission technologies. This is important in that the primary natural resource input to renewables is land (Ong, Campbell, Denholm, Margolis, & Heath, 2013), and to have such standout technologies deliver with 42% of the land requirements of others is a significant environmental advantage (Allan et al., 2019).

Whilst eventually UHVDC technology and appropriate market targeting will enable economic transmission of electricity from the North West of Western Australia to the lower south east part of China, ammonia based green hydrogen may have marginal advantage.

We conclude that in the long-term Cyan Hydrogen should be sidelined in favour of development of fully renewable technologies for energy export including "Green[13]" ammonia-based hydrogen transport and ultra-high voltage direct current subsea (UHVDC) technology for electricity transmission. This is the basis of the new economy in our region.

We recommend that during the transition period, the State Government actively participate in discouraging short term microeconomic gains to industry that cause subsidy of incumbents by the Australian community The Government should encourage new industry to maximise macroeconomic gains in the long term seeking to demonstrate these new technologies.

Any other advice related to the assessment of greenhouse gas emissions by the EPA that would further clarify or improve the guidelines

We submit the following as essential to consideration of the EPA project approval process.

Interactivity of Environmental GHG Activism and Western Australian Economy: A Pathway

Our research shows that the concept of intersectionality at the State level demands a multilayered approach to Decarbonising the Pilbara which is beyond the scope of the EPA and calls for a State and National response to deliver an economic, social, cultural and environmentally nuanced transition to a sustainable and resilient society, based around our natural endowments. The window for action is clearly narrowing.

As a concept, intersectionality is opposed to monism, the idea that each category of social relations can be adequately analysed or understood separately from each other, as a single dimension. It is worth emphasizing that intersectionality is not the opposite of privilege or advantage: it is possible to be intersectionally advantaged or privileged as well as intersectionally marginalized, dominated or oppressed (Weldon, 2008).

The State Government and other industries acted as a catalyst for Woodside to get the business case up for the first Australian LNG plant many years ago. We now believe there is

[13] Blue is widely identified as, and nominally the colour identified with fully fossil natural gas derivatives (e.g. blue Hydrogen) and renewable energy represented by green.

a third way in comparison to the "us and them cut and thrust" on display over the EPA recommendations where the natural gas industry saw an end to the era which had such strong state support. There is a new transition occurring globally that the natural gas industry and the Pilbara region need to be part of. This requires collaborative "intersectional" work which can lead to significant legacy industries in the Pilbara, in part sponsored by and advantageous to the LNG partners operating there now. We have identified more than USD 200 billion potential investment in offshoot industrial development, also in part based around the same goals as that of the EPA.

Current Macroeconomic Outlook for Australia's intersection with the LNG Industry

There are a series of key macroeconomic challenges facing Western Australia beyond the one contemplated in this submission. WA is the biggest CO2e emitting state in a high emitting nation, in a world increasingly wise about the impacts of Climate Change, where fossil fuels are unpopular and LNG may currently be attractive, but this is likely to change, and where the industry creates a huge externalised debt for Australians. Our recent research examines the macroeconomic influence of LNG on the State.

Current gross annual revenue across the ten Australian LNG project operators is estimated at AUD 70 billion with the possibility of this increasing to AUD 156 billion. This translates to a present value between AUD 884 to AUD 2,040 billion. Future and foreseeable externalized costs borne by the Australian people outweigh the benefits currently paid by the industry. These costs are at best equivalent to and at worst eleven times greater than the value of any benefit. Should the industry internalise these costs, they would represent between 3 and 16% of gross revenue, something that in our trade exposed democracy would normally share between project equity partners and customers.

Currently these major externalised costs will be borne by the Australian people, given Australian policy settings. These costs are projected to be between AUD 2.23 billion and AUD 25.4 billion per annum, representing a present value of between AUD 16.3 billion and AUD 198 billion. They are:

- fuel subsidies to the LNG industry, which will cost the Government somewhere between a net present value of AUD 8.0 billion and AUD 100 billion, at an annualised rate between AUD 1.6 billion to AUD 21.6 billion per year; and,
- GHG offset costs. Under current policy settings, Australians will subsidise the GHG emissions for the LNG industry by at least a present value of AUD 8.3 billion and up to AUD 97.8 billion dollars, at an annual rate between AUD 0.68 billion to AUD 3.83 billion per year.

Total annual dividends paid to the Australian people in exchange for the twin activities of hosting the LNG export industry, and vesting the nation's gas assets to the industry, are estimated to be in the order of AUD 3.52 billion per annum, including:

- significant companies participating in the LNG industry in Australia paid on average AUD 1.3 billion per annum of company tax on revenue of AUD 89 billion per annum for the privilege of operating in Australia (1.4%) for the period 2014-2016,
- AUD 0.82 billion per annum of Petroleum Resource Rental Tax (PRRT, 0.9%) for the monopoly rights to exploit the petroleum resources they control but are otherwise owned by the Australian people.

- royalties on the natural gas used in LNG production of approximately AUD 1.4 billion per annum from 4 out of the 10 operating facilities. The other six extract the gas from federally controlled waters, and thus are only expected to pay PRRT.

Notionally, the dividends may be split into two privileges:

- For hosting the industry and use of social and hard infrastructure, the companies returned 1.4% of revenue, though significantly variable amongst the companies;
- For access and exploitation of Australia's gas consumed in the industry, Australians in recent history achieved a return of 0.9% with a further 1.4% extracted from one large project combined with three smaller ones for royalties.

The total current cash flow return of up to 2.3% to Australians is in return for the gas asset invested in the project. Appropriately leveraged projects may remit cash flow returns in excess of 40% of revenue to the project partners and financiers, in return for the cash asset invested. The later payments return initial capital invested and provides a profit for the investment. The former payments for the gas neither assist in replacing the depleted assert nor give an adequate return.

We conclude that the current externalised costs to the Australian people of hosting the LNG industry in Australia are unsustainable and unfair. However, should these costs be internalised to the industry, the incumbent industry may also be commercially compromised. Thus, a transition strategy is needed.

Further, our estimate of the <u>global</u> GHG amelioration costs attributable to the Australian LNG industry will be at minimum between AUD 307 billion dollars and AUD 629 billion present value. They represent an indicative increase in supply chain pricing necessary to internalise the costs of emissions of between 26% and 55% of gross revenue for exported LNG.

These global externalised costs are significant. The moral and ethical conundrum is: "Who pays"?

Our research collected standardised data around the Australian LNG industry and its position within the Australian domain. Its purpose thereafter is to at least underpin recommended policy settings to facilitate visionary and strategic action. We are working to present options for a better integration of the activities of the industry to leverage a better and sustainable future for both the industry, and the host and asset owning nation, Australia. At best the data will provide an information platform for informed debate around the role of the LNG industry in Australia.

This industry will in the long run become relatively insignificant in Australia, either through exhaustion of quality gas or through a carbon constrained world turning away, perhaps within the current generation's lifetime. What legacy does it want to leave in Australia? What legacy do the Australian people want it to leave, to supplant the Australian natural assets it consumes?

LNG clearly holds a dominant economic position as one of few energy transport options globally. It however cannot compete with renewables as a short to medium term sustainable remedy for the world's energy supply, in its current guise. The industry has the potential to maximise its claim to providing a transition fuel (from fossil to renewable) by embracing a much wider scope for their role as transitional/facilitative energy suppliers.

The LNG industry has seen a rapid increase in demand as imbalances in regional fossil energy supply force an increasing demand for international trade. This demand is also expected to grow further as China moves for the first time to replace its coal consumption perhaps with natural gas, motivated by a desire to reduce local and regional atmospheric pollution causing ill health amongst its citizens (Russell, 2018).

Our overall analysis shows that this needn't have been the case and need not be the case in the future as more cost effective options are available and are where the world's investors are moving.

Our research seeks to examine the Australian LNG industry and its Greenhouse gas emissions, its consequences and options. It recommends policies which will enable:

- the industry in Australia to assume a globally important leadership role in advancing its claim to commercialise a potentially beneficial transitional fuel towards a renewable future, and to ensure positive action is taken in a timely fashion;
- Western Australian Government to act to maximise the societal benefit of hosting the industry by setting the policy and legislative environment to springboard into a sustainable economic social and environmental state; and,
- The Federal Government, as a host to an influential proportion of the LNG industry, acts to maximise the societal benefit of hosting the industry by using it to springboard into a sustainable economic, social and environmental future

Summarizing One Pathway to Break the apparent Binary of Existential GHG related Climate Change with Western Australia's looming Economic Existential Threat

'Existential threat' has become part of the dialogue about the future based on the writings of Professor Nick Bostrom, an Oxford University Professor in Philosophy. Others are now applying it to the climate change issue and the need to create a new economy that is net zero in emissions as quickly as possible to avoid runaway climate change impacts (Newman, Beatley and Boyer, 2017).

Our research suggests that WA, and the Pilbara region in particular, faces an existential threat from sudden collapse of key markets in natural gas. Our research also shows that Western Australia has the opportunity to reconceive its industrial and energy strength, and leverage the third wave of large scale resource developments in the North of Western Australia: its world class solar insolation resources are located not in the Pilbara region but just to its North in the desert lands of the south/south west of the Kimberley region, channelling north west across the coastline north of Derby to both Timor Leste and Indonesia, and south west to the large industrial complex of the iron ore and LNG industries. The combination of all these markets will attract energy intensive high value add industries such as the aluminium smelting companies currently slowly exiting Australian shores to cheaper cleaner and more reliable energy suppliers elsewhere. The region has the potential to rival and surpass similarly emergent regions but based on renewable energy and local labour.

The attraction for Indonesia will be to emulate China's emergence based on low energy cost and relatively cheap labour costs to create an internationally competitive industrial complex based on the next generation of energy providers. Further, good policy development by WA and Australia may encourage a "free development zone" all around the Timor sea for these three regional neighbours to bolster regional and economic security, something which is valuable for all.

The attraction for East Timor is that it can do something similar, enable vision beyond that of fossil fuel exploitation. Although there is short term value in natural gas, it is a resource which is likely to find itself stranded as world trade decreases under coastal and global environmental concerns and moves quickly to other decarbonized energy sources which are more cost effective in the longer term. This will be an investor-led process as is happening with coal (Newman et al, 2017).

The attraction for Australia and particularly the Kimberley and Pilbara regions is to develop a completely new suite of technologies, based on a world class development, which not only enables the nation to leverage its natural resources into world class manufacture, but to revitalise its manufacturing prospects by:

- Cornering several of the best renewable energy technologies and bringing them to the world; and
- Providing a reason for very high technology energy intensive and high capital investment manufacturers to return to Australia rather than pack up and leave much as has happened over the last 20 years.

Our estimates of the export market exceed USD 20 billion plus per annum, eclipsing that for LNG and reaching toward parity with our iron ore exports.

Finally, and just as importantly, the vexed problem of our carbon ghetto caused by the LNG and iron ore industry in the Pilbara is addressed enabling these producers to become carbonless and lower cost producers in a new regional economic hub.

CUSP's research over the last 6 years has mapped a pathway which provides subsidy-free highly reliable coal-competitive renewably-based energy, to attract high value-add energy intensive industry to create a social and economic super region around the rim of the Timor sea.

Key points are:

- Both Australia and Indonesia would like to attract new energy-reliant heavy industries. This is hard to do today, as most companies are looking for the least expensive energy cost as well as large quantities with high reliability and most importantly are very happy if this can be achieved with carbonless energy supply. Australia has seen a net loss of these industries over several decades;
- Similarly, there is a social responsibility to turn older and existing energy dependent industries away from carbon intensive fossil fuel reliance in both countries, but to do so without economic penalty;
- Both Australia and Indonesia are vulnerable to international natural gas pricing which is pricing domestic industry out of the market;
- Indonesia also has a need for new energy sources at least equalling all of Australia's current demand over the next decade should it wish to meet its social development policies;
- Most energy policy is focused on residential, commercial and less energy intensive industrial sectors due to the seemingly impossible ability to address energy intensive and heavy industry – this is likely to change globally as the focus shifts to them now as outlined in recent IPCC reports;
- Indonesia also has a population which can provide competitive skilled labour costs against competition from some of the major Asian Nations (India and China);
- Australia has the largest and world beating solar resource in the Kimberley and Pilbara regions without a large enough current demand to facilitate its development;
- There is a (closing) time gap currently in a handful of emerging solar and power technologies which if deployed at scale and in a timely manner for this project will underwrite a new world class industrial base for the proponent states (Australia and Indonesia) therein developing their own manufacturing and science base to serve the world market.

The proposal is to create a world scale industrial cluster around the Timor Sea targeting energy intensive resource value add (e.g. aluminium smelting) and manufacturing industries based on competitive labour costs, low cost high volume and reliable low carbon electricity supply (approx. 97% reduction from equivalent in gas), thus enabling access to established shipping routes and perhaps establishing some new ones.

This is only likely with close collaboration at a government to government level between Australia and Indonesia.

The first step is for the research community and the state government to:

- **Undertake a significantly more resourced due diligence analysis on the transition strategy to a net zero economy driven by new industries in the Pilbara;**
- **Work to build support at the intergovernmental (WA, Australia, Indonesia and Timor-Leste) level and regional and international infrastructure funds with the ultimate aim of sovereign funding of approximately USD 13 billion to build own and operate the first (of potentially nine) electrical energy links between Indonesia (IndoLink) and the Pilbara (PilbaraLink);**

- **Work with the Federal Government and other State Governments to understand the positive economics of transmitting electricity (TransNational link) rather than natural gas from the Pilbara and linking the region into the National Rail Network, perhaps even with electrically powered trains;**
- **Work to gather research and development resources on a scale which ensures Australian technological and hence market leadership for some direct and emerging technologies both integral and subsidiary to the roll-out of this regional development program;**
- **Work to develop major industrial policies and programs to catalyse Australian and other participant nationals towards entrepreneurial opportunities in direct development of the technologies identified as being critical to the success of the precinct;**
- **Work to develop cultural, social, environmental and economic policy programs and infrastructure in the regions to address local equity in the Pilbara and Kimberley (for example University location, industrial support, and land management in the region);**
- **Work to gather a cluster of energy companies to invest an initial combined USD 7 billion to provide the renewable high-quality low cost and high-volume energy to the IndoLink and PilbaraLink transmission paths;**
- **Work to gather a cluster of energy intensive high value add manufacturers and resource developers who may invest in Australia and Indonesia over the longer term, including local industrial players in the LNG, Iron Ore and Alumina industries, to create the new net zero industrial hub in the Pilbara.**

Attachment 1: A Briefing Paper regarding Fugitives and the State of Knowledge in the Natural Gas Industry

Introduction

Fugitive emissions by definition are the uncontrolled emissions of green-house gases (GHG), primarily methane, from the fossil fuel industry.

Fugitive emissions occur during the production, processing, transport, storage, transmission and distribution of fossil fuels. Emissions from decommissioned underground coal mines are also included in this sector.

Methane is the second most impactive GHG, currently contributing nominally 17% of the unbalanced radiative forcing creating climate change (Thompson et al., 2018).

Methane is a very potent GHG, with relatively small emissions having a disproportionate effect. Its relative impact is currently estimated to be 34 times greater than CO_2 when viewed over the standard 100-year horizon. It is a short-lived gas in the atmosphere and its global warming potential (GWP) with a 10-year horizon (GWP10) is significantly 86 times greater. Should the 10-year nominal horizon be considered more appropriate, then application of the differences in GWP indicate that methane would contribute nominally 34% of current radiative forcing. Further research continues to not only improve to our understanding of methane's contribution to climate change but often to identify an ever increasing impact (Etminan, Myhre, Highwood, & Shine, 2016).

The common global standard is to use a 100-year GWP in reporting notional relative impacts. However, this was a nominal standardisation which may be less relevant today as the impacts of climate change loom ever more imminent. To recognise the urgency of action on the overall climate change challenge is to recognise the increased need to act on reducing methane fugitive emissions.

For comparative purposes pre-anthropomorphic levels of atmospheric methane concentrations have been around 600-700 parts per billion (ppb) and with a similar trajectory to CO_2 concentrations, by 2018 had risen to 1858 ppb. More alarmingly atmospheric methane growth has been very strong in the years 2014–2018 (Nisbet et al., 2019).

The following graphic entitled "Figure 15: Recent trends atmospheric methane concentrations" indicates recent trends in this measure (solid blue line). It indicates the rapid rise in the period from 1984 to 1999 then a hiatus until around 2006 when the concentration began to rise again, accelerating further in 2014. The graph also indicates the rate of growth (amber dotted line).

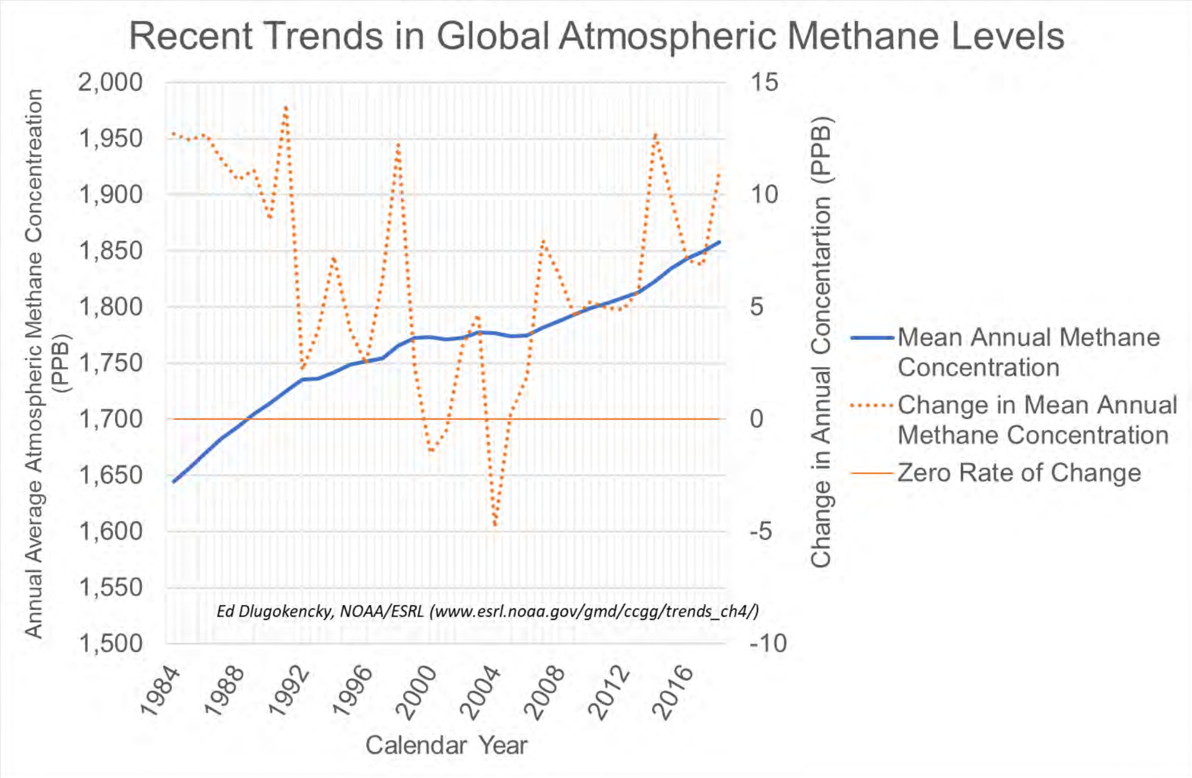

Figure 15: Recent trends atmospheric methane concentrations

At least one study into this variability in atmospheric methane over the last 30 years (Thompson et al., 2018) has concluded that the increase in methane between 2007 and 2014 is likely due to an increase in microbial sources, predominantly natural wetlands and agricultural (36 ± 12 Tg/yr), as well as fossil fuel sources (15 ± 8 Tg/yr). In contrast to other recent studies, a reduction in the atmospheric sink of methane was found not to be a significant factor in explaining the recent atmospheric increase. Subsequently a best estimate is that 30% of the current increase is attributable to fossil fuel's fugitive emissions. More research is necessary to improve understanding of this.

Encouragingly some researchers postulate that the hiatus in concentrations and indeed occasional reduction from 1999 to 2006 is likely due to the improved hygiene around fugitive emissions from the fossil fuel industries. If this is the case the industry has shown it can react responsibly. It is probable that the industry will come under sustained pressure to do even better in the very near future.

A large increase in U.S. methane emissions over the past decade has been inferred from satellite data and surface observations (Turner et al., 2016). This study contrasted National inventory estimates by the U.S. Environmental Protection Agency which indicate no significant trend in U.S. anthropogenic methane emissions from 2002 to the present. The study using satellite retrievals and surface observations of atmospheric methane, contrarily suggests that U.S. methane emissions have increased by more than 30% over the 2002–2014 period. This large increase in U.S. methane emissions could account for 30–60% of the otherwise unexplained global growth of atmospheric methane seen in the past decade.

The stated timeframe parallels an unprecedented surge in the exploitation of unconventional gas in the US. Chinese researchers also conclude that "*The energy industry methane emissions showed a strong positive correlation with national methane emissions, …*" (Weng, Xue, Cui, & Li, 2019).

How much does Australia contribute through its fugitive emissions?

The Australian Case

In Australia the trends are similarly significant. The latest Quarterly Update of Australia's National Greenhouse Gas Inventory (for September 2018) provides a good snapshot: Australia's greenhouse gas emissions continue to rise and fugitive emissions represent 10.7% overall. Fugitive emissions relative and real growth is the fastest all emissions.

The following graphic entitled "Figure 16: The impact and time series trends of Australian fugitive emissions against all others" demonstrates this.

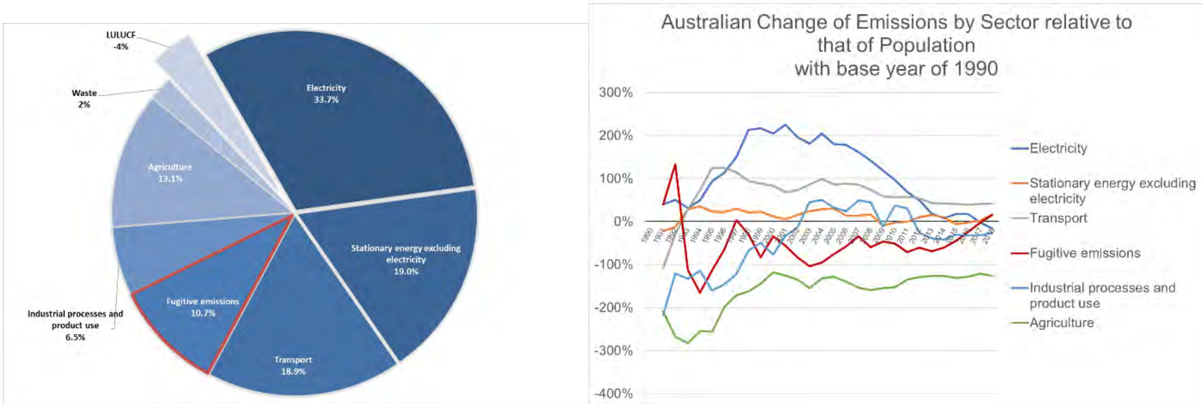

Figure 16: The impact and time series trends of Australian fugitive emissions against all others

The report also indicates that the industry itself reports fugitive emissions from oil gas and coal as being at an all-time high annualised rate of 30.8 Mtpa CO2e. The following graphic entitled "Figure 17: Comparison of Australian based coal fugitive emissions against those for oil and gas" shows the quarterly emissions estimates by relative contribution over time for coal on one hand and oil and gas on the other. For the first time in Australia's recent history the reported fugitive emissions from crude and gas (almost all gas) were greater than those for coal production in the March 2017 Quarter.

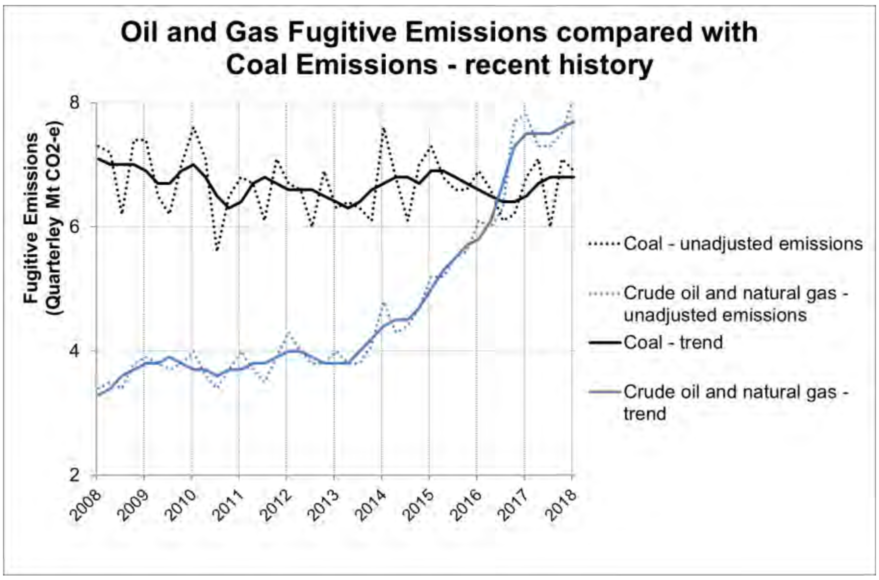

Figure 17: Comparison of Australian based coal fugitive emissions against those for oil and gas

Whilst coal-derived estimates are stagnant, the trend concerning oil and gas is alarming. Whilst the recent increase in natural gas production from both coal seam and conventional sources has provided an economic boost to Australia, the environmental costs are now becoming obvious. Importantly, most fugitive emissions in the oil supply chain come from production and to a lesser extent refining. The latest Australian Energy Statistics from the Australian Department of the Environment and Energy show that 87.4% of the energy produced in Australia from oil and gas is gaseous and 76% of crude oil and gas processed in Australia is gaseous. The major driver in Australia's fugitive emissions is the unprecedented growth in its LNG export industry coupled with a much smaller organic growth in domestic gas consumption. The oil industry is a comparatively minor contributor.

The data also indicates that the rate of fugitive emission measured in emissions per energy content for oil and gas is currently three times that of coal, indicating both the poor innate qualities of natural gas in this respect, and potentially the poor performance of this sector in constraining its product.

Clearly the bulk of the fugitive emissions in the oil and gas category are from natural gas flows in Australia and are increasing in line with the increased production for export through the LNG industry.

The following graphic entitled "Figure 18: The rise and rise of Australia's Natural Gas exports" indicates the destinations and quantities of the produced natural gas in Australia. The increase from 2004 and the rapid increase from 2015 is entirely due to the commissioning of various LNG export plant across Australia. The graph demonstrates the impact of the rapid growth of the LNG industry, with notably more gas exported than domestically consumed for the first time in 2013. As of 2018, nearly 70% of Australia's annual gas production is now destined for export compared with 13.4% in 1990: a remarkable increase.

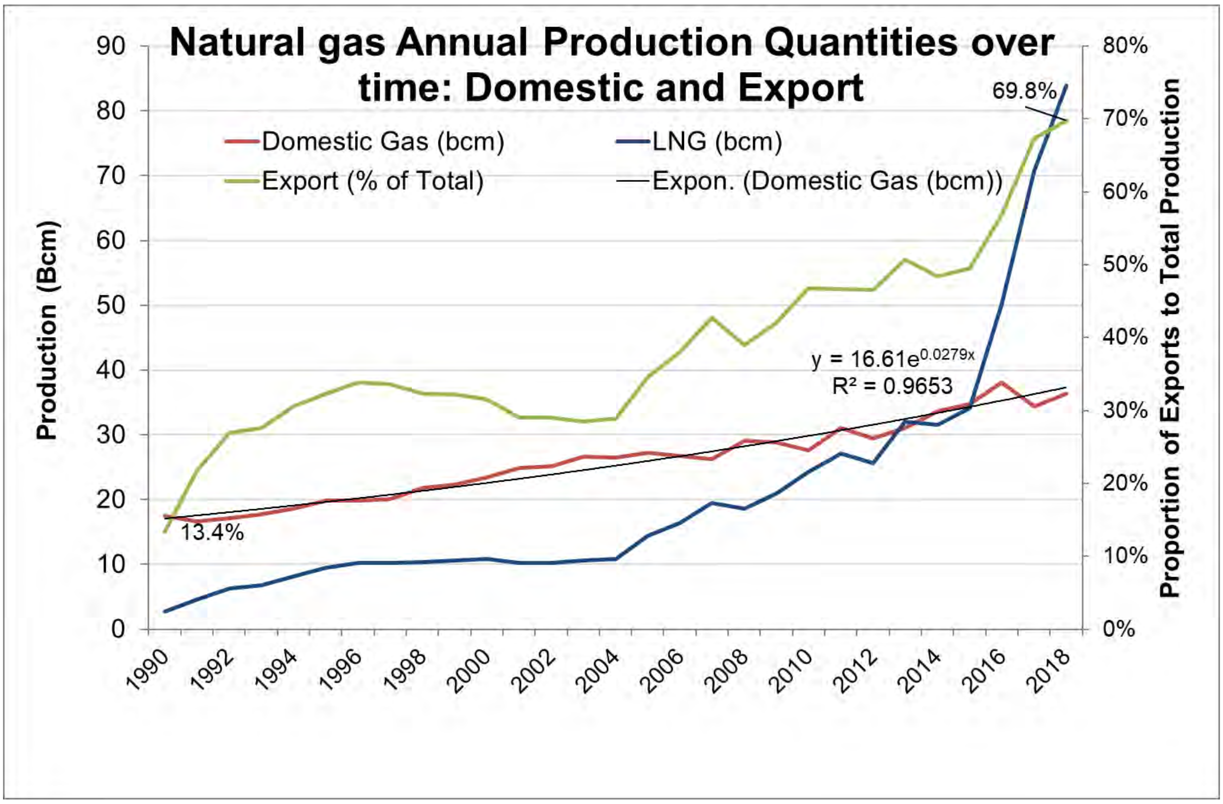

Figure 18: The rise and rise of Australia's Natural Gas exports

Discussion

In Australia the LNG industry is generally recognised as a trade exposed energy intensive industry and is regularly excluded from rigorous scrutiny and regulation of its emissions, including fugitive emissions. Further, the industry proponents claim generically that natural gas to be a suitable transitional fuel, with better emissions characteristics than coal.

Putting to one side the contestability of the industry mythology around being a good transition fuel under current and general understandings, fugitive emissions rates for natural gas and particularly LNG can alter the relative efficacy of overall GHG emissions of natural gas when compared with coal.

In 2012 research indicated that a fugitive emission rate in the order of 3.2% for a typical natural gas supply chain would create a GHG emissions equivalence to coal for electricty production (Alvarez, Pacala, Winebrake, Chameides, & Hamburg, 2012). Updating the results (due to a change in the methane GWP from 24, used in that study, to the current scientific undertsanding of 34), shifts the equivalence point to a fugitive emission rate of 2.4%.

Recent studies (Paul Balcombe, Anderson, Speirs, Brandon, & Hawkes, 2017; P. Balcombe, Brandon, & Hawkes, 2018) indicate that in the US, methane and CO_2 emissions from the natural gas supply chain vary widely. For methane-only emissions, median estimates are 0.8–2.2% of total methane production, with mean emissions of 1.6–5.5%. The study concludes that heavy tail distribution is the signature of the disproportionately large emitting equipment known as super-emitters, which appear at all stages of the supply chain.

Another study (Littlefield, Marriott, Schivley, & Skone, 2017) indicates that 1.7% of the methane in natural gas is emitted between extraction and delivery (with a 95% confidence interval from 1.3% to 2.2%).

Conclusively the margin for the net benefit of natural gas over coal is highly sensitive to the assumed fugitive emission rate, which in turn has yet to be conclusively determined, particularly for LNG supply chains.

The actual emissions in the industry are a subject of significant (and at times acerbic) debate, with the primary differences appearing to be between traditional “bottom up” approaches (as advocated by the American Petroleum Institute on which Australian legislation and regulation is based) and a “top-down” regional assessment by satellite and other emerging technologies. The former consistently and systematically seems to underestimate the emissions, whilst the latter appears to have some difficulty in attribution of source.

Australia has a very patchy and perhaps unreliable evidentiary base for its inventory collection, enabling the US industry consensus to be a proxy for real Australian experience. The Departments of Environment and Energy last undertook a review in 2017 and conclude in part:

> *“… fugitive emission processes from the gas industry are highly variable – both spatially and over time – and that uncertainties remain significant”*

Data on fugitive emissions for LNG production in Australia is even more sketchy, with the only authoritative source still being a research note from the American Petroleum Institute (API) specifically for the LNG industry in 2017. It continues to rely on a “bottom-up” methodology.

Indicatively for complex plant such as LNG processing facilities, recent research (Lavoie et al., 2017) into methane emissions from natural gas-fired power plants and oil refineries using air shed techniques, indicated that average CH_4 emission rates were, for the gas plant between 21 and 120 times larger than facility-reported (bottom-up) estimates and, similarly between 11 and 90 times for refineries. It is possible that complex production facilities such as LNG plant suffer similar disparities. The issue is that there is no definitive data to indicate one way or the other in Australia.

Policy options

Theoretically the natural gas production transport and use supply chain is totally enclosed and thus zero fugitives are possible. At least one researcher indicates a feasible cap at 0.9% in comparison to indicative rates of more than double this. Australia is now a leading exporter of LNG and has a moral and legal imperative to reduce the climate change impact of its fugitive emissions. Notwithstanding this, the following policy options may significantly contribute to reduction of Australia's actual fugitive and thus overall GHG footprint:

Know the Problem

Emerging techniques are converging on a scientifically verifiable "air-shed" and "bottom up" capability to determine actual fugitive emissions. The reliance on US industry-provided data is not sufficient. Australia should join the lead and implement in this capability as it is now a global player in supply of LNG.

Regulatory Regime

In many multinational industries self-reporting and regulation has failed on many fronts. The performance of Australian natural gas, and particularly the LNG industry is unknown because of self-reporting. The regulatory regimes around environmental protection, particularly GHG control, are weak, with possible industry capture. Benchmarking can no longer be an industry internal function. It is clear that the concept of industry best practice within oligarchic industry is self-referential and thus self-defeating. Development of a coordinated and well-resourced independent functional body or group to extend industry best practice, its implementation and audit is essential.

Attachment 2. Why Australia has a responsibility to lead global mitigation efforts.

Frequent statements are made that Australia has only a minimal contribution to global emissions. This is not so if historical emissions are considered.

Australia ranks 15th overall on cumulative historical GHG emissions accounts dating from 1751 to 2017, in a league table of 224 jurisdictions[14], as indicated by the graphic entitled “Figure 19: Top 20 Country Rankings for Historical Cumulative GHG emissions consumed” showing the top 20 below:

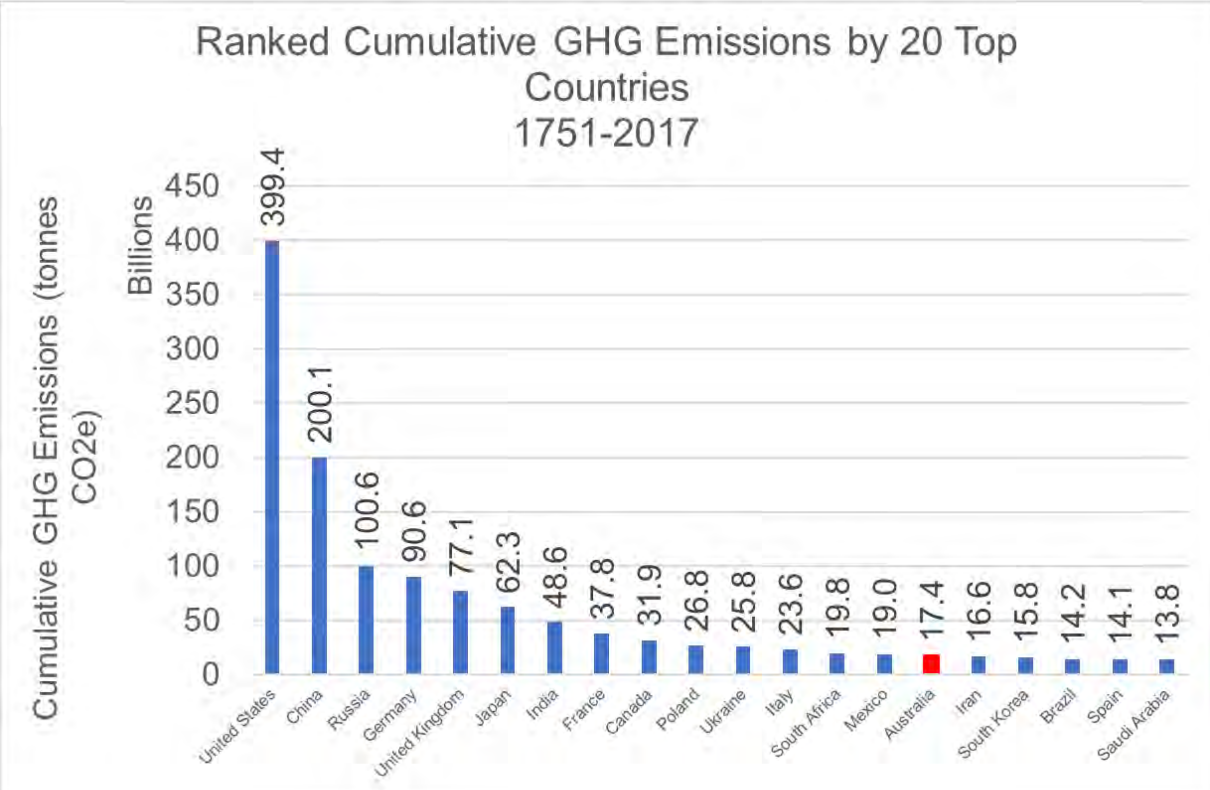

Figure 19: Top 20 Country Rankings for Historical Cumulative GHG emissions consumed

Given Australia’s relatively small population and youth in comparison to many with a longer history of expansionist economies and subsequent industrial development, this high ranking at 17.4 historical billion tonnes of GHG emitted is remarkable.

At face value this would appear to place the historical burden on a country such as the United States or China superficially due to aggressive industrialisation. However, a human scale is more indicative.

When sheeting home the responsibility to the individuals who constitute each society, Australia’s ranking rises to 7th amongst nations having emitted more than 10 billion tonnes of GHG since 1751. This is indicated in the graphic below entitled “Figure 20: Country Rankings for Historical Cumulative GHG emissions per capita consumed”:

[14] Website “Our World in Data: CO2 and Greenhouse Gas Emissions” a joint venture between Oxford University and NFP Organisation Global Change Data Lab

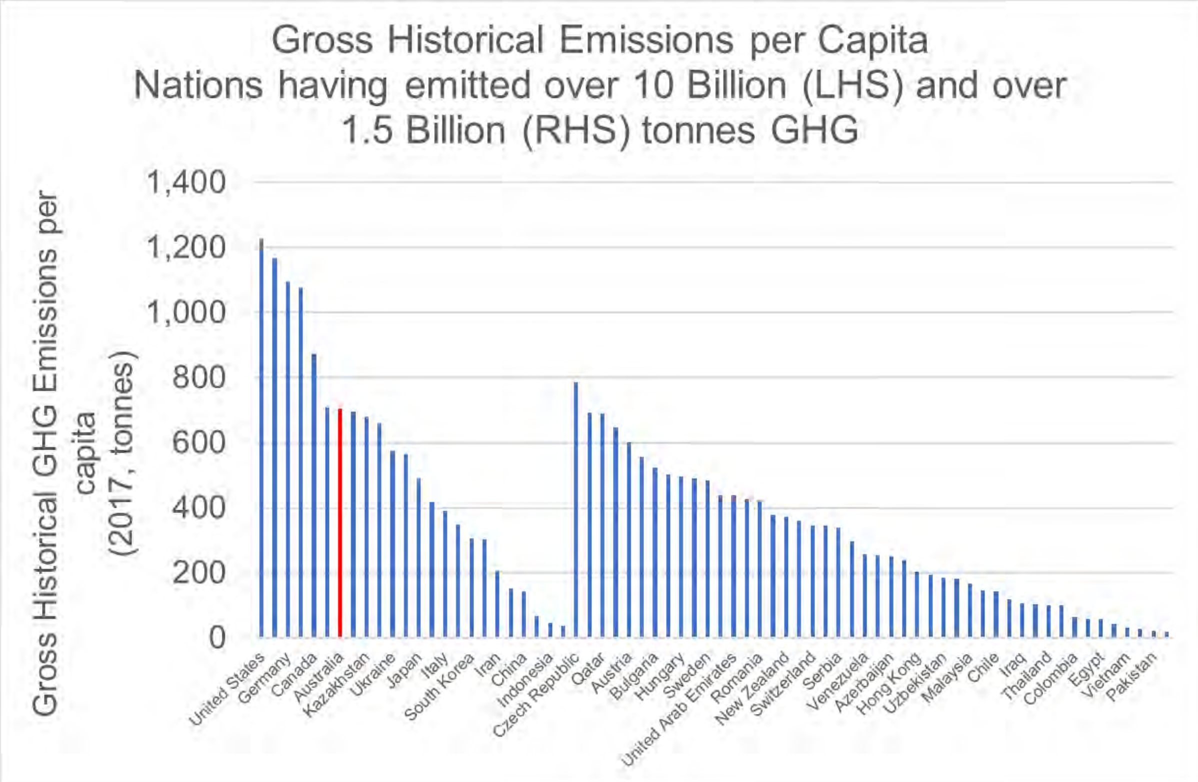

Figure 20: Country Rankings for Historical Cumulative GHG emissions per capita consumed

The apparent gap when considering aggregate emissions between those related to a US resident and an Australian one is remarkably reduced with an Australian individual historically being associated with 57% of that for the US one. On a similar basis the Chinese figure is just under 12% of a US resident.

Our conclusion is that the very large and more recent contribution by Australians to historical emissions which underpin the current state of the climate speak clearly to the Paris Agreements section 4.1 and its aspiration to undertake global action equitably.

Definitions

Carbon Leakage	Carbon leakage occurs when there is an increase in carbon dioxide emissions in one country as a result of an emissions reduction by a second country with a strict climate policy
EIS	Environmental Impact Statement required for consideration of a project by the EPA
Greenhouse Gas Protocol	GHG Protocol establishes comprehensive global standardized frameworks to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, value chains and mitigation actions. Building on a 20-year partnership between World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), GHG Protocol works with governments, industry associations, NGOs, businesses and other organizations.
Scope 1 Emissions	the Australian Government's Australian Greenhouse Emissions Information System (AEGIS) definition is that they constitute the direct greenhouse gas emissions (of an organisation);
Scope 2 Emissions	the Australian Government's Australian Greenhouse Emissions Information System definition is that they constitute the indirect greenhouse gas emissions (of an organisation), from the generation of purchased electricity. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organisational boundary of the entity. Emissions from electricity generation consumed within the electricity, gas and water sector are included for completeness although this electricity use includes own use of generators and does not necessarily meet the definition of scope 2 emissions. The sum of scope 2 emissions is equal to the direct (scope 1) emissions from electricity generation (IPCC Source Category 1.A.1.a);
Scope 3 Emissions	all other indirect emissions that occur in a company's value chain. We include both upstream and downstream emissions due to the lifecycle of a product or service. Hertwich and Wood (Hertwich & Wood, 2018) separate out downstream emissions from Scope 3 emissions in their definitions but this is not the approach of the Greenhouse Gas Protocol itself adopted as an international standard by many;
Value Chain	as per Porters definition it comprises the disaggregated but strategically relevant activities undertaken by a firm
Value System	as per Porters definition it comprises the disaggregated but strategically relevant activities undertaken in the complete lifecycle of a product or service across at least but not limited to an individual organisation

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