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Should Santos' Proposed Barossa Gas 'Backfill' for the Darwin LNG Facility Proceed to Development?

Barossa Has More CO2 Than Any Gas Currently Made Into LNG, Making Market Access Difficult

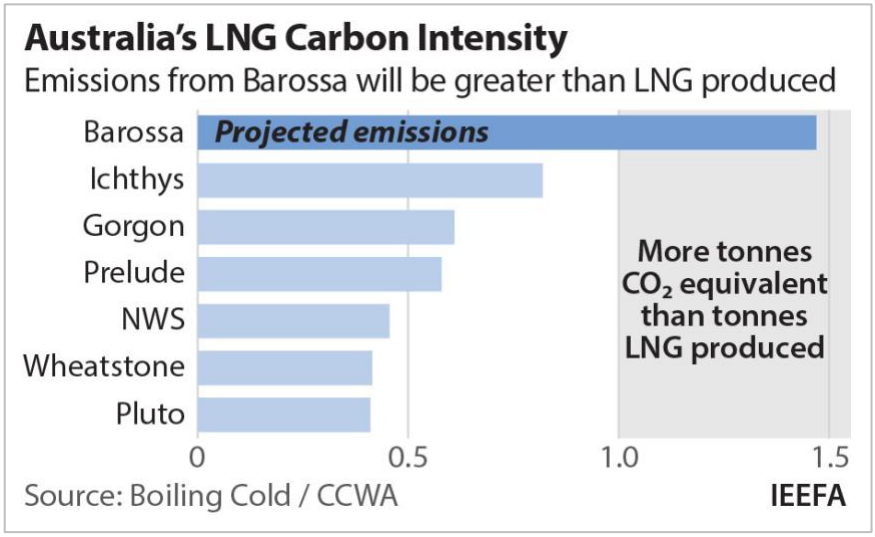
Executive Summary

The proposed high carbon Barossa offshore gas development project 300km north of Darwin, Australia is intended to replace production from the Bayu-Undan field currently supplying dry gas to a liquefied natural gas (LNG) facility in Darwin.

The Barossa gas reservoir's major owner and operator Santos has announced a final investment decision (FID) for this project.[1] It now says it will proceed to develop the gas reservoir.

The plan, initially developed by the previous operator, ConocoPhillips, is to 'backfill' the existing Darwin LNG plant with gas from Barossa when the LNG plant depletes its current Bayu-Undan gas supply in the next few years.

However, two major issues with this plan have been ignored. Santos' proposed Barossa to Darwin LNG development would be both a major financial risk and a serious climate risk for all if it were to go ahead.



Note: Gorgon's SEP is about the same as Prelude as its CO2 re-injection system has mostly been offline for the past 4 years since LNG startup.

[1] Santos. Santos announces FID on the Barossa gas project for Darwin LNG. March 2021.

A high reservoir CO2 content is poison for plans to develop certain reservoirs for LNG production.

Barossa offshore gas contains a very high level of carbon dioxide (18 volume% CO2) – more than any gas currently made into LNG - which means it can never be responsibly made into acceptable LNG.

Adding the venting and combustion emissions at the Darwin LNG plant (2.05 million tonnes of CO2 per annum) to the Barossa total offshore emissions of 3.38 million tonnes of CO2 per annum (MtCO2pa) gives a grand total of 5.4 MtCO2pa to produce 3.7 million tonnes of LNG per annum – extreme by any standard.

This makes the Barossa to Darwin project 'a CO2 emissions factory with an LNG by-product' – a truly questionable investment in a rapidly evolving market.

Further risks and uncertainties have arisen with the recent award by Santos of a contract with BW Offshore for the floating production storage and offloading unit (FPSO) at Barossa. This includes the build and operation of this large and complex unit which alone will emit up to 3.8 MtCO2pa. BW Offshore have been successful in building and operating conventional, oil-producing FPSOs, but their current fleet averages a gas-handling capacity only one-tenth of that required for Barossa and with nothing like the complexity of processing for partial CO2 removal.

The Barossa to Darwin project is like a CO2 emissions factory with an LNG by-product.

This paper explains what the Barossa proposal is all about and why this high-carbon gas resource is such a threat, both to the climate and to the shareholders who would be involved.

Contents

Carbon Dioxide Emissions Ignored in the Barossa Development

The executive summary of the 'Barossa Area Development, Offshore Project Proposal, draft for public comment' (OPP),[2] revised March 2018, by ConocoPhillips Australia (CP) and submitted to the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA), an Australian government statutory agency established under the Offshore Petroleum and Greenhouse Gas Storage Act 2006 (OPGGS Act), states that:

> *"The Barossa offshore development area is within the Bonaparte Basin, approximately 300km north of Darwin in the Northern Territory. The area encompasses petroleum retention lease NT/RL5 and potential future phased development in the smaller Caldita field to the south in RL NT/RL6. …*
>
> *"The project development concept includes a Floating Production Storage and Offloading (FPSO) facility, subsea production system, supporting in-field subsea infrastructure and a gas export pipeline, all located in Australian Commonwealth waters…*
>
> *"The FPSO facility will separate the natural gas and condensate extracted from the field with the dry gas transported via a gas export pipeline for onshore processing. The condensate will be exported directly from the FPSO to offtake tankers. … The project proposes to provide a new source of dry gas to the existing Darwin LNG (DLNG) facility…"*

It may be noteworthy that no mention is made in this description of one other expensive, complicated and essential function of processing on this Floating Production Storage and Offloading unit (FPSO). That is, to reduce the carbon dioxide (CO2) content of the gas.

Barossa gas needs to be reduced from its massive 18 vol% CO2 to meet the 6 vol% CO2 requirements of the Darwin LNG plant.

This vital feature is listed as just one part of one point in the 19-point list of the FPSO's "main design elements, facilities and services" in Section 4.3.3.1 on page 110 of the 477-page (plus appendices) OPP document. But it is the most notable feature in terms of the magnitude of emissions from this development and in the difficulty often experienced by operators in making it work effectively.

Barossa gas needs to be reduced from 18 to 6 vol% CO2 to meet the requirements of the Darwin LNG plant.

[2] Conoco Philips. Barossa Area Development. Offshore project proposal. 2018.

The LNG Process: Techno-Economic Background

All CO2 contained in gas to be liquefied in any LNG plant must be removed in a preliminary process, and that CO2 is deliberately vented to the atmosphere. After that preliminary step, the energy-intensive cooling and liquefying steps are undertaken requiring compression using gas turbines to drive process compressors and electricity generation. This typically consumes about 8-10% of the incoming gas' energy value.

Both the amount of vented CO2 and the CO2 content of the turbine exhausts are dependent on the reservoir gas content. These two main sources of CO2 emissions in the production of LNG - venting and combustion - are greater if the incoming gas composition is higher in CO2.

The rate of emissions per tonne of LNG rises more than proportionally as the CO2 content of the feed gas increases. Capital and operating costs also rise disproportionately.

Emissions of Greenhouse Gases From the Barossa Development

Reduction of the CO2 content of the Barossa reservoir gas from 18 vol% CO2 to 6% results in average venting from the FPSO of 1.82 million tonnes of CO2 per annum (MtCO2pa). One has to go to page 127 (S4.3.5.5) and Table 4-7 of the OPP document to find this significant point.

It is also worth noting here that 18 vol% CO2 in the mainly methane gas stream corresponds to approximately 36% CO2 by weight, given that CO2 is almost three times more dense than methane.

In S4.3.5.5 of the OPP, emissions are more finely described, and with various uncertainties in the actual or average field CO2 content, the possible range of vented emissions is said to be between 1.4 and 2.1 million tonnes per annum (Mtpa) from the FPSO. The reason for this range is not stated, but presumably it stems from the different compositions of the gas in the larger Barossa (18%) and smaller, nearby Caldita (13%) reservoirs, and varied ratios of production from the two sources over the life of the project.

The reduction of Barossa's CO2 content results in an average venting of 1.82 million tonnes of CO2 per annum.

In addition to the estimated average vented CO2 of 1.82 Mtpa (Table 4-7, p128, OPP), emissions from combustion of fuel gas (for compressor power, electricity generation, etc) and flaring range from 0.7 to 1.7 MtCO2pa and average 1.56 MtCO2pa. The average total of emissions offshore is then 3.38 MtCO2pa.[3] This total

[3] It is to be expected that combustion emissions are higher with higher reservoir gas CO2 content, as more energy is required to achieve the separation of CO2 and methane and the gas used to produce that energy carries more CO2 even before it is combusted.

is roughly equivalent to the emissions from 735,000 passenger cars[4] or 1,390,000 cars per Santos' rate (when addressing its proposed carbon capture and storage (CCS) project at Moomba, mentioned as a possible carbon credit project against Barossa emissions).[5]

These figures are summarised in the following table.

Table 1: Offshore Emissions From the Barossa Proposal

MtCO2pa	Low Case	High Case	Average
Vented Offshore	1.4	2.1	1.56
Combustion Offshore (including flaring)	0.7	1.7	1.82
Total Offshore Emissions	**2.1**	**3.8**	**3.38**

In addition, the OPP notes (at p127, s4.3.5.5) that emissions of methane and nitrous oxide will also contribute to the overall net greenhouse gas (GHG) emissions profile during operations. This might be a significant omission, since both the alternative CO2/methane separation technologies being considered may allow some 'methane slip' and so would incur further CO2e (equivalent) emissions.

[4] U.S. EPA: 4.6te/car/y
[5] Santos. Santos to be net-zero emissions by 2040. 1 December 2020.

Benchmarking Reservoir CO2 Content With Other Australian Gas Projects

The OPP document also provides (p127) a comparison with 'native CO2 contents' reported from other Australian gas projects offshore the north and west coasts of Australia, only a couple of which have been developed for LNG.

Table 2: Feed Gas CO2 Content for Various Australian Gas Developments

Operator	Reservoir	Vol% CO2	Development
PTTEP	Montara	13	Developed for liquids, blowouts.[6] Oil producer under new owner.
Shell	Prelude	9	Floating LNG
INPEX	Ichthys	8-17 (average 9)	LNG
Woodside	Browse	10	Not developed
ConocoPhillips	Barossa/Caldita	18/13	Not yet developed
ENI	Evans Shoal	27	Not developed

To this list might have been added the following gas fields which are feeding LNG plants in Western Australia:

Table 3: Feed Gas CO2 Contents for Various Australian Offshore Gas Developments to LNG

Operator	Reservoir	Vol% CO2	Development
Woodside NWS T1-5	Rankin/Goodwyn/etc	<2	LNG
Chevron	Janz/Gorgon	0.5-14 (average 9)	LNG with Carbon Capture and Storage
Chevron	Wheatstone	2	LNG
Woodside	Pluto	2	LNG

Source: Various.[7]

It can be simply deduced from the latter two tables that a high reservoir CO2 content is poison for plans to develop certain reservoirs for LNG production.

Even so, the reservoir CO2 content is rarely if ever mentioned by operators, and particularly not when exploration is delivering news of discoveries (unless it is a low figure).

[6] A well blowout is failure of various kinds which allows uncontrolled emissions of the reservoir fluids. An example is the infamous Montara oil spill and gas release in late 2009, for which Indonesian fishermen are still claiming compensation.

[7] Ichthys Project Draft EIS. Benchmarking S9.9.3. Table 9.4. For Wheatstone, see Helium in the Australian LNG Economy. C J Boreham et al, GA 2018. APPEA Journal 2018. Page 58. For Pluto, see S1.2: Woodside. Pluto LNG Project: Greenhouse Gas Abatement Program.

Benchmarking Barossa's Projected Emissions With Other Australian LNG Projects

When the proposed Barossa development's total offshore emissions of 3.38 MtCO2pa is added to the Darwin LNG emissions onshore of 2.05 MtCO2pa (licenced limit, p128 OPP), the total emissions would be 5.44 MtCO2pa. This is roughly equivalent to the emissions from 1.2 million passenger cars (U.S. EPA) or 6% of the total Australian car fleet (or 2.2 million cars based on Santos' equivalence factor).

Adding the venting and combustion emissions at the Darwin LNG plant to the Barossa total offshore emissions gives a grand total of **5.4 MtCO2pa** to produce 3.7 MtLNGpa – truly 'a CO2 emissions factory with an LNG by-product'.

Barossa is truly a carbon dioxide emissions factory with an LNG by-product.

For the Darwin LNG facility and its gas supply system with an LNG capacity of 3.7 Mtpa, this translates to an 'emissions intensity' or 'Specific Emissions in Production, (SEP)' of 1.47 tCO2/tLNG. This figure far exceeds, in fact more than doubles, the average SEP for the Australian industry as a whole.

For context on the 1.47 t/t figure, the following table was presented in a previous (April 2020) paper[8] reviewing the whole Australian LNG industry and its emissions, based on EIS data (Environmental Impact Statement – similar to Offshore Project Proposal) before and after the recent capacity boom.

Table 4: Increases in Total Australian LNG Production and Emissions Over the 2014-19 Expansion Period

		2014	New	2019
LNG Production	MtLNG/y	24	62	86
CO2 Emissions	MtCO2/y	13	47	60
Specific Emissions in Production (SEP or emissions intensity)	tCO2/tLNG	0.54	0.76	0.70

During the 25-year projected life of the Barossa-Darwin LNG system, its SEP might range from 1.1 to 1.6 tCO2/tLNG, emitting somewhere near 136 MtCO2 in total.

[8] IEEFA. The Growth of Australia's LNG Industry and the Decline in Greenhouse Gas Emission Standards. April 2020.

International Benchmarking of LNG Plant Feed Gas CO2 Contents

Barossa to Darwin LNG could therefore produce about 4% of Australia's total LNG production while causing 9% of that industry's emissions (i.e. 3.7/86 = 4.3% and 5.44/60 = 9.1%).

This would *not* be a good position for Australia, particularly as the European Parliament has just voted to introduce a carbon levy on imports into the European Union from countries with weaker emission rules. This would certainly include Australia.

Table 5 is indicative of the competitive position which Australian LNG producers are facing in terms of emissions intensity.

Table 5: International LNG Projects and Reservoir Gas CO2 Content

Project	Start-up Year	Reservoir V%CO2
Qatargas	1993	2.2
RasGas, Qatar	1999	2.3
Nigeria LNG	2000	1.8
Oman LNG	2001	1.0
Atlantic LNG, Trinidad	2005	0.8
Snöhvit, Norway	2007	5.7 (CCS)

Source: Ichthys Project Draft EIS, Benchmarking S9.9.3, Table 9.4.

Note that U.S. LNG producers are mostly located with connection to the gas grid with Henry Hub reference feed gas price and conditions. It is understood that generally, gas contains about 2 v% CO2. So U.S. producers also already have 'clean' competitiveness compared with some Australian LNG producers.

Changes in the LNG Market To Favour 'Cleaner' LNG

Pavilion Energy, a Singapore-based energy trader, broke new ground in April 2020[9] when it requested that LNG suppliers contribute towards the development of an industry standard to measure LNG's total GHG emissions and called for tenders due June 2020.

In November, Pavilion and Qatar Petroleum announced[10] the signing of a 10-year sale and purchase agreement (SPA) for the supply of up to 1.8 million tonnes of LNG per year from 2023. Each LNG cargo delivered under this agreement will be accompanied by a statement of its GHG emissions measured from well to discharge port.

Changes of Ownership in Barossa and Darwin LNG

In October 2019 Santos Ltd bought out ConocoPhillips' northern Australia business (which included major portions and operatorship in Barossa and Darwin LNG) for approximately US$1.4 billion. Santos' shares rose in Australia and ConocoPhillips' shares fell in the U.S.

The sale price pleased some, but RBC Royal Bank's valuation was around US$1.63 billion, according to Bloomberg.[11] Sanford C Bernstein & Co analysts reported Conoco's northern Australia business had a net assets value of about US$1.8 billion, citing Rystad Energy AS.

Perhaps somebody knew something? Was ConocoPhillips' new climate change action plan[12] a factor? The intersection of that plan with the plans of the company's Australian branch to go for FID on Barossa in 2020 must have been interesting. Presumably Santos has no such concerns.

'If other companies will not back it, Santos has a very expensive problem.'

According to the author of a key article[13] about this development, "Barossa would produce Australia's dirtiest LNG and if other companies will not back it, Santos has a very expensive problem".'

Since that was written in August 2020, the governments of Japan, South Korea and others have announced their intentions to aim for net-zero emissions by 2050, and China has announced a similar aim to be achieved by 2060. This may further reduce

[9] Reuters. Singapore's Pavilion Energy seeks industry standard for green LNG. 2 April 2020.
[10] Pavilion Energy. Pavilion Energy and Qatar Petroleum Sign Strategic LNG Supply Agreement for Singapore. 9 November 2020.
[11] Bloomberg. Santos Targets Asia LNG Growth With $1.4 Billion Conoco Deal. 14 October 2019.
[12] ConocoPhillips. Impact on Business and Strategy.
[13] Boiling Cold. Santos' dirty big $2B Barossa bet. 19 August 2020.

the motivation of partners and customers from those countries to join the Barossa project.

In 1999 ConocoPhillips had increased its ownership position in the Bayu-Undan field by acquiring the assets of BHP to become the majority shareholder and operator. The field was then developed and operated as a condensate and LPG stripping operation with gas re-injection offshore until the LNG project was developed and commenced operations in 2006.

Darwin was the first LNG plant to use many technical innovations, including the use of the much more efficient aero-derivative gas turbines rather than the typical frame machines.[14] This did at least set up ConocoPhillips to sell their proprietary technology for the six LNG trains built at Gladstone, Queensland from 2015 -2019.

At that time it was also widely known that Darwin LNG would be the first LNG plant to be committed to construction without at least 20 years of proven gas reserves. It had 17 years supply. This dubious distinction is now coming back to bite the current owners lead by Santos.

Darwin LNG was the first plant committed to construction without at least 20 years of proven gas reserves.

FPSO Contract Adds to Risk

It was recently announced that Santos has awarded a supply contract to Norwegian firm BW Offshore (BWO) for the Barossa floating production storage and offloading unit (FPSO).[15] The contract, worth around US$2bn, specifies the scope to cover engineering, procurement, construction, installation and operation of the FPSO. BWO owns a fleet of 15 of the 270 FPSOs operating around the world.

Most FPSO's are employed in stabilising, storing and offloading stabilised crude oil, with any associated gas used for fuel, and in many cases simply flared. This was the case for the first Australian FPSO, BHPP's Jabiru Venture in 1986, followed by many more.

If the gas:oil ratio is very high however, instead of being flared, the gas must be dried, compressed and sent to shore by pipeline for local use or further processing to LNG. There are a small number of FPSOs on which gas processing is advanced to the point of LNG production, such as Shell's giant US$17bn Prelude FLNG offshore Western Australia.[16] Such complex ventures however are very risky, costs tend to overrun initial estimates, startups are frequently delayed, and the CO2 removed from the gas is inevitably vented.

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[14] ConocoPhillips. The Darwin LNG Project.
[15] The Market Herald. Santos (ASX:STO) awards major Barossa contract ahead of final investment decision. 24 March 2021.
[16] Boiling Cold. No winners from Shell's $US17B Prelude floating LNG. 15 May 2020.

Has BWO sufficient experience in building and operating large CO2 removal facilities as required on Barossa? Such a plant processing 800 million standard cubic feet per day (mmscfd) from 18 v% CO2 to 6 v% is a challenging proposition onshore, let alone on a moving ship located 300km from land.

BWO's fleet (per website) averages 82 mmscfd of gas handling capacity, with the largest at 353 mmscfd still less than half the capacity required for Barossa. None boast CO2 removal facilities.

For a scale comparison, Esso Australia's Kipper gas conditioning plant17 at Longford, Victoria, cost about A$1bn in 2015-17 and processes 400Mmscfd from 20 %CO2 offshore gas to 2% CO2 pipeline gas quality.

BWO's Sustainability Report for 2020[18] includes the statement: 'Take urgent action to combat climate change and its impacts'. Is BWO's participation in the Barossa development consistent with that statement? How does enabling emission of 5.4 MtCO2pa for 25 years fit with that?

Some Hanging Questions

Will Santos have good luck when it drills three infill production wells at the Bayu-Undan field from the second quarter of 2021? The objective is to extend the field life and enable continued production at the Darwin LNG plant. This would probably be a stop-gap measure while it gathers strength to push through with the Barossa development.

Will Santos try for 'backfill' gas supply to Darwin LNG from other relatively close fields in the Bonaparte Basin that it has a position in, such as Ascalon/Saratoga or Petrel/Tern/Frigate? Will it do anything to keep Darwin LNG running?

Will Santos rely on a carbon capture and storage (CCS) project at its mature fields near its gas processing plant at Moomba in the Cooper basin[19] which is planned to sequester 1.7 MtCO2pa, government assistance permitting? Santos have mentioned it as a possible carbon offset for Barossa gas, but the sequestration plan would have to more than three times larger to cover Barossa's 5.4 MtCO2pa emissions.

Or will Santos walk away from the development, give up on Barossa and making Darwin LNG a stranded asset? Will Santos face the fact that Barossa contains such high emitting gas that it can never be made into acceptable LNG in the very competitive future market?

This is the big and real risk to investors in Santos and its partners in Barossa and Darwin LNG.

Does BWO have the experience and commitment to build and operate the complex Barossa FPSO? If so, where will the operational and ethical responsibility lie for this

[17] Oil & Gas Journal. Esso Australia completes Longford gas conditioning plant. 10 May 2017.
[18] BW Offshore. Sustainability Report 2020. Page 9.
[19] Santos. Santos And Mitsubishi Sign Spa For Barossa LNG Supply. 7 December 2020.

potential climate disaster - with Santos and other Barossa/Darwin LNG shareholders or with BWO? How does advancing this project, which will emit 5.4 MtCO2pa for 25 years, square with the principled statements on social and environmental responsibility of both companies and the Paris Agreement?

One more question remains: Why was such a development approved by NOPSEMA in the first place? After all, the 'EM' (Environmental Management) in 'NOPSEMA' was added to the title of the national offshore petroleum safety authority when the Federal Environment Department moved some people from Canberra to Perth in about 2014.[20] They might have been too far away in Canberra from the Oil & Gas industry head offices for convenient meetings. But now, are the 'game keepers' and 'poachers' simply too close together in the world's most isolated capital city, Australia's 'Little Houston'?

[20] NOPSEMA. Clarifying arrangements for Environmental regulation of petroleum activities in Commonwealth waters. March 2014.

About IEEFA

The Institute for Energy Economics and Financial Analysis conducts research and analyses on financial and economic issues related to energy and the environment. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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John Robert is a Process Engineer and Industrial Economist with more than 40 years of experience in directly developing and/or managing estimates for capital and operating costs for LNG plants, along with benchmark comparisons for export competitiveness and reviewing the potential impact of emissions trading schemes such as Australia's proposed Carbon Pollution Reduction Scheme (CPRS) on LNG and chemicals projects. He spent almost eight years at Exxon in the Australian petrochemicals industry, followed by a similar period as an Australian Government Trade Commissioner in Europe and the Middle East. John was a business development manager and technical / economic consultant with Davy McKee (later Aker Kvaerner) for some twenty years, and then an engineering manager with MEO Australia Limited, covering all aspects of innovative offshore methanol and LNG projects in the Timor Sea, and was responsible for the engineering development of the Timor Sea LNG Project (TSLNGP) since its inception in early 2002.