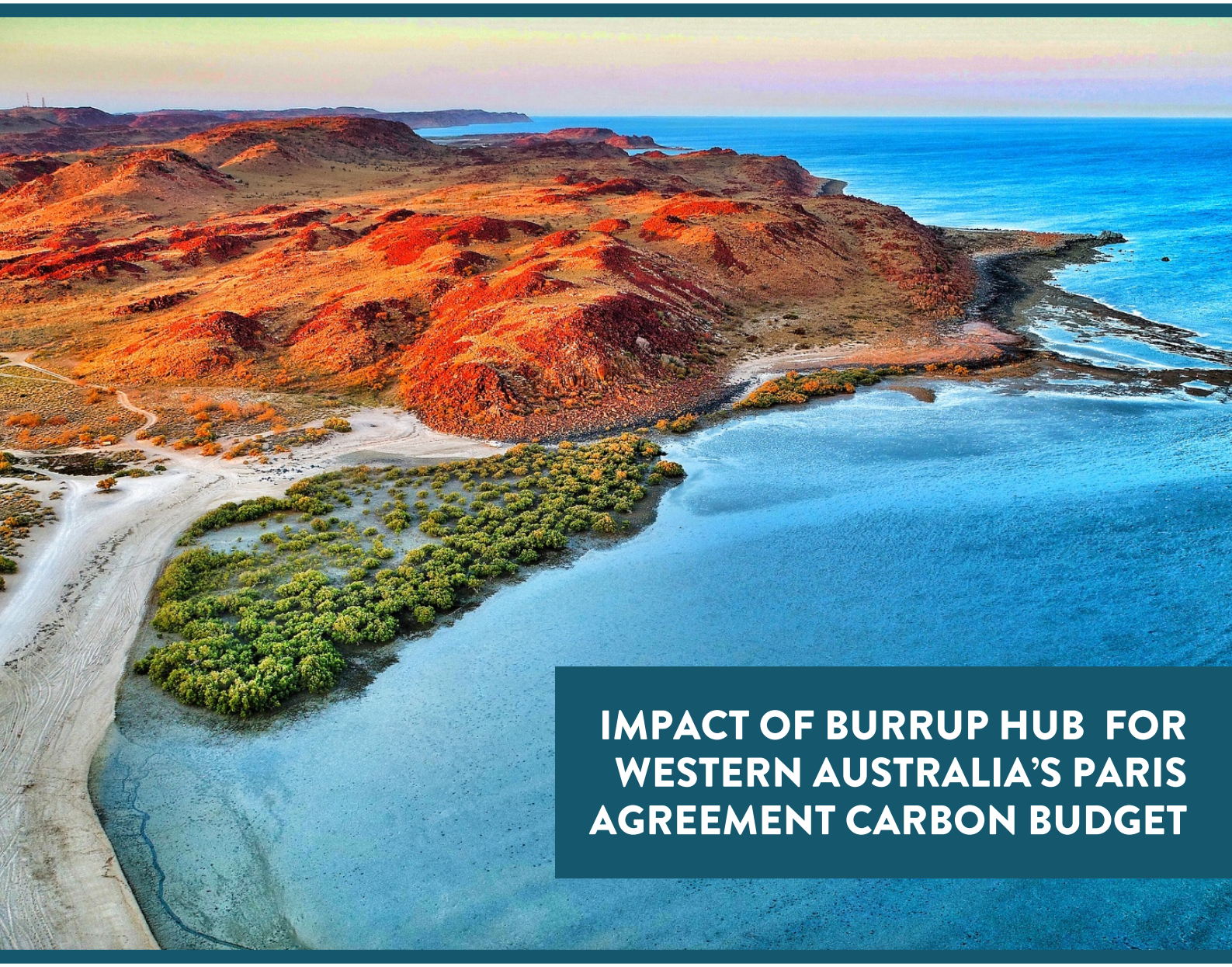
CLIMATE ANALYTICS



IMPACT OF BURRUP HUB FOR WESTERN AUSTRALIA'S PARIS AGREEMENT CARBON BUDGET

February 2020

EXECUTIVE SUMMARY

This study analyses the impact of the Burrup Hub LNG projects for Western Australia's carbon budget under the Paris Agreement and its net zero emissions 2050 goal. It builds on the comprehensive study we published earlier on Western Australia's carbon budget under the Paris Agreement, which developed sectoral and overall benchmarks for Western Australia's emissions pathway.

This study finds that the Burrup Hub - as proposed - is not consistent with Western Australia implementing the Paris Agreement and achieving its objective of net zero emissions by 2050, nor with the national and global emission reductions necessary to implement the Paris Agreement.

This is in stark contrast with the claims by the project proponents, Woodside, that emissions from the project are "acceptable" and that the impact is "low". This report shows that the likely scale of domestic emissions from the Burrup Hub will significantly undermine the ability of WA and Australia to meet Paris Agreement targets and, at best, could force other sectors to make much deeper reductions.

The report also shows the total GHG intensity of LNG produced from the North West Shelf (NWS) LNG plant component of the Burrup Hub is likely to increase by 75% from about 0.4 tCO_2e/LNG produced to over 0.7 tCO_2e/LNG by 2030 as it sources gas from the CO_2-intensive Browse development.

The fast ramping up of LNG processing has made the biggest contribution to the increase of greenhouse gas emissions in Western Australia in the last ten to fifteen years. In 2005, the LNG sector emitted about 6% of WA's 2005 GHG emissions (excluding LULUCF). Emissions have tripled and have risen, we estimate, to about 23% of the State's 2017 GHG emissions.

As of 2019, the LNG facilities within the Burrup Hub had a share of about 9% of WA's GHG emissions (excl. LULUCF), and these CO_2 emissions have nearly doubled since 2005 – and are set to nearly double again by the early 2030s.

We estimate the total Western Australia LNG industry emissions at about 22 Mt CO_2e per annum in 2019 and this can be expected to approach 30 Mt CO_2e per annum by the late 2020s. The Burrup Hub contributes about half of this (~16 Mt CO_2e per annum), and the NWS Plant alone contributes about a third (estimated average of 10 Mt CO_2e per annum) of the total emissions over the proposed lifetime until 2070. The NWS plant emissions are likely to be close to 12 Mt CO_2e per annum in the 2030s when this plant can be expected to be using Browse-sourced gas at a high level. This means at full production, the GHG intensity of LNG produced by the NWS Plant in the 2030s is likely to be above 0.7 tCO_2e per tonne of LNG shipped, far above the recent state average of about above 0.4 tCO_2e per tonne of LNG shipped.

Meeting current Paris Agreement target

The Burrup Hub project is being proposed at a time when governments are moving to meet their Paris Agreement 2030 targets. Australia's 2030 target is 26-28% below 2005 levels so it is important to examine how the Burrup Hub's domestic emissions compare to both the 2005 baseline and the effect they could have on the achievement of Australia's Paris target for 2030.

Annual emissions from the Burrup Hub by 2030 are projected to be about 21% of WA's 2005 emissions (incl. LULUCF). If these are not reduced then other sectors would need to reduce emissions by about 44% from 2005 levels to meet an overall state-wide 26% reduction target.

Western Australia's LNG industry, if allowed to continue unabated, would mean Australia would need to increase its 26% Paris Agreement target to 30.5% by 2030. The Burrup Hub's contribution would be 2%; the WA LNG as a whole would contribute 4.6%.

Meeting a Paris Agreement-compatible target

It is well-established that Australia's 26-28% reduction by 2030 goal will not meet the objectives of the Paris Agreement and does not place Australia on a feasible trajectory towards zero net emissions by 2050. To be consistent with global efforts to limit warming to the Paris Agreement's long term temperature goal of 1.5˚C, and to put the country on a cost-efficient pathway to achieve zero net GHG emissions by around 2050, Australia would need to reduce emissions in the range of 44-61% (from 2005 levels) by 2030. The Burrup Hub project - as proposed - would not be consistent with this, and, if unabated, its projected emissions (4.6-6.5% of Australia's 1.5 compatible pathway) would mean other sectors would need to do more (3%).

The Burrup Hub would have an even greater impact on other sectors in WA. Translating this Australia-wide Paris Agreement-consistent target to Western Australia would mean a reduction of 49% by 2030 (from 2005 levels) taking into account the challenge to reduce emissions in the large LNG sector. The Burrup Hub's projected unabated 2030 emissions are likely to make up about 41% of a Paris Agreement compatible emissions pathway for WA, so other sectors would need to reduce emissions by about 68% by 2030[1].

Carbon budget implications

The Burrup Hub alone, if it were to go ahead as planned, is estimated take up about half (49%) of the state's carbon budget for the entire energy and industry sector . Cumulative emissions of the Burrup Hub until 2070 (expected end of lifetime) would take up around 80% of WA's carbon budget.

The Barrup Hub alone would burn up around 7-10% of Australia's Paris Agreement compatible budget for the entire energy and industry sector to 2050; the WA LNG industry as a whole about 18-20%.

At a global level, the Burrup Hub alone would contribute about 1% of the total global energy and industry carbon budget calculated on Paris Agreement consistent mitigation pathways. This is about the same as the share of the entire carbon budget for Australia's energy and industry emissions to 2050.

Gas needs to phase out alongside other fossil fuels

Woodside's that the project will help reduce global emissions through increasing the use of gas globally ignores recent scientific literature and market developments: Global implementation of the Paris Agreement means the recent growth in the use of natural gas cannot continue, whether for the power sector or in other applications. Under the Paris Agreement compatible pathways, demand for natural gas in the power sector in Asia, a major source of LNG demand, is likely to peak by around 2030 and then decline to close to zero between 2050 and 2060.

The mitigation measures outlined by the project proponents, Woodside, rely on offsetting and are completely inadequate to achieve the necessary Paris Agreement compatible emissions reductions. On the mitigation side, it would have to include the following key elements:

- Carbon capture and storage of reservoir carbon dioxide to at least an 80% level, and preferably substantially higher than this capture rate;

[1] For the WA LNG sector as a whole the relevant numbers are 79% and -88% respectively.

- Introducing renewable energy quickly into LNG manufacturing process to replace the present use of natural gas at the plant, combined with measures to reduce fugitive emissions
- Upstream emissions from offshore production facilities are projected to grow quickly and virtually no mitigation measures have been proposed, so it is therefore urgent that CCS and/or renewable energy systems are evaluated and deployed at scale.

Whilst Woodside has sought to make a case that there will be an indefinitely growing demand for LNG, it is clear that this is due to a selective choice of global emission pathways that are not consistent with the Paris agreement. If the world properly implements the Paris Agreement, it is very likely there will be a significant drop-off in demand for natural gas in the power sector by the end of the coming decade, and technology trends are already pointing in the direction.

What this means is that there is a major transition risk emerging of stranded carbon assets combined with a lack of preparedness for job losses and economic dislocation. Both Western Australia and the Federal Government have a responsibility to fully understand and anticipate this risk, not make it worse.

The Burrup Hub seems to be a prime candidate for becoming a stranded, carbon-intensive asset as it is projected to use increasingly carbon intensive natural gas resources, nearly doubling the average greenhouse gas intensity of LNG from the north-west shelf plant from close to 0.4 to 0.7 tCO2e/tLNG, a fact which is unlikely to be overlooked by markets or when it comes to carbon prices in the form of taxes or trading systems.

Stranded carbon assets are increasingly seen as a central economic problem for the future, including by the Reserve Bank of Australia. The mitigation measures described above could be coupled to a transition strategy for the LNG industry and feed positively into the growth and establishment of an export hydrogen market. However this will not happen through the action of the Burrup Hub proponent who shows little sign of appreciating the gravity of the challenges posed by the Paris Agreement, for the climate system, the natural environment, domestic Australian policy or international action.

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Cover photo: Hearson's Cove, Burrup Peninsula - Murujuga National Park, Western Australia. Photo by willo258

INTRODUCTION

This report provides an assessment of the implications of the Burrup Hub liquefied natural gas (LNG) projects, including the Browse Basin to North West Shelf and North West Shelf expansion proposals for Western Australia and Australia's carbon budgets and emissions pathway benchmarks, including targets for 2030 and reaching zero emissions by 2050, that are consistent with national and global efforts to limit global mean warming to 1.5°C above pre-industrial levels. In common with other states, WA has an objective of net zero greenhouse gas (GHG) emissions by 2050.

In Climate Analytics (2019a), we calculated the carbon budget for Western Australia's fossil fuel (energy and industry) CO_2 emissions for the period 2018-2050 in line with the Paris Agreement to be **about 950 Mt CO_2 which if current emission rates were to be continued, would be consumed within 12 years.** To stay within this budget, it is essential to decarbonise all energy and industry sectors and reach zero carbon emissions from fossil fuel and industry across all sectors of the economy by around 2050 (and around 2060 globally). This is consistent with the state's own objective of reaching net zero greenhouse gas emissions by 2050 and implies eventually phasing out all fossil fuels not only for power generation but for all other industry processes. An important conclusion from our earlier study is that sooner or later **Western Australia will have to transition away from exporting natural gas towards renewable based energy exports, such as Green Hydrogen.**

The fast ramping up of LNG processing has contributed most to the increase of emissions in Western Australia. As of 2019, the emissions from LNG sector as a whole in WA were equivalent to about 23% of the State's 2017 **GHG emissions (excl. LULUCF)** - emissions comprising the LNG facilities within the Burrup Hub had a share of 9% of WA's **GHG emissions (excl. LULUCF). At the national level these fractions were 4% and 1.6% respectively. WA LNG** GHG emissions have increased by 370% since 2005 and Burrup Hub related GHG emissions increased by about 85% over the same period to 2019. By 2030 Burrup Hub related GHG emissions are expected to increase a further 83%, and **WA LNG** GHG emissions as whole by about 22% (after accounting for carbon capture and storage of reservoir CO_2 at the Chevron Gorgon LNG plant).

These projection raises the question of the impact and risks of such a large new gas development as proposed with the Burrup Hub, including the Browse basin to NWS proposal and the NWS extension proposal, and its consistency with the Paris Agreement.

THE BURRUP HUB

The project proponent, Woodside, claims that the GHG emission impacts of North West Shelf Project Extension and the Browse to North West Shelf Project are "acceptable".

The Browse to North West Shelf (NWS) Project and NWS Project Extension are part of Woodside's larger Burrup Hub "vision" as a regional WA LNG production centre. The Hub will advance the current Pluto LNG and NWS facilities through linking proposed projects, including a Scarborough floating production unit; Pluto Train 2; Browse to NWS Project; NWS Project Extension and the Pluto-NWS interconnector (Woodside, 2019a). The Hub plans to develop approximately 40 trillion cubic feet of gross dry gas resources from Scarborough, Browse, Pluto and NWS facilities accelerated with new infrastructure to allow for the processing of third party resources and other Pluto offshore reserves (Woodside, 2019a). The Scarborough to Pluto Train 2 plans to expand the existing Pluto facility to include a second gas processing train, with its first cargo scheduled in 2024 (Woodside, 2019a). The Pluto-KPG Interconnector entails a pipeline to transport gas from Pluto to the NWS Karratha Gas Plant (KPG)

(referred to here as NWS Project), with start-up scheduled for 2022 (Woodside, 2019a). The Browse to NWS Project is targeted to start up around 2026, and involves two floating production storage and offloading units delivering gas through a pipeline to NWS (Woodside, 2019a). The NWS Project Extension will use gas from the Browse to NWS Project for over 30 years, and allows for the processing of third party gas (Woodside, 2019a).

It is important to take into account the Browse to NWS and NWS Project Extension as part of the larger Burrup Hub, to fully assess the impact. In particular, the NWS Project extension will extend the life of these integrated facilities to 2070 and beyond, and allow for processing not only from Browse but resources from the interconnected facilities and other third party gas (Woodside, 2019a) despite the state target of net zero emissions by 2050.

The Burrup Hub spans the jurisdictions of state and federal waters with approvals needed from the Western Australian Environmental Protection Agency (EPA) and the Commonwealth Department of Environment and Energy. Separating the 'vision' into several proposals subject to different authority approval, with different timeframes obscures the total greenhouse gas emissions impact of this proposal.

It is vital to assess the project through a strategic integrated approach to understand the impact of the Hub's cumulative emissions, its effect on WA and Australia's emission pathway through 2030 and beyond, and on the GHG intensity of LNG produced by the two LNG Plant that comprise the Burrup Hub, the NWS Project and Pluto.

In this report, we attempt to take and integrated approach and hence analyse the contribution of the Burrup Hub project with its proposed mitigation plan to emissions and how these impact on WA and Australia achieving Paris Agreement compatible 2030 emission reductions and the objective of net zero emissions by 2050 consistent with the Paris Agreement Long Term Temperature Goal (LTTG).

In addition, we analyse the contribution of the project to global emissions and whether the proposed project is consistent with the Paris Agreement LTTG.

LNG SECTOR IN WESTERN AUSTRALIA: TRANSITION NEEDED FOR PARIS AGREEMENT

In Climate Analytics (2019a) we have shown how each sector of WA's economy needs to contribute to decarbonisation and reaching net zero emissions in 2050. The key elements of the transition of the LNG sector in Western Australia identified in our study are the following:

- Likely reduction in demand for natural gas in Asia under the Paris Agreement;
- Capture and storage of reservoir carbon dioxide that is otherwise vented to the atmosphere;
- Introducing renewable energy quickly into LNG manufacturing process.

In our earlier work we have shown that under the Paris Agreement, demand for unabated natural gas in the power sector in Asia, a major source of Western Australian LNG demand, is likely to peak by around 2030 and then decline to close to zero between 2050 and 2060 (Figure 1). This is a robust result from of an analysis of 1.5°C compatible mitigation pathways assessed by the IPCC to be consistent with the Paris Agreement Long-term Temperature goal, and taking into account that Carbon Capture and Storage (CCS) is increasingly unlikely to be able to compete on cost and environmental grounds with renewable energy and storage.

Renewable energy and storage provide a more cost-effective solution and additional benefits for sustainable development, with costs continuing to fall, while there are no observed cost improvements for CCS in power generation and incomplete capture would need to be compensated with additional, and likely expensive, efforts to remove carbon dioxide from the atmosphere. These pathways show that Paris Agreement implementation is likely to result in a substantial reduction in natural gas demand in the power sector in Asia without CCS, reducing from peak levels in 2030 to close to zero by 2050.

Short and medium term policy recommendations or investment decisions based on the benchmarks and projections for coal and gas power generation that rely on CCS use but are not transparent about the extent of their reliance on this technology (as presented by the WEO Sustainable Development Scenario, SDS as used by Woodside) will most likely lead to wrong decisions, considering the low adoption rates of this technology and other concerns related to the use of these technologies for fossil fuel power plants.

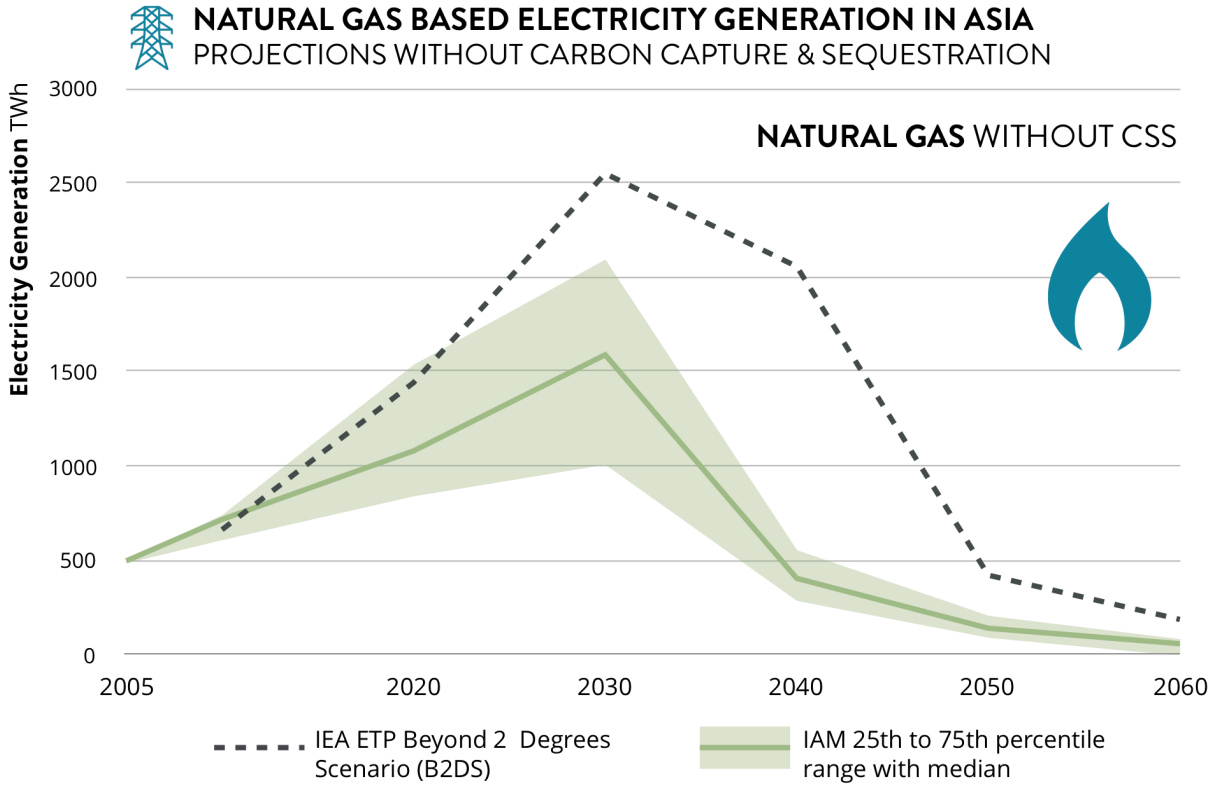

Figure 1: Electricity generation from natural gas without CCS in Asia. Shown are the median for PA-compatible Integrated Assessment Models (IAM), as well as the results from the IEA ETP B2DS for some of the underlying pathways, both for the Asia region. Source:(Climate Analytics, 2019b). *The relative cost of CCS makes deployment of this technology unlikely in our assessment. The earlier IEA B2DS scenario shows a much higher natural gas demand than more recent fully Paris compatible scenarios. Source: Climate Analytics* (2019a).

The Sustainable Development Scenario (SDS) from the International Energy Agency is a significant outlier, with very high coal and gas-fired power generation, compared to Paris Agreement compatible pathways. This holds for all time periods for coal, and for the 2025-2040 period for gas, both with and without CCS. The implied reliance on CCS to lie within the emission bounds of Paris Agreement compatible pathways, calls into question the wisdom of the use of the WEO SDS as a benchmark for policy and investment decisions.

In effect, Woodside is asking state and national governments, and its investors, to bet that carbon capture and storage will be rolled out rapidly at massive scale in its core markets over the next 5 to 10 years, and that the costs of CCS will drop faster than the costs of renewables and storage in the power

sector. All the available evidence points in completely the opposite direction, with very little sign of CCS being rolled out at scale anywhere, let alone for gas powerplant, with gas powerplant being increasingly out competed by renewables and storage in markets around the world, and with ongoing rapid costs decline is expected in renewables and storage, but not in CCS. In other words, from this perspective, Woodside's claims that the Burrup Hub development is Paris consistent do not stack up and risk leaving the state of Western Australia with a long term costly stranded asset.

Irrespective of whether or not the demand reductions implicit in the Paris Agreement Asian power demand scenario above occur, the cumulative domestic emissions of the LNG industry need to be reduced substantially. The basic options examined in Climate Analytics (2019a) through carbon capture and storage of reservoir CO_2 and by introducing renewable energy quickly into the LNG manufacturing process - would need to be deployed.

In Climate Analytics (2019a) we estimated a carbon budget for Western Australia's fossil fuel CO_2 emissions for the period 2018-2050 at around 950 $MtCO_2$, about 0.17% of the remaining global carbon budget. The LNG sector carbon budget within this report was estimated at 208 $MtCO_2$. Under the scenario in this work, all energy and industry emissions would have to be reduced by 37% in 2030 compared to 2005, the WA LNG sector would still increase emissions by 170%, but then reduce by 73% in 2040 to reach zero in 2050.

BURRUP HUB LNG PRODUCTION AND WESTERN AUSTRALIA'S EMISSIONS

The proposed Burrup Hub is a significant contribution to the projected continued growth of the LNG sector in Western Australia, which has doubled in size over the last five years to about 45 million tonnes of LNG (MtLNG) per annum production capacity in 2018[2], and is set to increase by about 35% to 60 MtLNG p.a. by, or shortly after, 2025 including the Burrup Hub with the extension of NWS and expansion of Pluto facilities (Climate Analytics 2019). The Burrup Hub facilities would comprise 44% of the total LNG capacity Figure 2: Growth of LNG production capacity Figure 2).

Browse production is currently anticipated by Woodside (2019d, p. 682) by mid-2020, and steady state is expected after 5 years and until about 2040 with other gas resources expected to feed into the NWS facility[3]. With the high CO_2 content in the Browse Basin, we estimate an increase in emissions intensity of the NSW facility from currently 0.4 tCO_2/t LNG to above 0.7 tCO_2/t LNG in the 2030s, leading to an increase of the average emissions intensity for all WA facilities to above 0.5 tCO_2/tLNG in the 2030s.

The GHG intensity of LNG production is calculated based on the upstream emissions from extraction and transport of natural gas and pumping it to LNG processing facilities, the venting of CO_2 from the natural gas reservoir, and the emissions from natural gas used in the liquefaction process. This is expressed in tonnes of CO2 equivalent per tonne of LNG (tCO2e/tLNG).

The methods used in this report to estimate the GHG intensity of each of these steps is based on, or calculated from, data largely published by Woodside in its various reports.

Woodside has tended to separate elements of this GHG intensity equation into different parts obscuring the full intensity of LNG production, particularly at the NWS plant based on the Browse gas. As a consequence the GHG intensity factors used here are higher than quoted in the North-West Shelf extension environmental review document (Woodside, 2019).

For example we calculate the total CO_2 venting intensity for Browse sourced NWS LNG to be in the range of 0.36 to 0.43 tCO_2e/tLNG compared to 0.09 tCO_2e/tLNG reported in Table 6-17 of (Woodside, 2019). The difference is because the lower intensity figure only accounts for the CO_2 vented at the NWS plant itself and does not include the CO_2 vented in the Browse production and transmission process.

Similarly the reported intensity of the NWS plant does not include the upstream emissions due to the natural gas required to produce the gas and pump it to the NWS plant, which amounts to about 0.16-0.19 tCO_2e/tLNG.

Along with a liquefaction intensity of 0.32 tCO_2/tLNG we calculate that soley Browsed sourced NWS LNG production would have a GHG intensity in the range of 0.85-0.97 tCO2/tLNG. We have used a value of 0.90 tCO2/tLNG as a likely average for soley Browse sourced NWS LNG production, more than double the report intensity of 0.41 tCO_2/tLNG for the NWS Plant at full production (Table 6-17,

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[2] See (WA Government, 2019)

[3] For the purposes of this work, in order to estimate the GHG intensity, of LNG production and in the absence of a published scenario or pathway by Woodside, we have assumed that the present supply of natural gas to the NW plant will decline to about one third of present levels by 2030, and be replaced by Browse sourced gas as this field ramps up production, reaching a peak from Browse sourced gas by around 2040 at about 95% of the maximum estimated production capacity for this field, before production from the Browse field declines significantly thereafter. As the Browse field declines, and also to replace the declining production from the present gas field presently supplying the NWS project, we have applied the Scarborough basin CO2 reservoir content and likely upstream energy and CO2 emissions. This results in the GHG intensity of NWS LNG production first increasing, and then as Browse declines, decreasing. It should be noted that if onshore resources are tapped to supply the north-west shelf plant notably from fracking, than the GHG intensity of LNG production would likely increase significantly above what we have estimated.

(Woodside, 2019)). As it is unlikely that Browse would supply all of the natural gas for the NWS plant the peak average GHG intensity from the NWS LNG plant calculated here to lower than 0.9 tCO_2/tLNG at around 0.7 tCO_2/tLNG. If however the gas resource making up the difference between what is available from the Browse field and what is needed to run the NWS LNG plant at its present full capacity[4] is sourced from a more carbon and energy intensive gas field than Scarborough (e.g. from onshore fracking) the average GHG intensity and absolute emissions would be significantly higher estimated here.

Woodside (2019d, 2019c) assesses the GHG impact in separate documents, one referring to the Browse to NWS proposal, addressing the upstream emissions, and a separate assessment of the NWS expansion project, assessing the downstream emissions.

Woodside (2019d)(2019d) concludes that GHG emissions, including estimated contributions of NWS scope 1 emissions attributable to the proposed processing of Browse feed gas by the NWS and scope 1 and 3 emissions are "acceptable".

In Climate Analytics (2019a) we estimated the greenhouse gas emissions based on the projected LNG production. Here we update this estimate based on the data provided by the project proponents.
We also showed that a Paris Agreement pathway for Western Australia consistent with the state reaching its objective of net zero emissions in 2050 implies decarbonising all energy and industry sectors, including the LNG sector, by 2050.

The total (Scope 1) emissions from the LNG industry in WA are based on estimates of CO_2 losses from natural gas reservoirs and plant specific emissions intensity based on available environmental impact statements and other studies (see Climate Analytics 2019a).

Along with the rapid growth of CO_2 emissions from the natural gas used to produce LNG[5], fugitive emissions from LNG processing and related activities and venting of the CO_2 from the natural gas reservoirs, have also increased rapidly. **Emissions from the LNG industry in WA are estimated here to be 20 Mt CO_2e per annum currently and can be expected to approach 30 Mt CO_2e per annum by the late 2020s[6] with the Burrup Hub contributing more than half to this and approaching 16 Mt per annum and the NWS alone contributing more than a third (11-12 Mt per annum) in the 2030s and 2040s (**Figure 3**).**

[4] The present maximum capacity of the NWS plant is understood to be 16.9 MtLNG p.a., although we note that the maximum capacity assumed in Woodside's environmental review documents is 18.5 MtLNG p.a. capacity. If the actual capacity of the plant was increased from present levels up to the latter value this would increase the estimated emissions in this report for this plant by 9-10%.

[5] For every tonne of LNG produced it is assumed that natural gas equivalent to 9% of the energy content of the LNG is required for the manufacturing process.

[6] Emissions from LNG production facilities are estimated here based on standard emission factors, energy balance, physical estimates of CO_2 losses from natural gas reservoirs and plant specific emission intensity based on environmental impact statements and other studies. These estimates are approximately 5% lower than the Clean Energy Regulator Scope 1 plant specific reports for the NWS Karratha, Pluto and Gorgon operations in Western Australia in 2017/18. The estimated Wheatstone emissions are only 45% of the CER Scope 1 reports for 2017/18, however this may be do higher than normal emissions associated with the scaling up of operations at this plant. In general LNG operations also supply domestic gas and data in respective EIS documents emissions associated with this are of order of 5% of the LNG related emissions. This is an updated estimate compared to our previous study, and includes carbon dioxide sequestration in Gorgon.

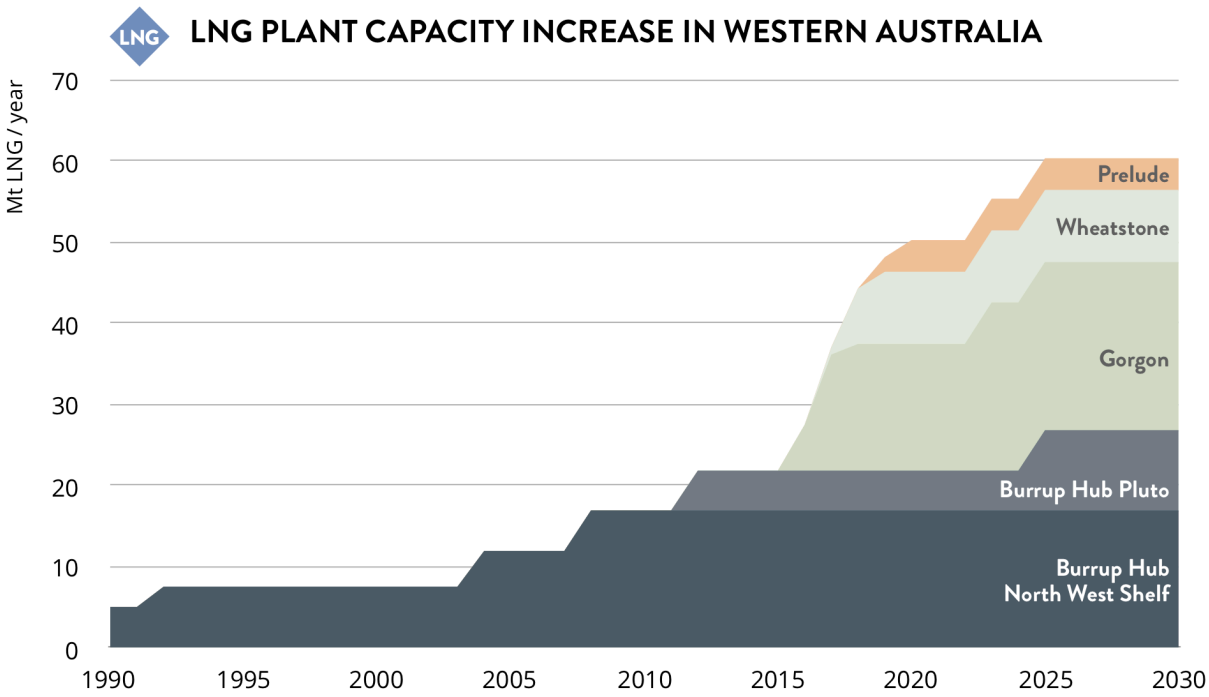

Figure 2: Growth of LNG production capacity in Western Australia. See for historical and prospective capacity development Government of Western Australia (2020) Western Australia Liquefied Natural Gas Profile January 2020. Available at: https://www.jtsi.wa.gov.au/docs/default-source/default-document-library/wa-lng-profile-0120.pdf?sfvrsn=fc74701c_4..

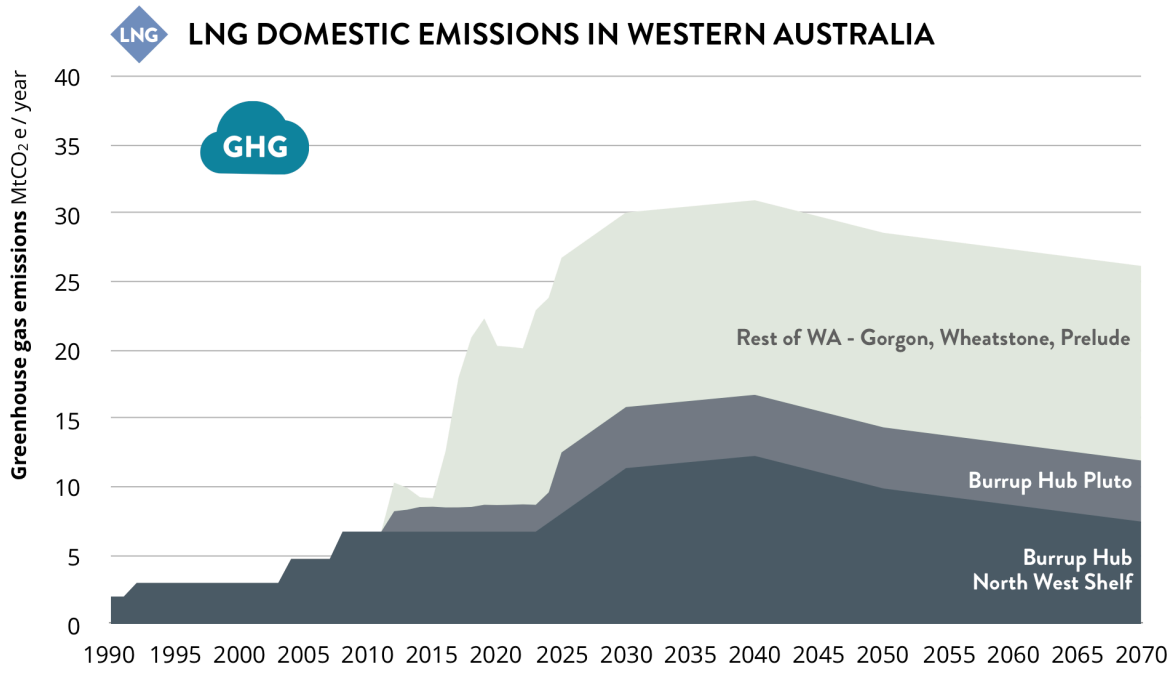

Figure 3 Growth of LNG related emissions (Scope 1) in Western Australia from natural gas used in liquefaction, CO_2 from natural gas reservoirs and fugitive emissions from the LNG manufacturing process until 2019 with projections to 2030. Whilst the intensity of CO_2 emissions from direct energy use and liquefaction have remained fairly stable, in terms of tonnes of CO_2 per tonne of LNG produced, there has been an increase in CO_2 vented from natural gas reservoirs due to the concentration of CO_2 in more recently exploited natural gas reservoirs. The reference case projection includes CO_2 CCS at the Gorgon LNG plant, which explains the drop of total emissions from 2019 to 2020, when it is assumed that the Gorgon CO_2 CCS is capturing 80% of the reservoir CO_2 and storing it in a secure geological formation. The figure includes the contribution of the of the Burrup Hub comprising the NWS and Pluto LNG plant and the gas resources that supply them including the Browse basin[3]. It is important to note that the emissions are linked to production capacity and for the early historical period are different from the actual emissions from plant that was not then operating at full capacity.

To assess the significance, we compare annual and cumulative emissions with corresponding total emissions in Western Australia as well as with Paris Agreement consistent benchmarks as identified in (Climate Analytics, 2019a). Results are shown in Table 1.

The projected cumulative emissions from the present trajectory of the LNG industry in Western Australia for 2018-2050 equal a Paris Agreement compatible carbon budget for all energy and industry sectors for the state until 2050 of about 950 Mt CO_2 (Climate Analytics, 2019a). **The Burrup Hub alone, if it were to go ahead as planned, would take up about half of the total WA energy and industry carbon budget by 2050. Cumulative emissions of the Burrup Hub until 2070 would take up around 76% of the WA carbon budget**[7].

Annual emissions from the Burrup Hub from 2025 onwards would be as high as 17% of current WA greenhouse gas emissions and 36% of emissions across all sectors (excluding the uncertain Land use, land-use change and forestry, LULUCF sector) in 2030 in a pathway for WA consistent with the Paris Agreement. This clearly shows that the Burrup Hub is not consistent with Western Australia implementing the Paris Agreement and achieving its objective of net zero emissions by 2050 as it would not leave enough space for other sectors of the economy.

This is in stark contrast with the claims by the project proponents, that emissions from the project are "acceptable" (Woodside, 2019d, p. 2191).

Table 1 Estimated annual and cumulative emissions from Burrup Hub and total LNG Sector, compared with current emissions in Western Australia and Paris Agreement benchmarks

	Annual emissions 2030 (Mt CO_2 e)	Share of current WA emissions (2017) (%)	Share of WA emissions PA Pathway 2030	Cumulative emissions 2018-2050 (Mt CO_2 e)	Share of WA PA carbon budget (%) [8]	Cum. Em. 2018-2070 (Mt CO_2 e)	Share of WA PA carbon budget (%) [9]
Burrup Hub – NWS	11.4	12%	26%	334	35%	507	53%
Burrup Hub - Pluto	4.5	5%	10%	130	14%	219	23%
Burrup Hub total	**15.8**	**17%**	**36%**	**464**	**49%**	**726**	**76%**
LNG Sector rest WA	14.2	15%	33%	**457**	**48%**	**742**	**78%**
LNG Sector total	**30.5**	**32%**	**69%**	**922**	**97%**	**1468**	**154%**

[7] Note this is a conservative estimate, as we have only derived a carbon budget for WA until 2050, which does not take into account the need for negative emissions after 2050, see Climate Analytics (2019).

[8] Carbon Budget is estimated for fossil fuel – energy and industry – CO_2 emissions. Emissions estimated from LNG Sector are almost completely (about 98%) comprised by CO_2 emissions.

[9] Note that the carbon budget for 2018-2070 would be lower than the 2018-2050 budget, due to the need for negative emissions after 2050.

Mitigation of LNG emissions - Paris Agreement and net zero emissions objective

Woodside does not explain how the Browse to NWS shelf proposal would be in line with WA's aspirational target of net zero GHG emissions by 2050, and only refers to "continuing to work to reduce (net) emissions intensity through improvements in energy efficiency, investments in bio-sequestration projects and innovation in our production processes", also referring to its published Climate Change Policy (Woodside, 2019b). This **implies relying on offsetting**, which we have shown is **not consistent with the WA state objective of net zero emissions and the Paris Agreement carbon budget**, given mitigation achieved outside of the LNG sector that would be used for offsetting would need to be implemented in any case, and not to compensate for no, or insufficient, mitigation in the LNG sector.

In order to meet the commitments of the Paris Agreement **significant abatement measures would need to be introduced in the LNG sector**. These would include extending carbon capture and storage for reservoir CO_2 losses to all LNG plants in Western Australia as well as replacing a significant fraction of natural gas used in LNG processing by renewable electricity.

The broad approaches assumed in our previous report (Climate Analytics 2019a) is that the level of CCS planned for the Gorgon plant of 80% from 2020 (which would capture approximately 60% of all the present total CO_2 reservoir emissions for LNG operations in WA) would be phased into to all plant so that from 2026 at least 80% of reservoir CO2 is captured and stored, combined with the phasing in of renewable energy so that by 2030, 50% of LNG manufacturing natural gas use is replaced by renewable energy, 90% by 2035 and by 2050, 100%.

One scenario therefore for the LNG industry in Western Australia under Paris Agreement implementation would be to more or less follow the modelled trajectory for natural gas demand in the power sector in Asia for the period 2030 to 2060 which would result in a substantial reduction in LNG demand, reducing from peak levels in 2030 to close to zero by 2050 (Climate Analytics, 2019a). A decline in demand for LNG industry consistent with the Paris Agreement reaching close to zero by 2050 would reduce all LNG related emissions very substantially.

Irrespective of whether or not the demand reductions in Asia discussed above occur, the cumulative emissions of the LNG industry need to be reduced substantially in the basic options examined here would need to be deployed in either case. In the reference case, the scale of the emission reductions to be achieved through carbon capture and storage of reservoir CO2 and by introducing renewable energy quickly into the LNG manufacturing process would be substantially larger than in the Paris Agreement Asian power demand case. For completeness we show both scenarios which achieve similar levels of cumulative reductions by 2050.

Applying the options described above to the reference case LNG production in our original study as is shown in Figure 5 would reduce the peak emissions from Western Australia LNG manufacturing to around 300% above 2005 levels from a projected 600% increase by the mid 2020's in the case with no policy action. This would bring emissions back to about 176% above 2005 levels in 2030, 16% below 2005 levels in 2040 and 46% below in 2050. Zero CO_2 emissions would be needed to be Paris Agreement compatible.

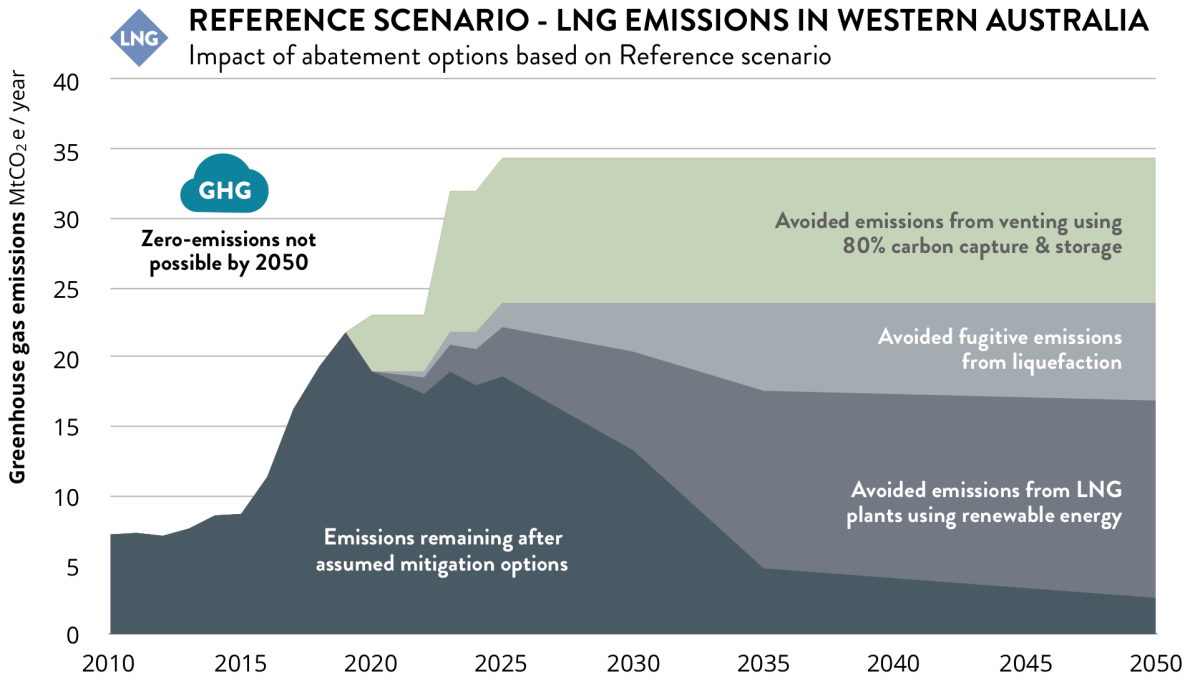

Figure 4 Relative role of the abatement options described in the text for reference case LNG demand from Climate Analytics (2019a). (Difference in reference case due to updated estimate. The reference scenario shown here does not yet include sequestration for the Gorgon facility. Source: Climate Analytics (2019a).

Under a Paris Agreement induced decline in demand from 2030 combined with the mitigation options discussed (carbon capture and storage, electrification), this would lead to LNG related emissions in 2030 being about 175% above 2005, around 80% below 2005 levels by 2040 and approach zero by 2050 (Figure 5).

In Climate Analytics (2019a) we have shown that such a mitigation pathway is necessary for the LNG sector for Western Australia to contribute its share to national emission reductions necessary to meet the Paris Agreement long-term temperature goal. National reductions in the range of 44-61% by 2030 compared to 2005 are needed to put the country on a cost-efficient pathway to achieve zero net GHG emissions by around 2050. The 1.5°C compatible state level greenhouse gas target for Western Australia consistent with this range is a reduction of 49% by 2030 (from 2005 levels) taking into account the challenge to reduce emissions in the large LNG sector.

Woodside claims that Browse to NWS project is compliant with the Safeguard Mechanism of the Australian Government (Woodside, 2019d). It has been shown repeatedly that the Safeguard Mechanism is inadequate as a policy to achieve emission reductions in line with the insufficient NDC, let alone in line with the Paris Agreement (Climate Action Tracker, 2019).

Woodside's (2019d) measures for the Browse to NWS Project beyond meeting the inadequate safeguard mechanism and relying on offsetting/carbon credits include "waste heat recovery units, active heating for hydrate management, the use of batteries and the use of nitrogen to purge the flare stack" which amount to only 1 MtCO2e reduction per year.

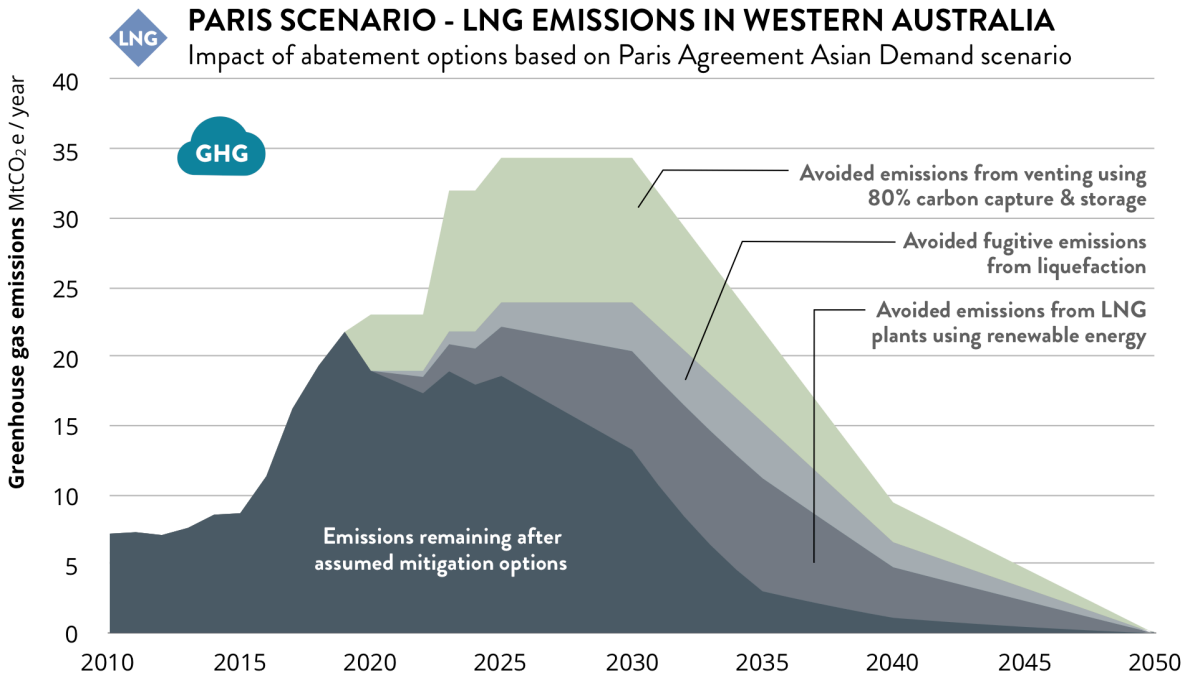

Figure 5: Relative role of different elements of a Paris Agreement LNG demand reduction scenario and mitigation options in reducing emissions from the reference case to close to zero emissions by 2050. The cumulative emissions remaining between 2018 and 2050 after the assumed mitigation options are applied un this Paris Agreement LNG demand scenario is 274 $MtCO_2e$. This amounts to approximately about 29% of the Western Australian Paris agreement compatible carbon budget for the energy system. There could be more or less emissions left depending upon the rate and scale of the actual mitigation options deployed.

CONTRIBUTION TO GLOBAL EMISSIONS AND PARIS AGREEMENT

When the LNG is burnt offshore in power stations significantly greater emissions occur but these are not counted domestically in Australia or in Western Australia under the agreed international greenhouse gas accounting systems used in the UNFCCC, Kyoto Protocol and the Paris Agreement, as emissions are accounted for in the country in which the LNG is consumed. These emissions are referred to as Scope 3 emissions.

We estimate the Scope 3 emissions of the Burrup Hub to be around 120 $MtCO_2$ e per annum[10] from 2025 onwards, with NWS contributing 75 $MtCO_2$ e per annum. Cumulative total Scope 1 and Scope 3 emissions for 2025 to 2070 (until the end of planned lifetime) of 6.1 Gt CO_2e are equal to about 1% of the total global energy and industry carbon budget calculated based on Paris Agreement consistent mitigation pathways and about the same as the share of the global carbon budget estimated for Australia's energy and industry emissions (Climate Analytics (2019a).

Global implementation of the Paris Agreement means that the recent growth in the use of natural gas cannot continue, whether for the power sector or in other applications. The analysis of global mitigation pathways in line with the Paris Agreement as assessed by the IPCC shows that under the Paris Agreement demand for natural gas in the power sector in Asia, a major source of LNG demand, is likely to peak by around 2030 and then decline to close to zero between 2050 and 2060, as shown above.

Woodside (2019d:678) refers to Australia being expected to restate its NDC in 2020 and update it in 2025. This is against the COP 26 decision agreed to also by Australia that confirms the need to increase ambition by 2020 to close the gap as also outlined in UNEP Emissions gap reports (UNEP, 2019) and IPCC Special Report (2018). Given the need to peak emissions in 2020 and to close the 2030 ambition gap this implies NDCs need to be ratcheted up in 2020, as it is not consistent with the Paris Agreement to wait until 2025.

Woodside (n.d.) refers to gas as a solution to climate change, including referring to the IPCC AR5 SYR (IPCC, 2014) stating that "switching from coal to gas-fired power can significantly reduce GHG emissions". However, Woodside ignores the more recent IPCC (2018) assessment relevant for achieving the Paris Agreement Long Term Temperature goal (LTTG) of limiting warming to 1.5°C to significantly reduce the impacts and risks of climate change. Woodside have justified the Browse to NWS project using the IEA's World Energy Outlook (WEO) Sustainable Development Scenario (Woodside, 2019d). This scenario is not 1.5 degrees Paris Compatible, as it limits temperatures rise to 1.7 to 1.8 degrees (Woodside, 2019d). Overall the Sustainable Development Scenario finds gas demand grows modestly to 2030 and reduces to present levels by 2040 (IEA, 2019). The WEO highlights the uncertainty surrounding the scale and durability of demand for LNG demand in developing countries, due to price sensitivity, competition from other technology which risks of suppliers being unable to recover investment costs (IEA, 2019) posing a huge stranded asset risk to WA and investors.

As shown above, the SDS is not an appropriate benchmark for short and medium term policy recommendations or investment decisions as it is not consistent with the Paris Agreement temperature goal nor is it transparent about the extent of reliance on CCS technology. In addition, it is a significant

[10] Based on current and projected production of 16.9 Mt LNG per annum at NWS and 9.9 Mt LNG per annum at Pluto, the emission factor used by Woodside for LNG (3.13 kg CO_2e/kg LNG) and the LPG, domestic gas and condensate estimates provided by Woodside (n.d.). For Pluto, we assume a proportional contribution for domestic gas, condensates and LPG, which leads to a share of 36% of Scope 3 emissons from Burrup Hub coming from Pluto.

outlier for coal and gas-fired power generation compared to Paris Agreement compatible pathways, even when CCS is included.

Woodside argue that LNG is an 'ideal partner" to intermittent renewable energy (Woodside, 2019d). Alternative firming capacity can be provided by batteries and other storage technology, which have been found to be more cost effective than gas in many geographies, including Australia. The CSIRO and AEMO found the levelized cost of solar and wind is lower than gas and other electricity generation options (Graham, Hayward, Foster, Story, & Havas, 2018). "Firm" solar and wind with two to six hours of battery storage or hydro is still more cost effective than gas or other fossil fuel generation (Graham et al., 2018). IRENA (2019) found that the costs of renewable energy has declined to the point that it is cheaper than new natural gas options without financial assistance. Bloomberg New Energy Finance found similar results, with wind and solar providing the cheapest form of electricity generation across two thirds of the world (BloombergNEF, 2019). An increasing number of studies shows the feasibility of 100% renewable energy.

CONCLUSIONS

We have shown that it is important to integrate all projects related to the Burrup Hub to assess implications for greenhouse gas emissions and consistency with the Paris Agreement and emission targets.

In contrast to the claims by Woodside that the greenhouse gas emissions impacts are "acceptable", we show that emissions from the Burrup Hub including the proposed NWS extension and Browse to NWS project would contribute significantly to Western Australia's emissions and make it impossible for Western Australia to achieve a pathway consistent with the Paris Agreement and its state objective of net zero greenhouse gas emissions by 2050.

The Burrup Hub, if it were to go ahead as planned, would take up about half of the total WA energy and industry carbon budget by 2050. Cumulative emissions of the Burrup Hub until 2070 would take up more than 80% of WA carbon budget.

At the Australian national level it has been estimated that a Paris Agreement compatible carbon budget for all energy and industry sectors until 2050 is in the range of 4.8-6.1 $GtCO_2$. On the present trajectory the **Burrup Hub alone** would burn up about 7-10% of this budget and the WA LNG industry as a whole about 18-20%.

Annual emissions from the Burrup Hub from 2025 onwards would be as high as 17% of current WA greenhouse gas emissions and 35% of emissions across all sectors (excluding the uncertain Land use, land-use change and forestry, LULUCF sector) in 2030 in a pathway for WA consistent with the Paris Agreement. This clearly shows that the Burrup Hub is not consistent with Western Australia implementing the Paris Agreement and achieving its objective of net zero emissions by 2050.

From an Australian-wide perspective, by 2030 the Burrup Hub is projected to produce about 2.6% of Australia's 2005 emissions (incl. LULUCF) and, with no mitigation, would add about 2% to the reductions needed to meet an economy-wide 26% reduction. Unabated, the entire WA LNG industry would add about 4.5% to the reductions needed to meet an economy-wide 26% reduction, meaning that to compensate for no abatement by the WA LNG industry, Australia would need to increase its target to 30.5% by 2030.

Cumulative total (Scope 1 and Scope 3) emissions for 2025 to 2070 for the **Burrup Hub alone** (until the end of planned lifetime) of 6.1 Gt CO_2e are equal to about 1% of the total global energy and industry carbon budget calculated based on Paris Agreement consistent mitigation pathways and about the same as the share of the global carbon budget estimated for Australia's energy and industry emissions.

The Burrup Hub project as proposed would not be consistent with Australia achieving the necessary reductions in the range of 44-61% by 2030 are needed for the level of action Australia needs to take in global efforts to limit warming to 1.5°C and to meet the Paris Agreement's long-term temperature goal. These emission reductions are needed by 2030 to put the country on a cost-efficient pathway to achieve zero net GHG emissions by around 2050. The Hub's projected emissions by 2030 are likely to be in the range of 4.6-6.5% of Australia's 1.5°C compatible pathway and, if unabated, this would mean other sectors would need to reduce by some 3% more (about 47-64% by 2030)[11].

11 For the WA LNG sector as a whole the relevant numbers are 8.6-12.5% and 49-66% respectively.

The 1.5°C compatible state level greenhouse gas target for Western Australia, consistent with this range is a reduction of 49% by 2030 (from 2005 levels) taking into account the challenge to reduce emissions in the large LNG sector.

Mitigation measures proposed by Woodside are inadequate compared to the scale of reductions needed to be consistent with the Paris Agreement, and rely significantly on offsetting emissions for example with bio-sequestration, which contradicts the need to reduce emissions across all sectors.

The claim by Woodside that the project will contribute to reducing emissions globally is not consistent with the recent scientific literature and mitigation pathways consistent with the Paris Agreement Long-term temperature goal, and therefore ignores the large risk of creating stranded assets through investing in fossil fuel infrastructure when there is a need to phase out fossil fuels, including gas, to achieve the Paris Agreement long-term temperature goal.

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AUTHORS

Bill Hare
Anna Chapman
Ursula Fuentes

Graphic design: Matt Beer

CLIMATE ANALYTICS

Climate Analytics is a non-profit climate science and policy institute based in Berlin, Germany with offices in New York, USA, Lomé, Togo and Perth, Australia, which brings together interdisciplinary expertise in the scientific and policy aspects of climate change. Our mission is to synthesise and advance scientific knowledge in the area of climate change and on this basis provide support and capacity building to stakeholders. By linking scientific and policy analysis, we provide state-of-the-art solutions to global and national climate change policy challenges.

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