Green LNG – Opportunities and Challenges

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Sustainability Report

The Abdullah Bin Hamad Al-Attiyah International Foundation for
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INTRODUCTION

GREEN LNG – OPPORTUNITIES AND CHALLENGES

As gas is the fastest-growing fossil fuel, so Liquefied Natural Gas (LNG) is one of the fastest-growing methods of delivering gas to international markets. LNG has the potential to cut greenhouse gas (GHG) emissions and other pollutants in coal-heavy regions such as east and south Asia.

However, gas and LNG are also coming under environmental pressure because of associated methane and carbon dioxide emissions. What options exist to reduce LNG's GHG footprint? How do different projects compare? And what other approaches are open to LNG exporters to strengthen their claims that LNG provides a sustainable energy solution?

Sustainability Report

This research paper is part of a 12-month series published by the Al-Attiyah Foundation every year. Each in-depth research paper focuses on a prevalent sustainable development topic that is of interest to the Foundation's members and partners. The 12 technical papers are distributed to members, partners and universities, as well as made available online to all Foundation members.

EXECUTIVE SUMMARY

- Gas in general is seen as having the brightest future of the fossil fuels, because of its abundance, reasonable cost, clean burning nature and relatively low carbon footprint compared to coal and oil.
- LNG delivered to Europe or China has a greenhouse gas (GHG) footprint barely half that of coal. It can gain significant market share from coal and oil by leveraging its environmental advantages, if it can remain cost-competitive and assure supply security.
- However, gas is coming under environmental pressure in the EU and parts of the US, because of its emissions of CO^2 and methane.
- The sustainability challenges to LNG are therefore dual: to gas in general, and to LNG in particular.
- LNG has in general, though not always, somewhat higher greenhouse-gas (GHG) intensity than gas delivered by pipeline, because of the energy used in the liquefaction process.
- Different projects have widely varying GHG footprints and other sustainability benchmarks, because of differences in resource quality, liquefaction efficiency, transportation distance, local environmental and community impact, applicable regulations, and other factors.

IMPLICATIONS FOR LEADING OIL AND GAS PRODUCERS

- Moves by the EU, financiers and insurers to target sustainability metrics can significantly affect the viability and market access of new and existing LNG plants.
- Developers of new LNG can significantly improve their sustainability by choosing projects carefully, managing stakeholder relations, targeting high efficiency and introducing technology such as electric drive, renewable power generation, and carbon capture, utilisation and storage (CCUS).
- The options for existing plants are more limited but include upgrades, feedstock sourcing, and logistic improvements and optimisation.
- The sustainability of LNG is not separable from that of gas in general; major exporters have to invest in the viability of gas by developing sustainable long-term pathways for use.

IMPLICATIONS FOR LEADING ENERGY CONSUMERS

- Choosing suppliers carefully is important to avoid inheriting high-GHG footprint gas.
- Major LNG buyers and traders can work more closely with LNG suppliers to reward more sustainable providers, reduce GHG footprint and optimise logistics.
- Leading producers and consumers can establish strong partnerships to develop and utilise innovative market approaches, such as, carbon pricing, carbon markets and cooperative mechanisms established under Article 6 of the Paris Agreement.
- Gas/LNG companies seeking to limit their Scope emissions may eventually have to restrict the end-uses of their gas to avoid unabated emissions.

GAS IS SEEN AS THE GREENEST OF THE FOSSIL FUELS, BUT STILL FACES ENVIRONMENTAL CHALLENGES

Most forecasts of future energy use show a growing role for gas, in both market share and absolute terms (FIGURE 1). This contrasts with a plateau and slow decline for oil, and a sharper drop in coal. Gas is cheaper than oil, and much cleaner in use than coal and oil. It is available from a wide and growing range of suppliers, whether from domestic production (in many countries), pipeline or increasingly LNG. LNG is expected to grow quickly to become the main method for delivering gas internationally, because of its improving costs and flexibility. LNG is forecast by BP to grow at 2.8% annually

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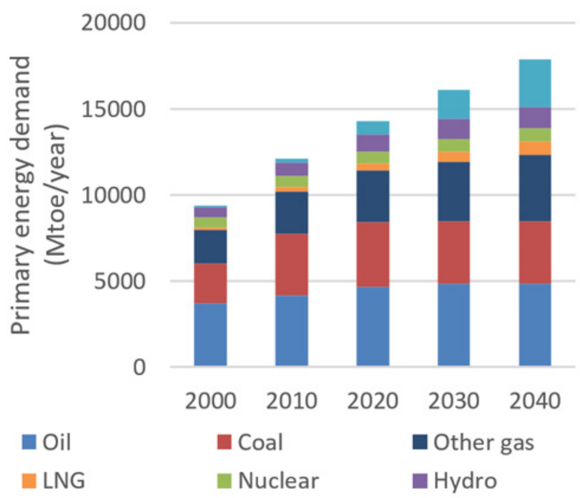
from 2020 to 2040, compared to 1.4% for other gas (domestic and international pipelines), 0.2% for oil, and -0.2% for coal.

FIGURE 1 FUTURE PRIMARY ENERGY CONSUMPTION BY SOURCE[i].



For flared gas, in countries such as the US, Angola and Nigeria, LNG is the most feasible way to market associated gas that would otherwise be burned.

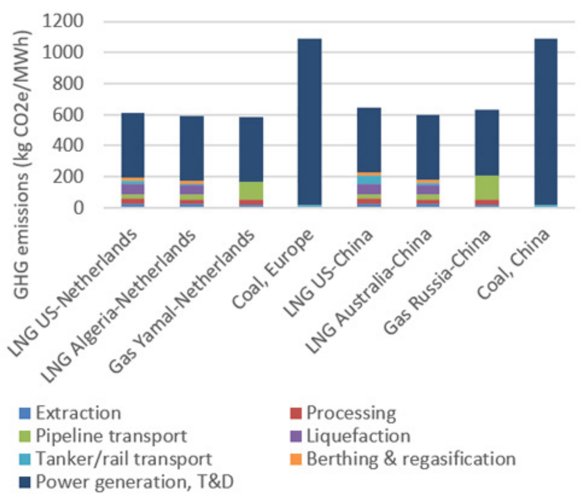
LNG producers and other oil and gas firms classify their GHG emissions into Scope 1, Scope 2 and Scope 3. Scope 1 is direct emissions from their operations; Scope 2 is emissions from their use of electricity purchased from other sources; and Scope 3 is the emissions produced when their products are used by others (i.e. when gas, oil and coal are combusted).

Oil and gas companies have control over their Scope 1 and, to an extent, Scope 2 emissions. However, fossil fuel companies are increasingly under pressure to limit all related emissions, including Scope 3 (see the Al Attiyah Foundation Sustainability Digest Issue 12, December 2019). Repsol has promised to eliminate Scope 3 emissions by 2050[ii], Shell to cut its emissions in half by 2050[iii], and Equinor to reduce its emissions in Norway by 40% by 2030 and to near-zero by 2050[iv].

Figure 2 compares the GHG footprint of LNG from the US, Algeria and Australia delivered to Europe or China, with Russian gas delivered by pipeline, and domestic coal. Overall, LNG has somewhat higher emissions than pipeline gas, but not enormously so. Long-haul LNG from the US to China can actually have a slightly higher footprint than pipeline gas, when accounting for pipeline leakage and the energy for compressor stations. Coal's upstream and midstream emissions are a small share of its total, but the overall footprint is much higher – more than 80% - than that of LNG, because of its high carbon dioxide release when combusted.

Upstream emissions of LNG (gas production, processing and liquefaction) are significant at around 25% of the total GHG footprint, including the emissions when the gas is combusted for power. Transport emissions (shipping and regasification) are less, ranging from 5-11% depending on the distance to market.

FIGURE 2 GHG FOOTPRINT OF LNG, PIPELINE GAS AND COAL[v]



LNG and gas in general have other major benefits over coal in hugely reducing air and water pollution, eliminating the problem of disposing of coal ash, and reducing coal mining (which is dangerous and can damage landscapes).

LNG FACES PARTICULAR SUSTAINABILITY CHALLENGES

LNG will have a growing role in supplying gas, because numerous emerging producers and consumers are too far apart or divided by geographic or political barriers, or end-user markets are too small, for pipelines to be viable. Up to 2040, 80% of the projected increase in international gas trade will be via LNG.

Major new international gas pipelines also face the issue of GHG emissions from upstream production, leakage and running their compressors. At the moment, concerns about the footprint of imported gas apply mainly to Europe, and there are few proposed new pipelines there[vi]. New pipeline imports into China or India would be competing against coal, giving them a more positive environmental profile.

LNG is not always higher-GHG than pipeline gas, but the energy used in liquefaction, shipping and regasification tends to give it a higher footprint. LNG plants are also often built in sensitive environments, or face community objections. LNG liquefaction can raise the overall GHG intensity of countries such as Australia and Canada, and thus create the problem of where emissions should be assessed and reduced.

Some jurisdictions already have emissions standards. For instance, British Columbia requires LNG plants to reach GHG intensity of 0.16 tonnes CO^2eq per tonne of LNG, which is lower than any existing plant in the world. Facilities not achieving this have to buy credits from other operations, with more penalties for emissions above 0.23 t/t[vii].

Policy on carbon taxes has been inconsistent, but Canada's minimum carbon price is intended to reach CA$50/tonne (about US$38.5) by 2022. That would equate to $6.2/tonne of LNG for a best-in-class LNG plant, or $0.13/MMBtu, not a large charge but equivalent to about 2% of the final price with LNG at $6/MMBtu.

During the 2020s, the EU, and possibly some other key LNG markets such as Japan and South Korea, may move to impose restrictions on the GHG footprint of imported gas, including LNG. This could be via an absolute ban on gas with a footprint above a certain level (which might fall over time), or via a carbon tax levied per tonne of supply chain emissions (and charged as a tariff for imports).

A growing number of financiers and insurers already restrict lending to fossil fuel projects, or at least particularly high-emission ones (coal and oil sands). Oil companies are also setting targets for reducing and eventually eliminating their own emissions. For instance, Equinor plans to reduce its emissions in Norway by 40% by 2030 (on a 2005 baseline), 70% by 2040 and near-zero by 2050[viii]. This would require such companies to substantially reduce the greenhouse gas footprint of their LNG plants, close them down or divest them (and not acquire high-emitting plants).

THE SUSTAINABILITY BENCHMARKS OF LNG PROJECTS VARY WIDELY

The GHG footprint of LNG plants varies widely (TABLE 1).

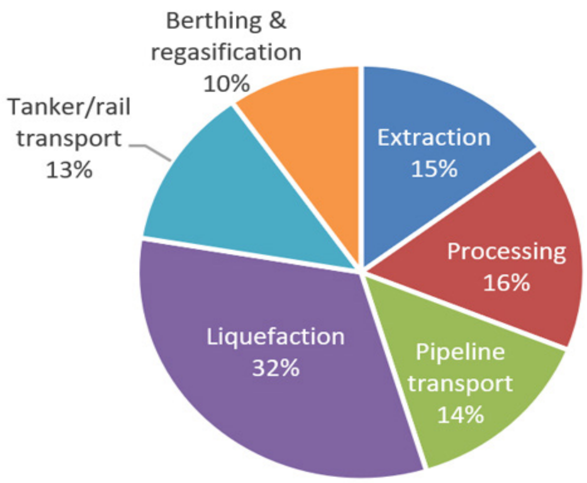
TABLE 1 GHG FOOTPRINT OF SELECTED LNG PLANTS[ix]

Plant	GHG footprint, tCO2eq/t LNG
LNG Canada	0.15
Sabine Pass (Louisiana, USA)	0.26
Gorgon (Australia)[X]	0.27
Australia Pacific	0.3
Pluto (Australia)	0.36
Gladstone (Australia)	0.39
Snøhvit (Norway)	0.29-0.34
Qatargas 2	0.41
Qatargas 1	0.49

This is because of many factors including differences in resource (reservoir quality, distance of field from plant, CO^2 content); location (offshore tending to have higher energy consumption than onshore); levels of flaring (for captured gas); local climate (colder ambient temperatures yield greater plant efficiency); and technology choices at the plant.

The split of emissions varies depending on the project, but FIGURE 3 shows a US example. About 45% of emissions come in the upstream, 32% in liquefaction, and 23% in transport and regasification.

FIGURE 3 SPLIT OF LNG CHAIN EMISSIONS[xi]



Liquefaction plant emissions can be reduced in various ways[xii] :

- General efficiency improvements;
- Waste heat recovery[xiii]
- Use of combined-cycle turbines
- Turbine inlet air cooling
- Appropriate sizing to reduce flaring
- Use of more efficient aMDEA solvent
- Electric versus gas turbine drive[xiv]
- Use of low-NO_x burners
- CCUS for separated CO^2 from feedstock
- CCUS for CO^2 from power/heat generation
- Elimination of other GHGs, e.g. SF_6 used in switchgear
- Recovery of boil-off gas from loading (as implemented in Qatar, with a 93% recovery rate yielding about 1 Mt/year of additional LNG[xv]).

For example, gas from the Montney shale in Canada, which will feed the LNG Canada plant, has CO^2 content of 1%, while the Horn River basin to the north contains 12% CO^2, and Australia's Gorgon field 14%[xvi]. Most of this CO^2 has to be removed to reach LNG specifications, and then can either be sequestered (as at Gorgon) or released into the atmosphere, adding substantially to emissions.

Qatar has for some years reinjected acid gas (the mix of hydrogen sulphide (H_2S) and CO^2 from gas processing), capturing 2.1 Mt per year. This is to be increased to 5 Mt/year by 2025 as part of the country's LNG expansion plans[xvii], reducing the plants' GHG emissions by 25%.

Gas processing plants can be run on electricity instead of gas, reducing direct emissions by 90%. Drilling rigs can be powered by gas instead of diesel, for a 28% GHG saving, and could be electrified where local grid or renewable electricity is available. Upstream methane emissions can be cut by using 'green completions', regular monitoring for leaks using satellite and drones, and electric instead of pneumatic actuators[xviii].

The type of liquefaction process makes a small difference, with Single Mixed Refrigerant estimated to be about 6% less efficient than Air Product's C3/MR[xix].

GHG footprint of delivered gas is further influenced by transportation distance (which varies between destination markets), vessel efficiency, and regasification facilities.

Shipping emissions can be reduced by:

- Using LNG-fuelled engines (rather than diesel or fuel oil);
- Installing on-board re-liquefaction;
- Slow steaming;
- Having on-board equipment for use or combustion of excess boil-off gas;
- Optimisation of logistics and delivery (e.g. swaps to reduce sailing distances)

There is less room for improvement in regasification, but the 'waste cold' can be used for district cooling (in hot climates) or for power plant inlet pre-cooling.

Gorgon CCUS

- The Gorgon field, feeding the 15.6 Mtpa Gorgon LNG plant in Western Australia, contains 14% CO^2.
- The Chevron-led joint venture constructed a CCUS facility at a cost of $2.5 billion to reinject the captured CO^2.
- CO^2 is injected into the Dupuy Formation, above 2300 m below the plant on Barrow Island, where it will be trapped by a thick shale.
- Injection will be 3.4-4 Mt/year, reducing plant emissions by 40%.
- Injection was planned to start in 2017 but was delayed by multiple problems including corrosion and pipeline leaks, and finally began in August 2019.
- The project has been accompanied by extensive monitoring of the injected CO^2.

THE SUSTAINABILITY BENCHMARKS OF LNG PROJECTS VARY WIDELY

Developers of new LNG plants, particularly those with a portfolio of options for new projects, can incorporate sustainability as a major decision criterion. Operators of existing plants have more limited options, but can make improvements by, for example, reducing methane leakage; upgrading efficiency; installing CCUS; changing feedstock sourcing (for plants that have a choice, mainly in the US); and optimising shipping logistics.

Finally, companies can reduce their overall footprint by purchasing offsets, such as reforestation. This is required in some systems, for instance in Canada, but is not accepted by all stakeholders.

RENEWABLES OFFER SYNERGIES WITH LOW-CARBON LNG

Electrification of gas processing and liquefaction reduces direct emissions by up to 90%. However, it will add to Scope 2 emissions, depending on the GHG intensity of the electricity grid. This in turn depends on the mix of generation sources and their efficiency. In much of Australia and the US, there would be little, no or a negative benefit to using average grid electricity (TABLE 2), although emissions factors should fall over time as renewable penetration increases.

The greatest reductions in GHG intensity will be seen where the local grid is primarily based on renewables (or nuclear). This is the case for British Columbia (Canada) and Norway, both using mostly hydro and some wind. Snøhvit in Norway, LNG Canada and Kitimat, use or will use low-carbon grid electricity.

TABLE 2 GRID EMISSIONS FACTOR FOR SELECTED LNG EXPORTERS[xx]

Region	Grid emissions factor (kg CO2/kWh)
Australia – Queensland	0.92
Western Australia	0.75
Indonesia	0.736
Louisiana	0.519
Georgia	0.519
Texas	0.4825
Typical LNG plant gas turbine	0.44
UAE	0.4382
Alaska	0.3777
British Columbia	0.0117
Norway	0.011

As other companies have done, LNG producers could contract with local utilities to provide 100% carbon-free power. Alternatively, they could construct their own renewable power, particularly in remote locations or where the national grid is unable or unwilling to provide renewable electricity. The competitiveness of solar power in sunny locations such as MENA and Australia suggest it would be both environmentally and economically attractive, at least to supplement the plant's gas turbines.

The required heat for both liquefaction and regasification facilities could also be supplied by renewable sources, such as biomass or concentrated solar power.

In the longer term, as attention grows on the carbon footprint of fossil gas, LNG exporters could supplement it with biomethane, if they have suitable local sources of biomass. Or, hydrogen or ammonia production and export could be added to existing LNG facilities, manufactured either from gas with CCUS, or by electrolysis of water with low-carbon electricity.

THE SUSTAINABILITY OF LNG IS NOT SEPARABLE FROM THAT OF GAS IN GENERAL

The main difference between the GHG footprint of gas in general and LNG is in the liquefaction, shipping and regasification. The upstream production, pipeline transport to the liquefaction plant (if any) and downstream use are common.

Despite its superior environmental performance, gas is coming under growing activist pressure. Even highly sustainable LNG plants will feel this pressure if financing and insurance for fossil fuel projects in general dries up, or the market size and/or price for gas falls.

Major LNG exporters therefore have to be part of the conversation and action to improve gas's sustainability. Accurate and trustworthy certification of emissions will become more important if some importing countries introduce carbon charges or benchmarks. Different certifications may be required for each step of the chain – upstream, liquefaction, shipping, regas and final use – particularly as the custody of the LNG can change at each point.

Medium-term actions to make gas use more sustainable include expansion into higher-carbon markets, such as replacing coal in power generation, diesel in trains and trucks, and heavy fuel oil in shipping. Sustainability also includes modern energy access, and LNG is particularly relevant to serving smaller markets or those without readily available pipeline gas, including south Asia, sub-Saharan Africa, and islands such as in the Mediterranean, Caribbean and archipelagic south-east Asia.

Methods to make gas fully sustainable indefinitely can include CCUS (in sectors including power generation, aluminium, steelmaking and cement); and conversion to hydrogen or other useful products or energy carriers, with CCUS to eliminate emissions.

LNG sustainability is not just about GHG emissions, although this is the largest issue. LNG projects also face local environmental and community opposition for issues such as pipeline rights of way, effects on biodiversity and habitats, marine impacts from dredging and cold-water discharge (from regasification). Gas production, particularly of unconventional gas (shale gas in the US, coalbed methane in eastern Australia) faces opposition for land-use disturbance, and allegations of air and water pollution. All these issues have to be carefully managed, as for any large energy project. Floating LNG liquefaction offers benefits of exploiting remote offshore fields and avoiding a large land-based footprint, so reducing such impacts.

CONCLUSIONS

LNG offers major benefits over coal in terms of GHG emissions and other pollutants. Its emissions are comparable, or only a little higher than, long-distance gas pipelines, although higher than domestically-sourced gas. This makes it particularly important for improving the environment in countries such as China and India, and those without domestic gas sources including Japan, South Korea and Taiwan.

However, LNG still comes with significant emissions and other environmental impacts. This is leading to growing scrutiny of LNG projects and imports, particularly in Europe. To remain competitive and even to maintain access to market, LNG plants will have to minimise their emissions along the value chain. The largest sources of emissions, and those with most room for reductions, come in the upstream and liquefaction, where efficiency, reducing methane leakage, electric drive, renewable integration and CCUS are all key technologies.

LNG producers are a subset of gas exporters. Eventually, LNG along with other sources of gas will have to define a low-carbon pathway for use, that can include CCUS, hydrogen and other non-emitting approaches.

APPENDIX

i. BP World Energy Outlook 2019

ii. https://www.worldoil.com//news/2019/12/4/repsol-s-carbon-reduction-pledge-puts-the-onus-on-peers-to-follow-suit

iii. http://www.gulfenergyinfo.com/sustainability-leadership/2019/november/exxonmobil-shell-neste-take-different-paths-to-sustainability?id=1757595

iv. https://www.reuters.com/article/us-norway-carbon-equinor/equinor-eyes-40-greenhouse-gas-cuts-in-norway-by-2030-idUSKBN1Z50F2

v. From data in https://www.energy.gov/sites/prod/files/2014/05/f16/Life%20Cycle%20GHG%20Perspective%20Report.pdf. Figures using 100-year GWP, and AR-4 model.

vi. Nord Stream II, Turk Stream and TANAP/TAP will be completed shortly. The only other significant new proposed pipeline is the East Med project, which faces major commercial and political challenges. See https://www.oxfordenergy.org/wpcms/wp-content/uploads/2019/10/Challenges-to-the-Future-of-LNG-NG-152.pdf. This excludes some intra-European pipelines.

vii. https://www2.gov.bc.ca/assets/gov/environment/climate-change/ind/lng/lng-env-incentive-program.pdf

viii. https://www.energyvoice.com/otherenergy/215587/equinor-aims-to-lower-emissions-in-norway-to-near-zero-in-2050/

ix. https://www2.gov.bc.ca/assets/gov/environment/climate-change/ind/lng/lng_emissions_benchmarking_-_march_2013.pdf

x. This assumes Gorgon's CO2 capture and storage plant is working as planned

xi. https://www.energy.gov/sites/prod/files/2014/05/f16/Life%20Cycle%20GHG%20Perspective%20Report.pdf. Figures using 100-year GWP, and AR-4 model.

xii. https://www.api.org/~/media/Files/EHS/climate-change/api-lng-ghg-emissions-guidelines-05-2015.pdf

xiii. https://www.onepetro.org/conference-paper/IPTC-18212-MS

xiv. https://inpex.energy/media/v2vnjpba/draft-environmental-impact-statement-11-chapter-9-greenhouse-gas-management.pdf

xv. https://www.fluor.com/projects/qatargas-jetty-boil-off-gas-recovery

xvi. https://unfccc.int/files/methods/other_methodological_issues/application/pdf/gorgon_co2_injection_project_new.pdf

xvii. https://www.aa.com.tr/en/energy/projects/qatar-to-store-more-than-5m-tons-of-co2-a-year-by-2025/26924

xviii. https://www.naturalgasworld.com/pdfs/LNG%20Canada%202019_Web.pdf

xix. https://www2.gov.bc.ca/assets/gov/environment/climate-change/ind/lng/lng_emissions_benchmarking_-_march_2013.pdf

xx. https://www.carbonfootprint.com/docs/2018_8_electricity_factors_august_2018_-_online_sources.pdf

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THE ABDULLAH BIN HAMAD AL ATTIYAH FOUNDATION
DOHA - QATAR

Barzan Tower, 4th Floor, West Bay, PO Box 1916 - Doha, Qatar

Tel: +(974) 4042 8000, Fax: +(974) 4042 8099
www.abhafoundation.org

AlAttiyahFndn
The Al-Attiyah Foundation