Greening The LNG Industry

February - 2021

The Al-Attiyah Foundation

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INTRODUCTION

GREENING THE LNG INDUSTRY

As countries continue to ramp up their climate change ambitions, the role of natural gas will be enhanced, as burning natural gas produces less greenhouse gas emissions (GHG) than burning coal and crude oil. However, companies producing, processing and transporting gas need to ensure that methane leaks are kept to a minimum, in order for gas to be widely accepted as more climate friendly than coal. Why are GHG emissions a growing concern for LNG exporters and buyers? How does the carbon footprint of LNG production and transport differ between projects, and what are the underlying drivers? How does the carbon footprint of LNG compare to pipeline natural gas and to other fossil fuels? What can companies do to reduce the carbon footprint of brownfield and greenfield LNG? Can this become a competitive differentiator?

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

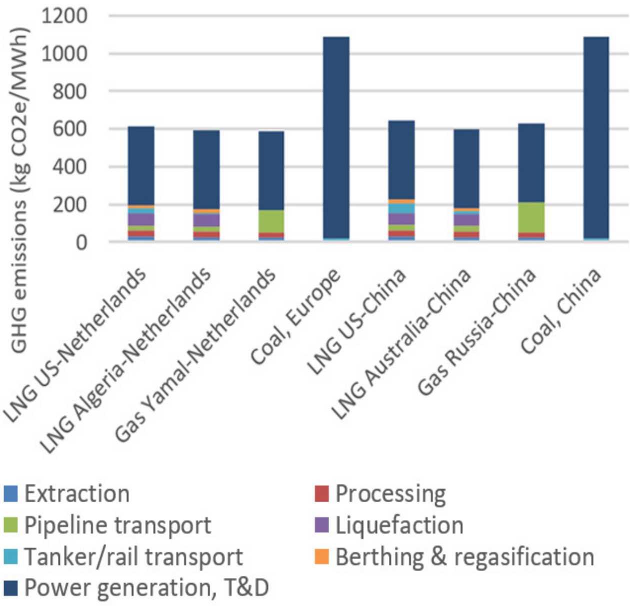
- Under most conditions, LNG offers substantial savings in GHG emissions versus coal and oil while being roughly comparable to long-distance gas pipeline supply.
- However, gas, especially LNG, has come under environmentalist pressure due to its GHG footprint, notably methane leakage, a potent greenhouse gas. This challenges LNG's expected role as an essential transition fuel.
- Planned EU emissions standards will exclude high-GHG footprint gas from the bloc and are likely to become a de facto standard for other jurisdictions and the LNG industry. This is a threat for high-GHG LNG exporters.
- GHG emissions come from throughout the LNG value chain, with liquefaction the single largest component. Emissions can be reduced through: portfolio choices about LNG developments; energy efficiency, design choices, and methane leakage reduction in the upstream, liquefaction, and transport sectors; carbon capture, use and storage (CCUS) in the upstream, processing, liquefaction, and end-use stages; using low-carbon electricity to power facilities; and improving LNG tanker efficiency, boil-off, and use of low-carbon fuels.
- Some leading LNG companies, including Qatar Petroleum, have made low GHG footprints a target and source of competitive advantage. Shell and Total, the two largest non-state LNG firms, have made carbon-neutral deliveries.
- Carbon offsets will become increasingly important for certified carbon-neutral LNG. The cost of offsets could raise LNG's delivered price between 10-100% when implemented on a large scale. Therefore, it will be essential for significant LNG exporters and traders to develop low-cost and verifiable offsetting arrangements.
- LNG will still face environmental/climate challenges, and LNG companies, therefore, need to be able to tell their story well, demonstrate their emissions reductions, and explore low-carbon synergies with their business, such as hydrogen.

LNG HAS TO ADDRESS ITS CARBON FOOTPRINT TO REMAIN A CLEAN FUEL

LNG has historically been regarded and promoted as a clean fuel. Its lower carbon content and minimal production of other pollutants such as sulphur oxides have made it an attractive replacement for coal and fuel oil. It provided a way to monetise gas and cut flaring in areas without a large local market. International oil companies, notably Shell, Total, and ExxonMobil, have invested heavily to build world-leading LNG liquefaction, transport, and trading portfolios, seeing it as a fuel with strong growth potential and less environmentally-exposed than oil.

However, LNG has now found itself caught up in a backlash against fossil fuels. As (Figure 1) shows, under reasonable assumptions, the GHG footprint of gas delivered by pipeline or as LNG is much lower than that of coal, at about 600 kg CO_2 equivalent (CO_2) per MWh of power generated, versus almost 1,100 kgCO_2/MWh for coal. This figure depends somewhat on the global warming horizon chosen since methane has a global warming potential (GWP) 84-87 times that of CO_2 over 20 years, but 28-36 times over 100 years (as CH_4 is gradually converted to CO_2 in the atmosphere). However, unless leakage rates are high, the choice of time horizon will not substantially change the conclusion that gas is far better for the climate than coal. It should also be noted that these figures apply to power generation, where gas has an additional advantage because of higher efficiency. For providing direct heat, the GHG benefits of gas over coal are much less.

FIGURE 1 GHG FOOTPRINT OF LNG, PIPELINE GAS, AND COAL[i]

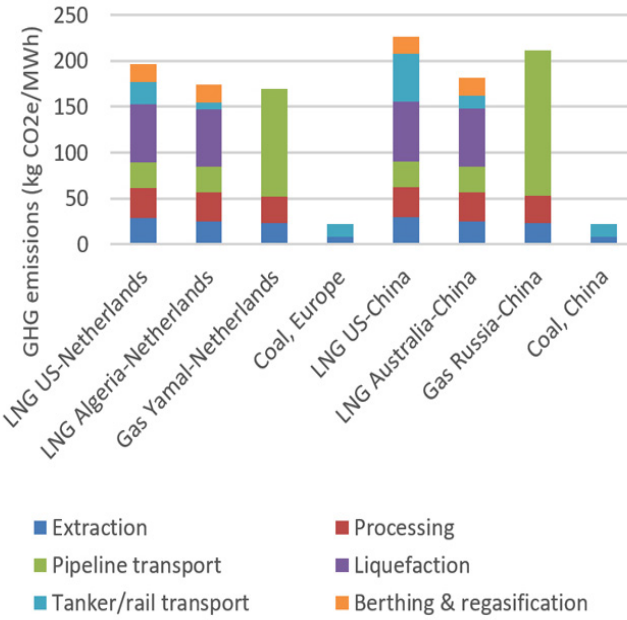


By removing the emissions during combustion, the supply-chain emissions can be seen more clearly (Figure 2).

The coal supply-chain emissions are relatively small. However, gas supply emissions are substantial, amounting to almost a third of the overall GHG footprint. Reductions here are therefore critical in maintaining the environmental credentials of gas.

It is also apparent that the supply-chain emissions of gas delivered as LNG or by pipeline are relatively similar but occur in different segments.

FIGURE 2 GHG FOOTPRINT OF LNG, PIPELINE GAS, AND COAL, EXCLUDING FINAL COMBUSTION[ii]



CARBON FOOTPRINTS

While gas has historically been seen as a relatively clean fuel this has changed significantly in recent years, particularly since 2019. Firstly, attention has grown on methane leakage, which substantially raises gas's global warming impact. Secondly, carbon-neutrality targets announced by the EU, UK, Japan, China and other leading economies have led to speculation on diminishing long-term role for gas in the future global energy system.

Major oil and gas companies, including Shell, Total, BP and others, have made commitments to be carbon neutral around 2050, in line with Paris Agreement goals and national targets. They also have intermediate targets for reducing emissions intensity (GHG per unit energy or unit product). These goals include not just 'Scope 1' (direct emissions) and 'Scope 2' (emissions from purchased electricity), but also 'Scope 3' emissions from the products when utilised or combusted by customers.

GHG and other environmental disclosure requirements are becoming increasingly strict, and investors, lenders and insurers are limiting their exposure to fossil fuels.

Some governments are imposing carbon taxes or performance standards, and this can be expected to expand. For instance, British Columbia, site of the under-construction LNG Canada plant, requires LNG plants to produce no more than 0.16 tonnes CO_2e/tonne LNG, lower than any operating LNG plant in the world, or buy credits. Above 0.23 tonnes CO_2/tonne LNG, further penalties apply[iii]. Canadian provinces are also required to phase in a carbon tax reaching CA$50/tonne (~US$39.4/tonne) by 2022, meaning an additional cost for LNG production of about $0.13/MMBtu.

LNG is particularly challenged because of the emissions in liquefaction, transportation, and regasification. The large and visible facilities required in the LNG chain can easily be monitored and opposed by environmental groups. Satellite monitoring of methane leaks are increasingly exposing major emitters[iv].

On a positive side, LNG has significant potential as a relatively cheap, low-carbon, and low-pollution, road and shipping fuel. The International Maritime Organisation has a target to reduce shipping's carbon intensity by 40% between 2008 and 2030 and cut absolute emissions by 50% by 2050. While LNG may not offer the entire solution, it could save about 15% of shippings' GHG emissions, which is significant. This contribution will only happen or enhance, if the LNG fuel itself has a low GHG footprint.

Most crucially, reducing GHG emissions from the LNG supply chain has become an issue of market access. In October 2020, French utility company, Engie, cancelled plans to buy 2.9 Mt/y of LNG from US firm NextDecade, reportedly because of the French government pressure over the high emissions of US gas production.

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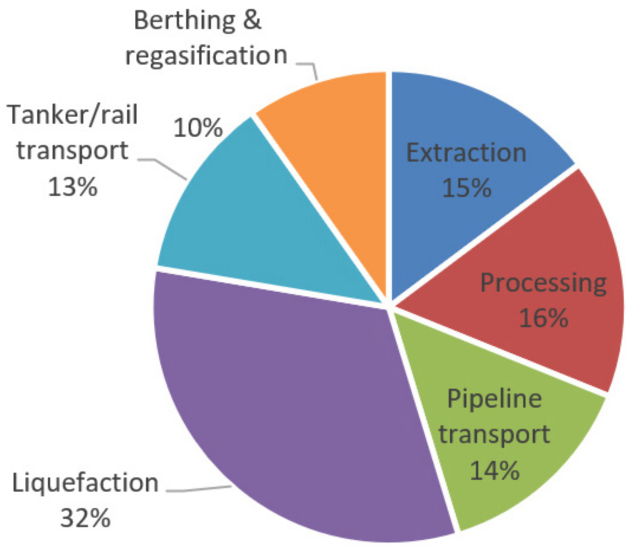
The Commission also plans to propose a carbon border adjustment tariff by June 2021, imposing a charge on carbon-intensive imports into the zone from countries that do not have comparably strict climate policies[vi]. The European Emissions Trading System (ETS) price has risen sharply since 2018, recently hitting a record price of €40.19/tonne (US$48.87/tonne). That would add $0.16/MMBtu to the price of imported LNG if translated into a carbon border adjustment tariff.

THE CARBON FOOTPRINT OF THE LNG INDUSTRY

The LNG value chain is complex, consisting of gas production and processing, liquefaction, shipping, storage, regasification, and final use. These segments are usually owned and operated by different companies, and LNG may be traded several times before reaching a final buyer.

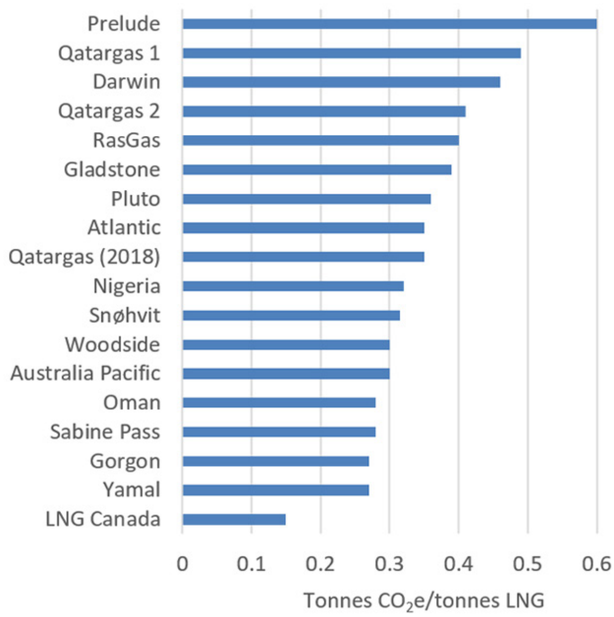
As (Figure 3) shows, emissions are significant all along the chain, though the largest single component is in liquefaction. These are figures for a US plant and may vary substantially between projects. These do not include emissions from the final use of the LNG. It can be seen that almost half of emissions stem from the upstream, about a third from liquefaction, and the remainder from transport and regasification.

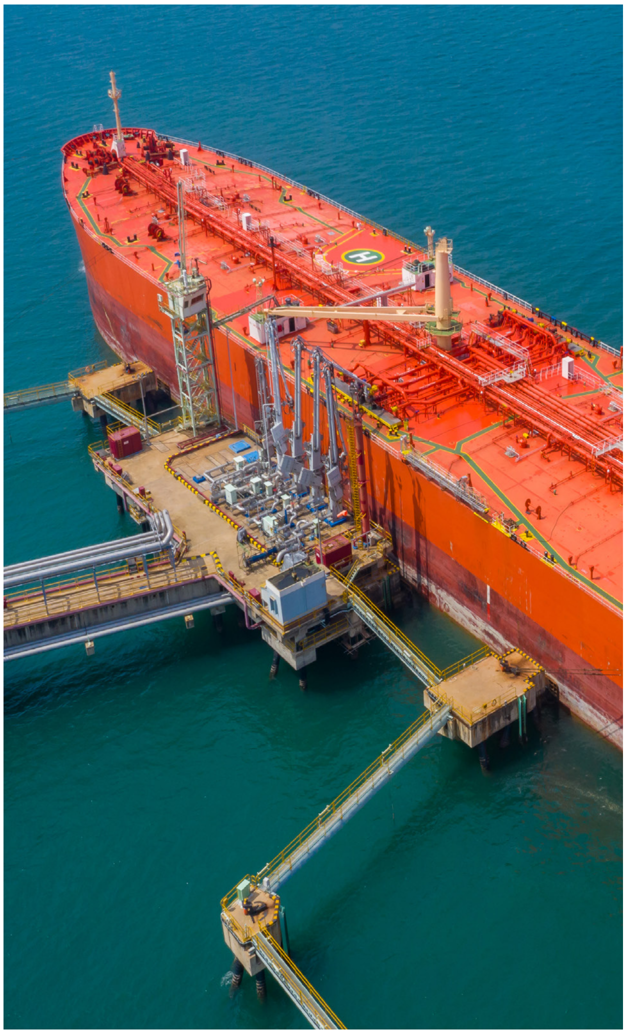
FIGURE 3 SPLIT OF LNG CHAIN EMISSIONS[vii]



Emissions vary substantially between plants (Figure 4), although the monitoring methodology is not necessarily consistent between all studies. It can be seen that the reported performance for Qatargas improved substantially from earlier sources to 2018, probably related to the implementation of the Jetty Boil-off Gas project, reductions in flaring, and other improvements.

FIGURE 4 GHG EMISSIONS FOR SELECTED LNG PLANTS[viii]





CARBON FOOTPRINT CAN BE REDUCED SUBSTANTIALLY

LNG developers have a wide range of options for reducing their GHG footprint, especially in greenfield projects. Brownfields or current operating projects have fewer degrees of freedom, and retrofits may be more complex and costly.

At the highest level, international companies have portfolio choices about which LNG projects they invest in, acquire, or purchase. They can focus on resources that appear likely to be low carbon, such as, sites close to infrastructure, with high-quality reservoirs and low CO_2 content in the gas. National oil companies developing domestic resources are more constrained, though they still may have choices between fields or reservoirs.

Efficiency is the next key area, including reducing flaring and methane leakage; and improving energy efficiency. Methane leakage comes from various parts of the value chain (Figure 5).

Production emissions, the largest single source, can be cut by methods such as 'green completions' (recommended by the International Energy Agency), capturing gas during well completion, and flowback.

Minimising process upsets, replacing pneumatic valves, using dry seal systems, plunger lift systems, desiccant dehydrators, compressor maintenance, and vapour recovery units are all options to cut leaks in appropriate situations[ix]. Drone and satellite monitoring is increasingly used to detect the small minority of 'super emitters that make up most emissions and, therefore, quickly correct leaks.

Routine flaring is another major source of emissions from plants drawing from associated gas, notably in the US, Algeria, and Nigeria. Flaring also releases substantial amounts of methane by incomplete combustion. The Environmental Defence Fund has argued that 40% of Permian Basin flaring could be cut by 2025 at no cost to operators[xi].

Upstream emissions can be cut further by running processing plants on electricity rather than gas (a 90% cut in direct emissions), which could be supplemented with low-carbon power. Fuelling operations and drilling rigs with gas rather than diesel offer a 28% saving on emissions. High-pressure ratio centrifugal compressors[xii] are up to 50% smaller and are more reliable.

FIGURE 5 SOURCES OF METHANE LEAKAGE FROM THE OIL & GAS INDUSTRY[x]

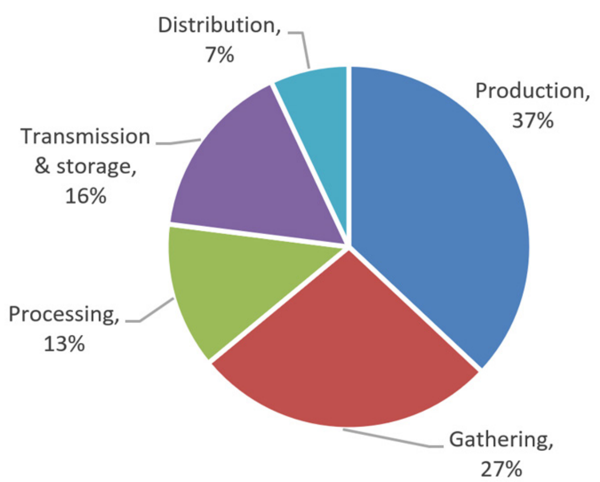
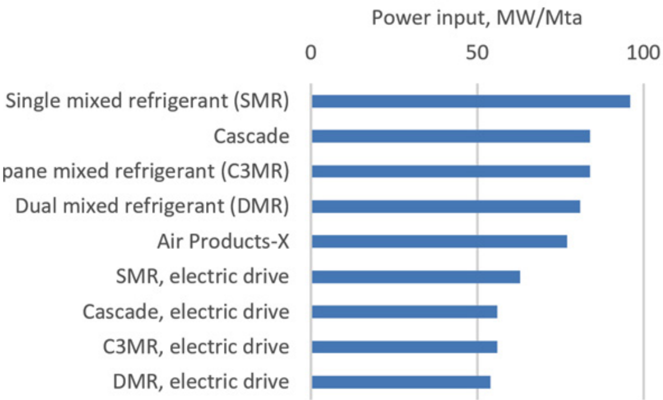


FIGURE 6 POWER CONSUMPTION OF DIFFERENT LNG PROCESSES[xiv]



LNG plant efficiency depends significantly on location and design choices (Figure 6). The Single Mixed Refrigerant process, typically used in smaller or older plants, is estimated to be about 6% less energy-efficient than Air Product's C3/MR[xiii]. Compressor efficiency has improved from 60-75% in the 1970s to more than 80% today; gas turbine efficiency has gained from 28% to 40%. Process improvements over this period may improve efficiency by about 10%. Combining these effects means that plants such as Marsa El Brega in Libya (1970), Skikda in Algeria (1972, rebuilt in 2013), Brunei (1973), ADNOC (1973), and Bontang in Indonesia (1977) are at a significant disadvantage to newer facilities, unless they are retrofitted.

Plants in colder climates, such as Norway's Snøhvit and Russia's Sakhalin, Yamal, and (planned) Arctic II LNG facilities, are inherently more efficient, with those in hot climates requiring about 25% higher energy for liquefaction[xv]. Boil-off gas during loading can be captured and reliquefied, as in Qatar's $1 billion Jetty Boil-off Gas Recovery to capture about 0.75 Mt/y of LNG[xvi].

CARBON FOOTPRINT CAN BE REDUCED SUBSTANTIALLY

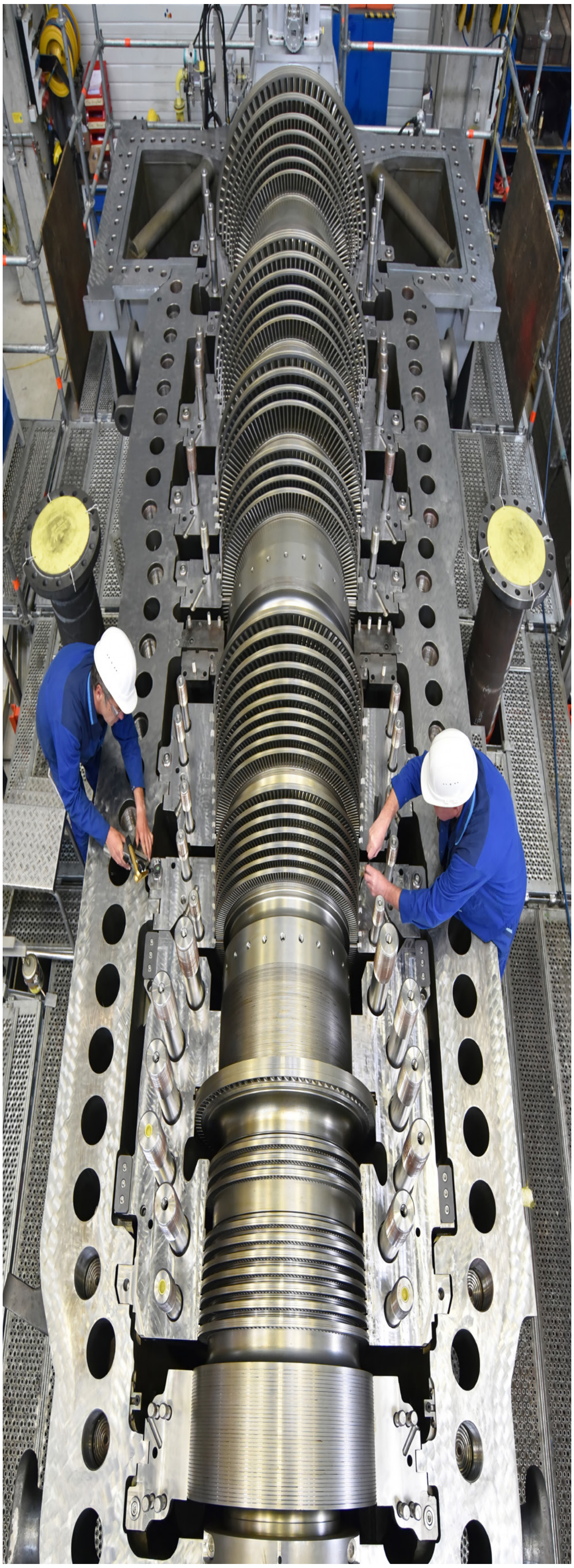
Other liquefaction improvements include higher-pressure feed gas (0.7% efficiency gain per bar), better ambient cooling (1% efficiency gain per degree Celsius), reduced heat input for acid gas removal, lower pressure drops, gas turbine air inlet chilling, nitrogen purges for flares, improved layout to reduce thermal losses, use of liquid expanders, and advanced digitised process control[xvii]. Future optimisation could include waste heat-driven absorption chillers for air inlet and process cooling.

Floating LNG (FLNG) is becoming increasingly popular for accessing remote or smaller offshore fields or where no suitable onshore site is available. However, the more constrained space and safety requirements for an FLNG plant may limit energy efficiency options.

Carbon capture, use, and storage (CCUS) is generally applied to CO_2 stripped from gas production, a necessary step to prevent freezing during the liquefaction process. No large-scale LNG plant worldwide uses CCUS on its process emissions (from gas combustion in the plant itself for power generation and other uses).

In future, CCUS may be more widely adopted to capture most of a plant's process emissions and reduce its carbon footprint close to zero. Since LNG plants are generally in petroleum-producing regions, there should be adequate nearby geological storage options. Nevertheless, carbon capture on power generation is a relatively costly process that will raise the plant's overall costs and energy consumption.

Low-carbon electricity can be used to run plant facilities. Purchasing specifically low-carbon electricity will further cut



emissions. LNG Canada, led by Shell, intends to buy hydroelectricity as part of the plant's demand[xviii]. Qatar's LNG expansion will partly use power from the under-construction 800 megawatt (MW) Al Kharsaah solar farm[xix] and a future 800 MW farm.

In future, FLNG plants could make use of offshore wind power, which is becoming increasingly cost-competitive.

Transport emissions can be cut by better scheduling and logistics. Plants closer to their primary market will also have an advantage. There are numerous options for improving shipping fuel efficiency via better design, streamlining, auxiliary sails, and other methods (see The Al-Attiyah Foundation report 'Plain Sailing And Soaring Smoothly: Emissions Reduction Strategies In Shipping And Aviation', October 2020[xx]).

LNG tankers have tended to move from diesel to LNG power, which cuts GHG emissions by about 15% in comparison to marine gasoil (diesel), as long as methane slip from the engine is limited[xxi]. It is foreseeable to see LNG tankers moving towards renewable methanol, biofuels, hydrogen-derived fuels or another low-carbon drive, in future.

Boil-off rates can be reduced by better insulation from the historic 0.3%/day to 0.125-0.13% per day[xxii]. On-board reliquefication is now commonly employed to cut loss of cargo and associated emissions.

Regasification can be made more efficient by using a source of waste heat (for example, the exhaust of a power plant) near the terminal. The 'waste cold' of regasification can also be used in a refrigeration facility, a district cooling plant, or to boost the efficiency of a power plant via inlet air cooling.

GHG emissions related to pipelines can be reduced, and possibly more quickly than that of LNG. Since most of the emissions for pipeline gas occur upstream (leakage and flaring) and in pipeline transport (leakage and compressor power), a reduction can occur by eliminating fugitive emissions and powering compressors with low-carbon electricity. This could be relevant for carbon-conscious jurisdictions where LNG and pipeline gas compete, notably Europe.

LOW CARBON FOOTPRINT CAN BE A COMPETITIVE DIFFERENTIATOR

Major and prospective LNG producers, including Qatar Petroleum, Shell, Total, and NextDecade, increasingly see a low GHG footprint as a competitive advantage.

Carbon-neutral LNG deliveries are a small but growing trend. In June 2019, Japanese consortium JERA delivered a cargo of LNG to India from ADNOC in Abu Dhabi, in which UN-certified emission reduction credits from Indian renewable projects were coupled with offsetting the emissions from its downstream use (Scope 3)[xxiii] . Also in the same month, Shell agreed to deliver a cargo each to GS Energy (South Korea) and Tokyo Gas, whose Scope 1, 2, and 3 emissions were fully offset with 'nature-based carbon credits'[xxiv]. In March 2020 and November 2020, Shell delivered similar offset cargoes to CPC (Taiwan). In February 2021, Total made its first fully-offset LNG delivery to CNOOC of China[xxv], with offset credits from a Chinese wind power project and a forestry project in Zimbabwe.

NextDecade, developing the Rio Grande LNG plant in Texas, plans to use CCUS to reduce its carbon footprint by 90% and to explore other options to cut the remaining 10%[xxvi].

> "Lower CO_2 emissions and carbon capture and sequestration are part of the basic design of our new LNG facilities being built as part of the North Field Expansion projects...Qatar Petroleum is implementing a series of projects and initiatives to reduce gas emissions...placing us firmly on the road to becoming a leader in the de-carbonization of the LNG value chain."
> Saad Al Kaabi, CEO, Qatar Petroleum and Energy Minister of Qatar.

Qatar's LNG expansion and CCUS plans have been very clearly predicated on being a low-carbon and low-cost producer (see quote in the box).

In November 2020, Qatar Petroleum signed with Singapore's Pavilion Energy to supply 1.8 Mt/year of LNG over ten years from 2023. The exciting feature of this deal was a commitment to jointly develop a methodology for determining the GHG footprint of this LNG from well to delivery port[xxvii].

The establishment of a standardised methodology is key in allowing LNG sellers to compete based on being credibly low-carbon and to meet standards for imports that may be set by bodies such as the EU.

The likely EU standard will affect the leading gas exporters to the bloc: Russia (17% of LNG imports and 45% of total European gas imports, including to Turkey and the UK), Qatar (27% of LNG and 7% of total gas), the US (15% of LNG and 4% of total gas), Algeria (13% of LNG and 8% of total gas), Nigeria (13% of LNG and 3% of total gas), and Norway (5% of LNG and 25% of total gas). Of these, Norway is already likely to meet any standard imposed. Algeria, Nigeria, the US, and Russia, which have high methane leakage and/or flaring levels, are more exposed.

Other customers, such as Japan, South Korea, and Singapore, would also likely adopt a common standard. LNG exporters who are not able to meet this standard could find themselves severely constrained in accessible markets.

These identified 'early adopters' of LNG import standards account for almost 60% of 2019 purchases. The situation may become similar to that for high-sulphur fuel oil or diesel, which cannot be sold in many global markets.

It would then be essential to see how far and fast standards or carbon pricing for other leading LNG importers is established, notably China, India, Taiwan, Pakistan, Thailand, and other emerging Asian and Latin American importers.

CARBON CREDITS WILL BE INCREASINGLY IMPORTANT FOR LNG

The need to offset emissions from final combustion of LNG, and unavoidable emissions along the value chain, means that substantial amounts of credits will be required. The LNG business will be competing with oil companies, airlines, and other emitters, with net-zero ambitious targets.

Current LNG consumption of 357 Mtpa is set to grow to about 735 Mtpa in 2040[xxviii]. This would require about 2.5 $GtCO_2e$ of offsets to become carbon neutral, minus any reductions in emissions from the supply chain or CCUS in end-use. Voluntary carbon offsets in 2019 amounted to 104 $MtCO_2e$ worldwide[xxix], meaning the offsets market will have to scale up enormously if it is to be able to serve the demand from the LNG industry, and other more extensive requirements from oil, aviation, and emitters.

On the basis of current and projected prices of offset credits, the implication is that full offsetting of the LNG industry's emissions may cost from $25-250 billion annually around 2040.

IMPLICATIONS FOR MAJOR OIL AND GAS PRODUCERS

- The LNG industry will face ever-tightening scrutiny from investors, regulators, environmentalists, and customers on its GHG emissions, backed up by tighter disclosure requirements and the availability of remote sensing data.
- Older and high-carbon LNG plants will particularly face increasing competitiveness challenges. Financing may not be available, market access may be restricted, and sales will face a price penalty or have to pay for carbon taxes or offsets.
- Conversely, a low GHG footprint will place low-carbon plants, especially new ones, at very competitive advantage. This will require a comprehensive and integrated approach to lowering emissions along the entire supply chain.
- Reducing LNG's GHG footprint will be increasingly important to retaining social and environmental licence to operate. While this applies now more to Scope 1 and 2 emissions, tackling the Scope 3 emissions (whether through CCUS, offsets, or other methods) will become increasingly important as the push for de-carbonisation widens.

IMPLICATIONS FOR MAJOR OIL AND GAS PRODUCERS

- The LNG industry should engage the EU, financial market authorities, and other key national regulators and policymakers on establishing robust, transparent, and straightforward methodologies for determining, assigning, and reporting the Scope 1, 2 and 3 emissions from LNG to make compliance feasible.
- The offset market scope will have to scale up enormously to meet demand from the LNG industry through nature-based solutions, DAC or other carbon dioxide removal. This, in turn, suggests that major LNG producers should develop their own verified carbon offsetting programmes or partner with leading offset players.
- Nevertheless, LNG will continue to face major environmental challenges as a fossil fuel that is considered to be inferior to renewables. Some climate change activists would always view the measures employed as ‘quick fix’ initiatives that result in carbon dioxide emissions reductions which are not ‘real’ or permanent.
- LNG producers will have to continue extending and deepening zero-carbon value chains, including broadening their offering into products such as hydrogen.

CONCLUSIONS

In general, LNG and natural gas will continue to have an essential part to play in future energy mix, being affordable, with low pollution and relatively low GHG emissions. However, whether it is a transition fuel with declining prospects towards 2050 or a destination fuel with a long-term role in the energy system depends on how much its emissions can be reduced.

In the near term, reducing emissions across the LNG supply chain will be essential to meeting import standards from the EU and other important markets. Low-carbon producers will enjoy a competitive advantage, while others unable to meet these standards will find themselves increasingly excluded and/or suffering price penalties. Greenfield projects have a relatively wide suite of options for cutting their GHG footprint; brownfield plants are more constrained but may still have the potential for upgrades and retrofits. Verifiability and transparent reporting will be key to access markets and financing.

In the longer term, given the targets for carbon neutrality around 2050-60 by major oil companies and national economies, LNG will also have to move towards being a near-zero carbon fuel. The existing and emerging technologies for achieving this need to be further developed and operated at scale.

APPENDIX

i. 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.
ii. 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.
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