LNG in Scotland

Research study

Scottish Enterprise

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Conversions

Density of LNG	450 Kg/m^3
Conversion of cuf to m^3	35.3145
Ratio of LNG to natural gas by volume	1:600

Units

cuf	cubic feet
h	hour
MW	Mega Watt
MWh	Mega Watt Hour
MMcuf	Million cubic feet
m	Meters
m^3	Cubic meters
kg	Kilograms
KW	Kilo Watt
KWh	Kilo Watt Hour
t	Tonnes
bar	barometric pressure

Acronyms

AHJ	Authority Having Jurisdiction
ALARP	As Low As Reasonably Practical
CCGT	Combined Cycle Gas Turbine
CD	Chart Datum
CHP	Combined Heat and Power
CMAL	Caledonian Maritime Assets Limited’s
CO2	Carbon Dioxide
ECA	Emissions Control Area
EIA	Enviromental Impact Assessment
EU	European Union
FID	Final Investment Decision
FSRU	Floating Storage Re-Gasification Unit
FSRB	Floating Storage Re-Gasification Barge
GVH	Gas Vehicle Hub
HAT	Highest Astronomical Tide
IGU	International Gas Union
LAT	Lowest Astronomical Tide
LNG	Liquefied Natural Gas
MARPOL	International Convention for the Prevention of Pollution from Ships
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
MV	Motor Vessel
NGVA	Natural & bio Gas Vehicle Association (Europe)
NOx	Nitrogen Oxide
NTS	National Transmission System (Gas)
OD	Ordnance Datum
PARC	Port and Resource Centre
Qflex	Qatar flexible
Qmax	Qatar Maximum
QRA	Qualitive Risk Assessment
ROM	Rough Order of Magnitude
Sox	Sulphur Oxide
STS	Ship To Ship
SWOT	Strength Weakness Opportunities and Threats
TTS	Truck To Ship

“The supply of safe, reliable energy underpins the continued growth of the Scottish economy and delivery of key services”

Draft Scottish Energy Strategy: The future of energy in Scotland (2017)

Contains private information

Executive summary

This report provides an assessment of the market demand for Liquified Natural Gas (LNG) for 2025 and 2040 in Scotland, exploring the potential economic development impacts and infrastructure issues.

LNG is liquified natural methane gas that can be quickly and easily turned back into gaseous state and delivered to the UK's homes, businesses and industry via pipelines or road transport. The European, UK and Scottish policy environment is broadly supportive of investment in LNG infrastructure in Scotland.

Natural gas is a fossil fuel, though the emissions from its combustion are much lower than those from coal or oil. Therefore, LNG has the potential to reduce emissions, in comparison with other commonly used fossil fuels. However, further understanding of the lifecycle emissions is needed.

There has been an increase in the take-up of LNG in the UK. New proposed investments in Scotland and the North of England are seeking to meet growing demand. Utilising more LNG appears to provide an opportunity to contribute to emissions reductions, develop low carbon technologies, linking energy efficiency, security and economic growth.

Demand in Scotland is expected to be driven from different sources, primarily marine transport, road transport, power generation, industrial use and residential demand.

The approach taken to assessing demand has been to assume that LNG can be used as an alternative fuel. The demand for LNG as fuel for transportation is expected to increase rapidly, but from a very low base:

- The introduction of emissions restrictions within the European maritime Emissions Control Area has prompted a move to LNG powered ships, as demonstrated by CMAL ordering two LNG powered ferries, that are currently under construction at Ferguson Shipyard on the Firth of Clyde. The adoption of LNG powered vessels will, in part, be dependent on the availability of the bunkering infrastructure.
- While the use of LNG in road transport has been promoted by the EU LNG Blue Corridor projects for over 4 years, there remain only 22 LNG fuelling station in the UK, only one of which is in Lockerbie, Scotland. However, road transport with its relative short payback period does have the potential to see a rapid conversion to LNG.

The Scottish Government's draft 'Energy Strategy' has the aim of moving to a low carbon economy, and by 2030 having over 50% of Scotland's heat, transport and electrical needs supplied from renewable sources. In addition, the Scottish Government has does not support new nuclear power stations under current technologies. Therefore, the decommissioning of Hunterston (2023) and Torness (2031) nuclear power stations could leave a significant gap in UK and Scotland's power generation capability and grid system, which could potentially be filled by a LNG gas powered power station.

Into this demand mix should also be added the potential of large industrial users of energy / gas to be supplied with LNG, such as energy intensive industries (e.g. Steel making, ceramics, paper, cement and lime manufacture, aluminium, etc) or businesses in remote areas (e.g. whisky distilleries).

The study outlines potential investments which could be made highlighting the likely scale of investment in LNG infrastructure. This includes transportation and regasification options such as onshore storage, floating storage and Gravifloat (or other similar technologies) which could meet the demand estimated for Scotland.

Investment in LNG could support economic development ambitions, safeguarding and creating jobs in the energy sector. The benefits from investment in LNG could see up to 350 temporary construction jobs and up to 150 operational jobs created and deliver up to £38 million GVA activity to Scotland's economy. This growth and jobs would be in place of growth and jobs in other energy sectors. There is also the potential to maximise the opportunities from LNG investment and align investments with reskilling and retaining skilled workers. LNG has a potential role in reducing carbon emissions (in comparison with other fossil fuels) which is positive.

There is a possible link between homes using natural gas and the incidence of fuel poverty. Small scale LNG could potentially supply homes with gas and play a role in reducing costs. However, this requires further assessment since there are some barriers to uptake (e.g. domestic conversion costs) and uncertainties about LNG unit cost beyond the mid-2020s.

There remain challenges at a global and Scotland level for increased LNG uptake including market, environmental and investment issues. At a strategic level, policy positions or policy led tools (e.g. public procurement) to support the uptake of different energy types or to encourage investments in certain infrastructure (e.g. ferries) could drive growth.

It is concluded from this research that there is an opportunity for further LNG and the development of LNG infrastructure in Scotland which should be explored further.

1. Introduction

Scottish Enterprise commissioned Atkins to undertake a brief market study into the opportunities for Liquefied Natural Gas (LNG) within Scotland and assess the infrastructure needs for a possible importation terminal.

The purpose of this study is to establish the market demand for LNG over the next 20 years, setting out the opportunities for maximising the economic impact arising from LNG investments in Scotland. The research builds upon activities outlined in the draft Energy Strategy being undertaken across Scottish Government and its agencies. The report presents critical insight and analysis of the LNG sector and the potential for future demand to drive LNG investments in Scotland.

Liquefied Natural Gas (LNG)

LNG is liquified natural methane gas which is chilled to -161ºC so that it becomes a cryogenic liquid. This liquefaction process means that LNG occupies about 1/600 the volume of methane in its gaseous form. This volume reduction means that LNG can be stored (often in tanks with efficient insulation) and transported over long distances. LNG is a fossil fuel but burns more cleanly and efficiently than other fossil fuels ie with lower carbon emissions than say coal.

LNG can be quickly and easily turned back into natural gas and delivered to the UK's homes, businesses and industry via pipelines or road transport.

1.1. Methodology

The methodology for this research is consistent with technical and economic studies of infrastructure investments. It utilises both empirical and secondary data sources. The research collected secondary information and undertook consultation with stakeholders from the following key groups:

- Investors and port operators;
- Scottish Government and Government stakeholders including Scottish Enterprise and Transport Scotland.
- Energy businesses in Scotland; and,
- Specialists in the energy and marine consultancy.

Informal face to face and telephone interviews were conducted with 15 stakeholders which enabled a high-level understanding of the potential for LNG in Scotland and the opportunities which it could deliver. A review of available industry, academic literature and reporting from Atkins' previous work on LNG projects was obtained. Data was also collected from a range of secondary sources including Scottish Enterprise, Peel Ports and BEIS.

1.2. Document structure

This document has been structured to present the findings of the study as outlined below:

- **Section 2:** Brief discussion of the environmental impacts and considerations of using LNG.
- **Section 3:** Identification of the study context including broad policy and technical context.
- **Section 4:** Assessment of the demand for LNG in Scotland.
- **Section 5:** Review of transportation and regasification potential investments.
- **Section 6:** An assessment of the economic development potential for Scotland arising out of LNG investment.
- **Section 7:** Summary of the study conclusions.
- **Section 8:** Suggested actions and next steps for Scottish Enterprise and stakeholders.

1.3. Study limitations

It should be noted that there is significant uncertainty in forecasting the expected demand for LNG due to the very low current usage, particularly in the transportation sector where LNG remains in the developmental stage. In addition, significant uncertainties such as; Government policies, infrastructure investment, operational performance and LNG pricing will all need to be better understood in order to increase forecasting reliability. This study therefore presents possible scenarios and should not be used as the sole basis for investment decisions.

2. Environmental impact from LNG

This study is focused upon the infrastructure and economic opportunities from LNG. Alongside these factors the environmental impact of LNG is important but complex and not the focus of the study. Further work is needed to identify and define the optimal contribution from LNG to supporting environmental and energy policy in Scotland. This section, briefly reviews the key environmental issues which this report touches upon throughout.

2.1. Emissions from LNG

A comparison of LNG against other fossil fuels, shows that it has noticeably lower emissions when burnt. Table 2-1 shows that LNG has one of the lowest greenhouse gas emissions when compared with other fossil fuels. However, solar and wind energy have emissions that are significantly lower than all fossil fuels. Despite this comparatively positive assessment of emissions, to get an overall perspective of the environmental benefits of LNG, a whole life cycle assessment is needed to consider the supply chains, extraction, liquification and regasification for the fuel.

Table 2-1 Total GHG (CO2, CH4 and N2O) per kWh

Fuel	CO_2	CH_4	N_2O
Burning Oil	0.24564	0.00052	0.00067
CNG	0.18485	0.00027	0.00011
Coal (electricity generation)	0.31907	0.00006	0.00277
Diesel	0.25011	0.00014	0.00277
Fuel Oil	0.26475	0.00021	0.00096
LNG	0.18485	0.00027	0.00011
LPG	0.21419	0.00009	0.00017
Natural Gas	0.18485	0.00027	0.00011
Other Petroleum Gas	0.20568	0.00024	0.00467
Petrol	0.23965	0.00048	0.00163

Source: Defra 2017: UK Government GHG Conversion Factors for Company Reporting

In comparison with solar, wind and tidal energy, LNG produces much higher greenhouse gas emissions. Furthermore, across all energy sources there is an emissions impact across the whole value chain. For example, nuclear energy's carbon impact is complex due to the extraction of uranium and constriction of power stations. In the case of LNG, natural gas can be extracted from many sources including shale rock formations using a process known as fracking.

This highlights how emissions are not 'geographically bound' and the whole life cycle of energy production processes should be considered. As such, the LNG emission footprint will need to consider extraction, liquefaction, transport and regasification processes and their energy sources and emissions footprint[1]. Further complications include the quality of the natural gas and the efficiency of turbines and compressors. Extraction, liquefaction and regasification in particular can be energy intensive processes, whilst transport by road or ship has an emissions profile. The evidence about the total lifecycle emissions impact from LNG is mixed, depending on type of extraction and technologies used[2].

A 'bridging' fuel?

LNG is cleaner than many other fossil fuels in terms of carbon emissions and toxic pollutants. The low emissions profile has seen LNG described as a 'bridging' fuel. Providing a bridge between current mixed

[1] API's LNG Operation methodology for estimating greenhouse emissions (2015) highlights the different elements but ultimately concludes that additional research is needed to improve the understanding of emissions from the LNG value chain.
[2] See for example Jaramillo, Griffin, and Matthews study on the comparative life cycle carbon emissions of LNG versus coal and gas (2005)

energy uses and a renewables dominant future. Different estimates exist for how long this 'bridging' period could be (e.g. over the next decade or 2050 and beyond)[3].

The transition to a fully renewables future is viewed as being challenging due to a gap in energy production which cannot be met by renewables. A fully renewable future is the ambition, but the transition period will see renewables being complemented by cleaner burning fossil fuels. The label of 'bridging fuel' suggests that LNG (and natural gas) is capable of both cutting greenhouse gas emissions and giving way to an emissions-free future. The emissions profile, as explored above is complex. Furthermore, to contribute to the transition, natural gas must replace other fossil fuels but also be phased out in the transition to a renewables-only future. This raises questions around the suitability of investing in LNG if the ambition is to replace it in the future. The timescales also have an implication on LNG infrastructure, although increasingly small-scale LNG is being developed to provide a flexible and demand driven response.

Carbon Capture & Storage

Further opportunities for emissions reductions could be driven by technological change. There is a further opportunity to decarbonise LNG production with the inclusion of CCS / CCUS (Carbon Capture Use and storage)[4] technologies across the value chain. The Global CCS institute[5] highlights how it is possible for CCS to be integrated with LNG but the potential for this varies by project. There are also cost and technological challenges for capturing CO^2 at different stages of the LNG regasification and power generation chain. The key issue in making CCS viable is finding acceptable uses for the recovered $CO^{2.}$ One possible use is EOR (Enhanced Oil Recovery) where by CO^2 is pumped into depleted oil reservoirs.

Bio-LNG

Bio-LNG is LNG extracted from anaerobic digestion (animal waste, landfill gas, wastewater bio-gas and digester gas) and could be another way to drive emissions reductions. Adoption of Bio-LNG is occurring in some countries and technologies are emerging to explore its viability and infrastructure requirements. Utilisation of bio-LNG could reduce life cycle emission impacts further and local production could reduce transportation costs and provide further economic advantages.

There are some chemical differences between bio-LNG and LNG but there is no difference in their use/handling and they can also be mixed. Norway and the Netherlands are exploring how bio-LNG can be used in shipping. As such bio-LNG provides an interesting area to explore further. The scale of the bio-LNG industry is small and although Scotland is investing in the bio-economy and biotechnology pilots, the existing infrastructure for LNG is not set up for large scale adoption.

Low carbon and new technologies

Further adoption of LNG in Scotland should be viewed in the context of a growth of low carbon and renewable heat technologies. Renewables support sizable emissions reductions and offer economic opportunities to reduce costs (for industry and householders), develop products, create services and develop economic activity and maximise resources. The development of renewables has helped to diversify Scotland's sources of electricity and heat, and to build up security of supply for the future.

Hydrogen has been identified as a potential renewable energy source which could drive future energy generation and also play a role in transportation. Hydrogen has the potential to eliminate or significantly reduce emissions which has led to several trials and exploration of its potential adoption in industry and transport. Examples include pilots and work undertaken by Peel and Cadent in North West England.

The viability of LNG projects has been observed to be impacted by investments in renewables[6]. There have been industry commentators[7] who have identified that the strength of renewables is leading to smaller LNG

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[3] See for example: McGlade, C., Bradshaw, M., Anandarajah, G., Watson, J. and Ekins, P. (2014) A Bridge to a Low-Carbon Future? Modelling the Long-Term Global Potential of Natural Gas - Research Report (UKERC: London).
[4] Carbon Capture Utilisation and Storage (CCUS) – sees CO2 captured from a gas fuelled power station using gas chilled to a cryogenic liquid about -60C (for CO2) and then transported (ship or pipeline) and injected into depleted oil reservoirs allowing Enhanced Oil Recovery (EOR). The individual elements of the technology is not new but making it work would be innovative
[5] Global CCS Institution: Opportunities for Integration of LNG with CCS – 2017, available at: https://hub.globalccsinstitute.com/publications/ccs-learning-lng-sector-report-global-ccs-institute/8-opportunities-integration-lng-ccs
[6] Brattle (2016) LNG and Renewable Power Risk and Opportunity in a Changing world
[7] For example; Deloitte (2015) LNG at the crossroads, identifying key drivers and questions for an industry in flux and LNG and Brattle Group (2016) Renewable Power Risk and Opportunity in a Changing World.

investments. The low cost of renewables increases the risk on sizeable LNG projects. This is certainly true of LNG supply projects but it is also a consideration further down the LNG value chain. Overall the industries operate harmoniously and there exist exciting areas of overlap (e.g. bio-LNG) which could offer further low carbon efficiencies.

2.2. Summary

LNG has environmental advantages and disadvantages which are complex to model and define. This report is not seeking to assess these in detail and therefore focuses upon natural gas as a relatively less carbon emitting fuel. The report assesses the infrastructure capability and economic impact potential in Scotland from investing in LNG.

In the context of this report, further work would be needed to understand the emissions profile of increased supply of LNG in Scotland, specifically those activities which could be undertaken within a Scottish footprint (e.g. transportation, regasification and burning).

3. Study Context

This section reviews the context for the study, identifying the policies, economic and industry context through an assessment of key policy, industry and market reports.

3.1. Policy

Rather than review all polices that could influence the future of LNG in Scotland, the sections below review key elements of policy and strategy which are considered important to the scale and type of LNG developments. The policy environment is dynamic and it is expected that further announcements could link to opportunities for LNG[8].

3.1.1. Scotland's Economic Strategy (2015)

Scotland's Economic Strategy[9] sets out a framework to create a: *"more successful country, with opportunities for all of Scotland to flourish, through increasing sustainable economic growth".* To achieve this objective, the strategy outlines a focus upon two main pillars; increasing competitiveness and tackling inequality. Investments in LNG infrastructure could support this overarching goal through reducing energy costs, improving energy security and contributing to global energy production. This could make Scotland even more competitive within the global energy market, creating economic activity and employment. To meet all goals around the economic strategy the investments should seek to support inclusive, sustainable growth and tackle inequality. This is explored in more detail in section 6 below.

Low Carbon Economic Strategy (2010)

The Low Carbon Economic Strategy (LCES)[10] which is an integral part of the Economic Strategy, highlights the need for the transition of Scotland's industries to low carbon processes, products and services. This is identified as an economic and environmental imperative and highlights the opportunities around rapidly expanding global markets in energy and technology led industries. The document provides a steer around low carbon vehicles which is "technology neutral‟ (not favouring any current technology) but identifies an opportunity for the Government to develop the market for low carbon vehicles and particularly electric vehicles (EVs). Overall the strategy appears to support investments in LNG, specifically where it makes the energy sector more diverse, reduces carbon emissions and is innovative. There is also potential for further support for LNG as the strategy highlights the opportunities in innovation across the energy sector and for skills transfers from oil and gas sectors.

3.1.2. Scotland's Draft Energy Strategy (2017)

Scotland's Draft Energy Strategy[11] is seeking a balanced energy supply mix which utilises low carbon sources and therefore tackles climate change. The Scottish Government identified the need to further decarbonise the whole energy system, with the ambition that half of Scotland's heat, transport and electricity energy needs will be met by renewables by 2030:

"an all-energy target for the equivalent of 50% of Scotland's heat, transport and electricity consumption to be supplied from renewable sources".

The Scottish Governments renewable electricity target is to generate the equivalent of 100% of Scotland's own electricity demand from renewable resources by 2020, a target which will require significantly more installed renewable capacity. This does not mean that Scotland will be 100% dependent on renewables generation, but rather that renewables will form the key part of a wider, balanced electricity mix.

An increasing amount of electricity generation in Scotland is coming from renewables (mainly onshore wind and hydro), with further contributions from nuclear and gas power stations. Scotland is supporting renewable energy projects and assessing how new energy sources can support the energy mix. Specifically, the Scottish Government is keen to support "new and innovative ways of using hydrocarbons[12]". LNG technologies are rapidly developing and in the context of other fossil fuels can be considered low carbon and innovative. LNG

[8] For example, proposals to create a public non-profit energy company in Scotland.
[9] Scotland's Economic Strategy (2015), available at: http://www.gov.scot/Topics/Economy/EconomicStrategy
[10] A Low Carbon Economic Strategy for Scotland (2010), available at: www.gov.scot/resource/doc/331364/0107855.pdf
[11] Draft Energy Strategy 2017 – para 95
[12] Draft Energy Strategy 2017 – para 75

is not new to Scotland or the UK but is emergent and technologies are developing rapidly which could drive innovative use.

The Strategy is flexible in that it does not outline which new hydrocarbon technologies will be supported in the future. The Government is keen on supporting technological innovation which further reduces the costs of energy technologies and maximises investments in energy efficiency. The Scottish Government has ambitions to support each technology and energy type where appropriate and where it meets criteria around benefits to the:

- Economy;
- Consumers; and,
- Environment.

LNG has the opportunity, if demand can be articulated, to support the Scottish Government's energy strategy. LNG could support the ambitions around decarbonising specific industries (e.g. particularly manufacturing and transport) and the reduced emissions profile (of NOx, SOX and CO2) compared to other hydrocarbons could see advantages for Scotland's climate and emissions goals[13].

LNG also has the potential to bring economic and social advantages to Scotland which the Energy Strategy is also seeking; the development of LNG can create jobs as well as improved health benefits (from reduced pollution). The Draft Strategy also identifies the levers that can be used to support hydrocarbon technologies, specifically land use planning, marine planning and energy consenting and licensing, which also represent areas where decision making over LNG infrastructure could drive more investment.

Draft Climate Change Plan (2017)

In addition to the Energy Strategy, the draft "Climate Change Plan"[14] commits to almost completely decarbonising road transport by 2050, with significant progress to be made by 2030. There are four main types of measures that are likely to contribute to transformational change around emissions savings from the transport sector. These include changes in behaviour, eco-driving, planning and improved fuel / carbon efficiency of vehicles. The latter measure is an area where LNG could potentially play a role. With rising fuel costs and pressure to reduce emissions, the transport industry is exploring LNG as a low carbon fuel of choice for marine vessels, heavy goods road vehicles, buses and other large vehicles.

3.1.3. Transport Strategy (2016)

The Transport Strategy (refreshed in 2016) highlights the plan for Scotland to achieve a safe, integrated and reliable transport system to tackle the issues of climate change, air quality and health improvement which impact on the high-level objective for protecting the environment and improving health. The Transport Strategy also supports the energy strategy and sets the context for transport policy making and informed decision making. The strategy highlights the need to embrace and procure low carbon vehicles, buses, hybrid and low carbon ferries. This is of relevance to LNG which has a lower emissions profile for vehicles and vessels. LNG therefore could support the transport sector becoming decarbonised (the transport sector was the second largest contributing sector behind energy supply, contributing 22% of all emissions[15]).

3.1.4. European Policy

The European Union is committed to growing the European economy while protecting the environment and its resources. The EU has signed up to reducing greenhouse gas emissions by 20% and wants to see a 20% increase in the market share of renewable energy – the aim is to achieve these targets by 2020 (Europe 2020). The EU sees that this reduction will be achieved through focused action on:

- Areas of high emissions (55% of total EU emissions) – Housing, agriculture, waste and transport.
- Binding national targets for raising the share of renewables in their energy consumption by 2020,
- EU supports the development of low carbon technologies
- Linking energy with efficiency, security and economic growth ambitions.

[13] Although as mentioned in Section 2 the emissions profile should be explored further.
[14] Climate Change Plan (2017)
[15] Scottish Greenhouse Gas Emissions (2015)

Utilising more LNG provides an opportunity to meet the above actions within the EU by contributing to emissions reductions and linking energy efficiency, security and economic growth.

LNG is highlighted by the EU as of importance to the improvement of air quality by supporting the transition away from pollutant heavy fossil fuels (e.g. petrol). The EU also highlights some potential issues where interventions or focus around LNG may lie[16]:

- LNG infrastructure does not have full coverage and member states were signposted to the opportunities afforded by the European Fund for Strategic Investments (EFSI) for upgrades or new investments.

- LNG can play a key role in ensuring adequate gas reserves in storage facilities and promoting the genuine diversification of energy supplies. The EU is keen that member states promote this and seek to ensure balance and achieve energy security.

- Effective and timely investments in LNG projects of common interest are important for the expansion of the LNG market in the EU. The EU is seeking to establish a fair distribution of investment and operating costs between the Member States and economic operators.

- The EU identifies that the use of LNG in the heavy goods transport sector, as well as in maritime transport, may significantly reduce environmental damage. The EU therefore, recognises that LNG could support improved environmental outcomes for the transport sector.

Despite the broad support from the EU, the technology and cost challenges of using LNG for road transportation are not fully resolved. The savings on fuel for businesses are often offset by other costs that are much higher than expected (e.g. improving safety infrastructure)[17]. This results in longer pay back for investments. Furthermore, supporting infrastructure across the EU is not developing as quickly as hoped. As a result, the adoption of LNG for road transportation has been slow. Going forward, the UK and Scotland's relationship with Europe could change and this uncertainty could lead to changes in policy direction and reductions in private sector investments.

3.1.5. Summary

The above strategies and policy documents highlight the ambitions of the Scottish Government for transport, energy and the economy. These align with EU policy which is supportive of LNG where it fits in with ambitions (e.g. reducing emissions and moving towards a renewable energy future) and other benefits (e.g. economic). Clearly UK legislation and policy is also of relevance. The Clean Growth Strategy's proposals to decarbonise all sectors of the UK economy through the 2020s highlights opportunities for economic growth and reducing emissions.

The Scottish Government's devolved powers extend to planning, public procurement, building standards, business rates, innovation and project funding. These levers can be utilised to deliver the relevant conditions for LNG infrastructure. Going forward any LNG infrastructure investments need to consider the local planning conditions, Scottish and UK policy and how they can contribute to the ambitions of these policies.

3.2. Scotland's energy sector

Scotland's energy industry constitutes one of the largest sectors of the Scottish economy[18]. This section highlights some of the features which are key considerations when assessing LNG as part of the energy mix.

- **Coal decline -** As highlighted the ongoing decarbonisation of key industries including energy, has seen coal fired stations in Scotland close, including Longannet in Fife which closed in 2016. The decline of coal has been more rapid than many anticipated. Five years ago, the fuel was generating more than 40% of the UK's electricity, however by the first half of 2017 coal supplied just 2% of power to the UK[19]. The decline of coal use in Scotland has placed more prominence on energy generation from nuclear, oil and gas fired power stations and renewable sources.

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[16] European Commission - an EU strategy for liquefied natural gas and gas storage communications (2016)
[17] See for example HSE terminal consent and operation issues related to terminals.
[18] Scottish Growth Sectors, available at: http://www.scotland.org/live-and-work-in-scotland/key-industries
[19] British Energy News (2017), how a major energy source lost its power in Britain, available at: https://british-utilities.co.uk/2017/the-coal-truth-how-a-major-energy-source-lost-its-power-in-britain-the-guardian/

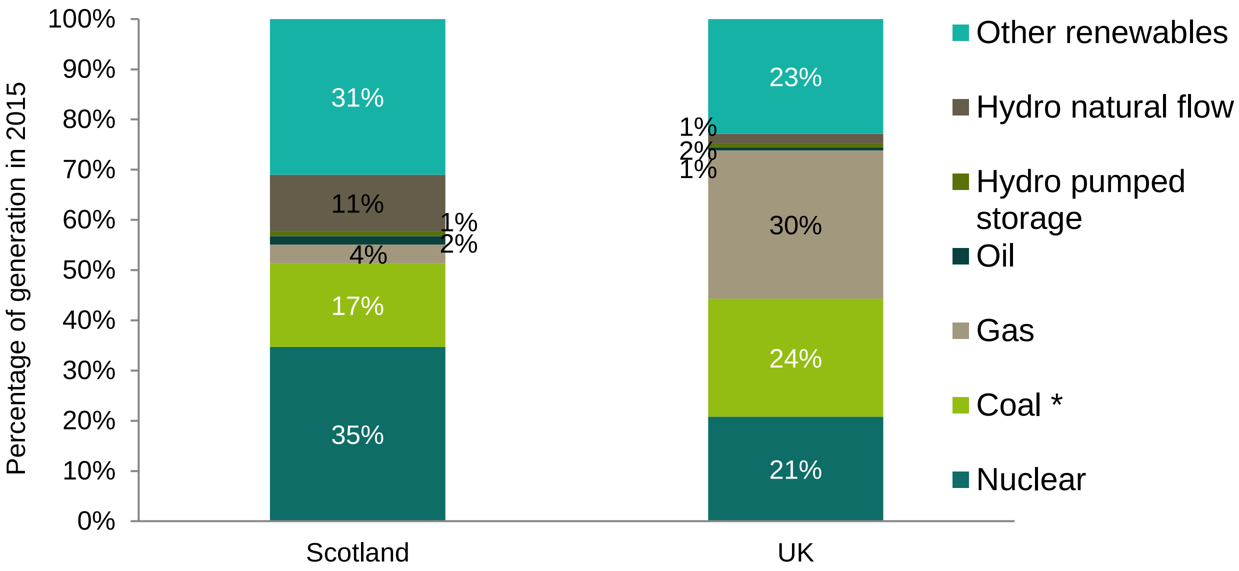
- **Oil and gas importance -** Oil and gas remain key sources of energy in Scotland – accounting for a combined value of 87% of total primary energy in 2014[20]; with the vast majority of Scotland's heating and transport needs supplied by fossil fuels. The oil and gas sector has made a longstanding and important contribution to Scottish society and economy.
- **Oil and gas transition –** The oil and gas sector has seen some challenges in the past decade and is entering a transition phase. The Scottish Government acknowledge in their Draft Energy Strategy[21] that *"At this stage in the transition the Scottish government remains committed to maintaining domestic oil and gas production and maximising recovery from the oil and gas fields in the North Sea and west of Shetland".* There is potential for further decommissioning to occur which will see Scotland become one of the first regions in the world to start decommissioning of older fields on a large scale. The use of CCUS technologies in conjunction with LNG power generation could provide an opportunity for EOR and therefore maximising oil and gas recovery from the North Sea.

3.2.1. Energy generation

Current energy generation in Scotland is characterised by low proportions of gas generation and decreasing levels of consumption (related to this is the increasing use of renewables for electricity generation)[22]. The Scottish Government has identified that total energy demand cannot be met by renewables alone but there could be a wider, balanced electricity and heat generating mix. Furthermore, although there have been decreasing levels of consumption there has been an expectation that the UK will need to boost its generation of electricity to accommodate demand from electric vehicles[23].

The below graph shows that Scotland has a very different energy generation mix to the rest of the UK, with a much higher proportion of renewables, nuclear and hydro and a smaller proportion of gas powered generation.

Figure 3-1 Generation Mix (%) - Scotland and UK, 2015



Source: BEIS 2015

The most common domestic heating fuel in Scotland is gas and 57% of all gas consumed in Scotland is used domestically[24]. The demand for gas varies in Scotland over the day, at weekends and during different months (e.g. heat demand is significantly higher in winter months). Gas demand in winter can be as much as five times

[20] Draft Energy Strategy 2017
[21] Draft Energy Strategy 2017
[22] Digest of United Kingdom Energy Statistics 2015, available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/633779/Chapter_5.pdf
[23] Scottish Power, National Grid and Cambridge Econometrics have outlined between 10-30% more power generation for a move to electric vehicles. See: http://www.bbc.co.uk/news/uk-scotland-scotland-business-41373466 and https://www.carbonbrief.org/analysis-switch-to-electric-vehicles-would-add-just-10-per-cent-to-uk-power-demand.
[24] Draft Energy Strategy 2017

as much as the demand for gas during summer. These fluctuations present problems to an energy future based on renewables.

The rise and fall in demand for natural gas can currently be easily handled by the gas utilities and the transmission networks that supply them. However, during extremely cold spells or other events (e.g. emergencies), demand for natural gas can peak sharply above normal demand. As a result, there needs to be a reliable supply of gas that can be quickly delivered into the distribution system to flatten out or "shave" peaks in demand. As a result, there is an increased focus upon how gas can be supplied and this is an opportunity for LNG.

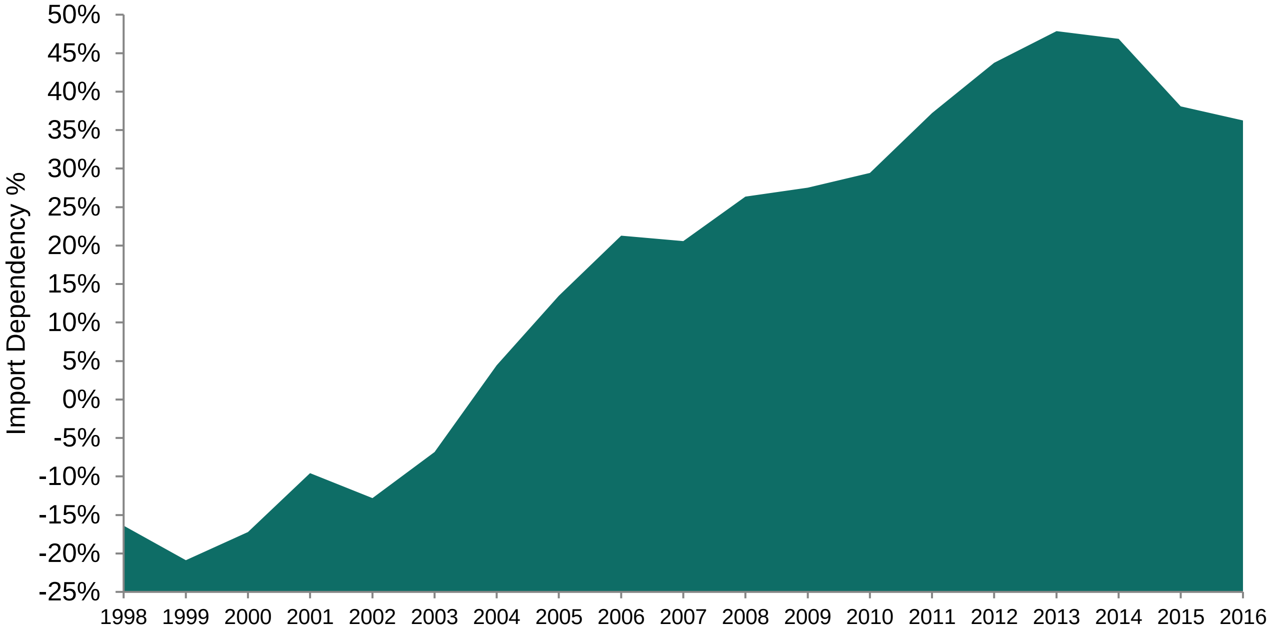
3.2.2. Scotland's energy security

The UK has become increasingly dependent on imports of energy (Fig 3-2). Since 2011, over a third of the UK's energy comes from abroad. The UK imports coal from Russia, gas from Norway and uranium from Kazakhstan. LNG is often sourced from Qatar (and increasingly the USA and other countries). The UK's ambition is to be less reliant on other countries for energy. Importing LNG could have negative energy security outcomes (e.g. imports from other countries) as well as positive (e.g. imports from more politically stable countries).

Developments like the closure of the UK's largest gas storage site (Rough off the east coast of Northern England), create risks to the supply of gas in the future. The closure will remove the around 70% of the UK's natural gas storage capacity and is expected to lead to more imports (e.g. from Norway).

Fig 3-2 identifies a general trend towards increasing import dependency which has decreased recently but is much higher than previous years. In the past, the UK has been a net exporter of energy (mid 1990s) and since then North Sea production has peaked (1999) and the UK has been a net energy importer since 2004.[25]

Figure 3-2 UK's Energy Supply – Proportion of Imports (Import Dependency) – Annual



Source: BEIS 2017

National Grid has previously operated a series of LNG liquification and regasification plants around the UK including at Glenmavis in Scotland, for the purpose of supporting the National Transmission System. However, the last of these facilities, Avonmouth closed in 2016. In addition, the UK's largest natural gas storage site (70% of the total storage capacity), Rough[26], off the East Coast of Yorkshire is reported to have reached the end of its design life and is expected to close once the existing gas is extracted, it was announced in June

[25] UK Perspectives 2016: Energy and emissions in the UK, available at: https://visual.ons.gov.uk/uk-perspectives-2016-energy-and-emissions-in-the-uk/
[26] See Appendix for further information on gas storage in the UK.

2017. This closure potentially leaves the UK more dependent on imports and at risk of greater volatility in prices in winter months. The closure will remove the UK of around 70% of its natural gas storage capacity and is expected to lead to more imports (e.g. from Norway).

Imports can meet energy demand where technological, cost, domestic supply, geography (e.g. isolated communities), specific energy use (e.g. energy intensive manufacturing activities) or demand (e.g. spikes in demand) issues exist. Gas plays a key role in the UK's energy security and is expected to continue to be of major importance as we make the transition to a low carbon future. The security, affordability and sustainability of the gas network are therefore critical to the future of Scotland's energy.

There are several questions emerging about whether generation capacity will continue to match demand in Scotland. This raises further issues around capacity, risk, management, energy mix, transmission charging, intermittency, flexibility, diversity, new generation (including nuclear energy and gas).

Specific risks include:

- Current low capacity margins are unsustainable - Low spare capacity could create risks to Scotland's energy system if there is also low generation availability (caused by low wind and/or network faults).

- New generation - Coal imports to the UK were 8.5 million tonnes in 2017, a decrease of 62.3% on the previous year's amount, mainly as a result of reduced power station demand. Scotland's energy generation sector is entirely coal-free, after the last coal burning power station at Longannet closed in 2016. The remaining generation life of some of the other power stations is also to be decided. The nuclear power stations in Scotland; Hunterston B is set to close in 2023 and Torness in 2031, highlights the long-term generation challenge. The current Scottish Government's policy is that these plants should not be replaced with new nuclear generation, using current technologies. This has led to some uncertainty for the mid-to-long term future for energy generation and recognition that new generation could be needed (and ideally renewable or low carbon).

Energy and the security of supply is more than ever an important issue, raising questions over the ways in which we generate, supply, pay for and plan the transition to a decarbonised economy. New energy generation and storage technologies as well as meeting demand side responses (e.g. network management and interconnectors) could greatly improve the flexibility, security, sustainability, and affordability of Scotland's energy system. LNG and its applications within power generation could be part of the mitigation options for the risks above, providing different sources for energy generation. However, LNG use in Scotland may not eradicate energy security risks and could exacerbate them due to further reliance on importing.

3.3. Trends in LNG

The LNG market has until recently been one of the fastest growing sectors for energy. In the past, a small number of countries, mainly in Asia had been trading and utilising LNG. However, the market has now developed into a dynamic and multi-connected industry connecting nations across the globe. Until recently the low price of LNG has deterred some supply side investments but has driven up demand, whilst other competitive and macro-factors have also affected growth leading to a recent restrained period of growth in supply in the industry.

This section explores some of these uncertainties and characteristics in the LNG industry and their impact upon investments in Scotland.

3.3.1. Macro influencing factors

There are several influencing factors upon LNG markets which are relevant for Scotland. These are summarised below:

- **Economic Growth:** LNG consumption is driven by growth in Europe and Southeast Asia. A slip in regional growth, particularly in China, would reduce natural gas demand in key supplying countries and affect the economic growth prospects of the world. The UK and Scottish economies are intertwined and whilst there have been some economic challenges in the past 12 months, the UK and Scottish economies are expected to continue to grow between now and 2022 although slightly slower than previously anticipated[27]. Economic forecasts for both Scotland and the UK are expected to be below their long-term average and the Scottish Government forecasts growth of 1% in 2016-17 and 1.3% in 2017-18[28]. Any economic malaise or slowdown in the UK and Scotland as well as key economic areas (e.g. USA, China, Europe etc) will likely weigh against energy demand including demand for LNG.

- **The relationship with the European Union:** The significance of higher and continuing levels of uncertainty because of 'Brexit' for the economy are a potential economic growth risk. However, 'Brexit' is likely to also affect legislative and environmental ambitions. This creates risks but also opportunities, recent trade visits show that the United Kingdom's exit from the European Union is an opportunity for Qatar and others to supply more LNG. Every level of policy making could be affected by Brexit. However, at this stage it is not clear what changes can be expected[29].

- **Political uncertainty:** A key risk to adopting LNG is that the market is susceptible to price spikes driven by political issues. The tensions between Russia and European countries and Qatar and other Middle East countries are examples, that have driven small price fluctuations in LNG. Price spikes could become more dramatic in the colder months or where a crisis has more impact. Political situations within and between countries could drive tighter gas supplies, importers may therefore restrict the expansion of pipeline networks and demand for LNG may rise.

  If further escalation of tensions between Qatar and other Middle Eastern countries occurs then supplies could be disrupted (current sea routes are through waters that are still accessible). If Qatar finds it difficult to access markets, then reliance for gas on other countries (e.g. gas from Russia) could lead to further political dimensions (and decisions) which could see cost rises and eventually a price rise which would affect the dynamic of the LNG market.

  LNG demand may also drop if political uncertainty drives more indigenous energy investments. It has been suggested that importers of LNG that have undeveloped gas resources (e.g. China) may seek to invest if LNG supply is constrained and domestic prices rise.

- **Socio-cultural factors:** Uptake of LNG is also driven by cultural factors. There has been a large movement in European nations including Scotland for low carbon energy use and particularly using photovoltaics and wind technologies. LNG remains a fossil fuel and as some sources are connected to fracking and this could pose risks for further LNG adoption.

- **Legacy:** LNG use is also impacted by historical use. For example, utilisation of LNG in remote communities is driven by previous installations, cost and culture. Furthermore, perceived additional costs (despite potential longer-term savings) and lack of knowledge about LNG can dissuade or slow take-up.

- **Export, Production & Liquefaction:** Around 70% of liquefaction capacity currently under development is in Australia[30]. If this capacity is brought to market as planned then Australia is set to overtake Qatar as the world's largest exporter of LNG by the end of this decade. This is both an opportunity and a risk. The US government is also likely to approve large volumes of US gas exports from the US shale gas industry (which also raises political issues). This increased capacity could meet growing demand. However, it could also create a situation whereby exports of cheaper gas drive a slowdown in investment and demand. Those projects with lower costs, direct access to markets, and committed buyers will move forward at the detriment of larger transformational LNG projects. The Chinese Government are making sweeping changes to domestic energy and industrial use for environmental reasons and this is also continuing to push up demand, particularly during winter.

- **Increased energy efficiency:** The relationship between growth and energy usage has weakened. As a result, the energy intensity of economic growth has declined over the last few decades as high energy prices and environmental concerns have driven the adoption of higher efficiency technologies.

  In the UK, this is best characterised in the domestic sector, more energy efficient products, initiatives to promote energy efficiencies and processes in the domestic sector have driven energy consumption reductions recently. Scotland has an Energy Efficiency Programme (SEEP) which is seeking new and

[27] Office of Budget Responsibility (2017); http://budgetresponsibility.org.uk/
[28] Scottish Government (2017) - State of the economy: https://beta.gov.scot/publications/state-of-the-economy-march-2017/
[29] See for example the UK Government's pages on Brexit: https://www.gov.uk/government/policies/brexit
[30] IGU 2017 World LNG Report, available at: https://www.igu.org/sites/default/files/103419-World_IGU_Report_no%20crops.pdf

innovative approaches to energy efficiency and reduction of costs. Furthermore, in the future UK households will have access to further home energy management technologies (e.g. internet of things), insulation and renewable heat measures. Technology and process improvements on both the demand and supply sides are expected to lead to greater productivity and energy efficiency. As a result, the energy intensity of economic growth is expected to reduce[31]. The combination of lower energy requirements and lower cost renewables could over time reduce the appetite for LNG imports.

- **New markets:** Economic growth in developing countries is expected to require new LNG import and regasification facilities to be built to meet growing global fuel needs, particularly where these countries have little indigenous oil and gas supplies. New markets and innovation will also drive new users. LNG is traditionally consumed for power generation, as a source for small-scale grids, an alternative transport fuel for shipping or HGVs which could provide a long tail of potential demand growth. Furthermore, new markets and new supplies could see the shortening of trading distances. This could positively affect economies of scale and the cost of shipping, driving an increase in volumes as incremental margins improve. This will reduce the natural gas price differential required to drive investment.

3.3.2. Scotland and the Global LNG Market

The combination of policy initiatives, technology advancements and the oversupply of LNG has contributed to the adoption of LNG as an alternative energy source across the world. Scotland (and the North of England) lacks the necessary LNG infrastructure to fully adopt LNG as a road transport fuel source across its economy. At the moment, the natural gas refuelling infrastructure in the UK is also heavily weighted towards England. This is a barrier to future adoption although potential investments by companies like Stolt-Nielsen are overcoming this.

Despite constraints, LNG already plays a small but increasing role in ensuring the diversity, reliability and competitiveness of the gas system for the UK and Scottish businesses and residents. At the moment 17% of gas is imported by ship as LNG[32]. The changes and characteristics in the global LNG market (see section 2.3.1) mean that there is the potential to examine the opportunities that LNG presents, and its potential to support diversification of Scottish energy supplies. This section provides an overview of how Scotland currently interacts with the Global LNG market.

3.3.2.1. Previous assets

In the past, Scotland has had LNG storage facilities. LNG storage services at Glenmavis were closed in 2013 and the facility was decommissioned. Because of this closure, LNG used in homes across Scotland (particularly North and West) is a result of LNG transported from the Isle of Grain terminal in Kent, England. The Glenmavis facility was opened in the mid-1970’s as a peak shaving and support facility to the National Transmission Network (as an economic alternative to network reinforcement). However, due to system failures at the facility it was closed.

3.3.2.2. Current LNG infrastructure

The UK has seen a higher level of gas imports from the European and Norwegian interconnector and the dependency on these sources is expected to increase. The UK currently has three principal LNG importation terminals:

- South Hook LNG Terminal near Milford Haven in Wales, has two LNG berths each capable of accommodating the largest LNG carriers (LNGCs). The Terminal has five cryogenic storage tanks, each with a working capacity of 155,000 (m3).

- Dragon LNG near Milford Haven in Wales has a single LNG berth capable of accommodating the largest LNGC. The Terminal has two cryogenic storage tanks, each with a working capacity of approximately 160,000 m3. While the re-gasification plant can deliver the equivalent of 6 MTPA of LNG to the UK National Transmission System (NTS)

- Grain LNG located on the Isle of Grain in Kent, has two LNG berths each capable of accommodating the largest LNGC’s. The Terminal has 1,000,000 m3 of LNG storage capacity. The re-gasification plant

[31] McKinsey (2016) The drivers of global energy demand growth to 2050, available here: https://www.mckinseyenergyinsights.com/insights/the-drivers-of-global-energy-demand-growth-to-2050/
[32] BEIS and British Gas 2017

can deliver the equivalent of 15 MTPA of LNG to the UK National Transmission System (NTS). The terminal also has a truck reloading capability

A fourth LNG import terminal, Teesside Gas Port, was operated by Excelerate Energy from 2007 to 2015, the terminal included a 138,000m3 Floating Storage Re-Gasification Unit (FSRU), which has since been relocated. The site is currently owned by Singaporean trading house Trafigura who in February 2017 declared their intention to put the terminal back into service by mid-2018. The terminal is located close to the UK NTS and potential industrial users[33].

In context to the above, LNG facility extensions are being considered at Isle of Grain (a 190,000 m3 storage tank, process plant and cryogenic line) as part of a phase 4 of growth[34]. Other planned investments are being assessed across the North of England:

- Meridian LNG is also assessing an agreement with US based suppliers for a floating storage and regasification unit (FSRU) in Morecambe Bay.

- Trafigura seeking to reopen the Teesside LNG import terminal with the investment of £30million[35] in fixed infrastructure

These investments and potential further expansion opportunities at Dragon, Milford Haven could see the UK position itself as a LNG hub to store and sell on export cargoes (from US and Qatar). In the past two years, the UK has exported a small amount of LNG highlighting the potential LNG value chain (see section 4) opportunities.

3.3.2.3. UK LNG Trends

UK demand is expected to continue to be served through the Isle of Grain and Milford Haven. UK imports since 2012 are summarised below.

Table 3-1 LNG Imports (GWh)

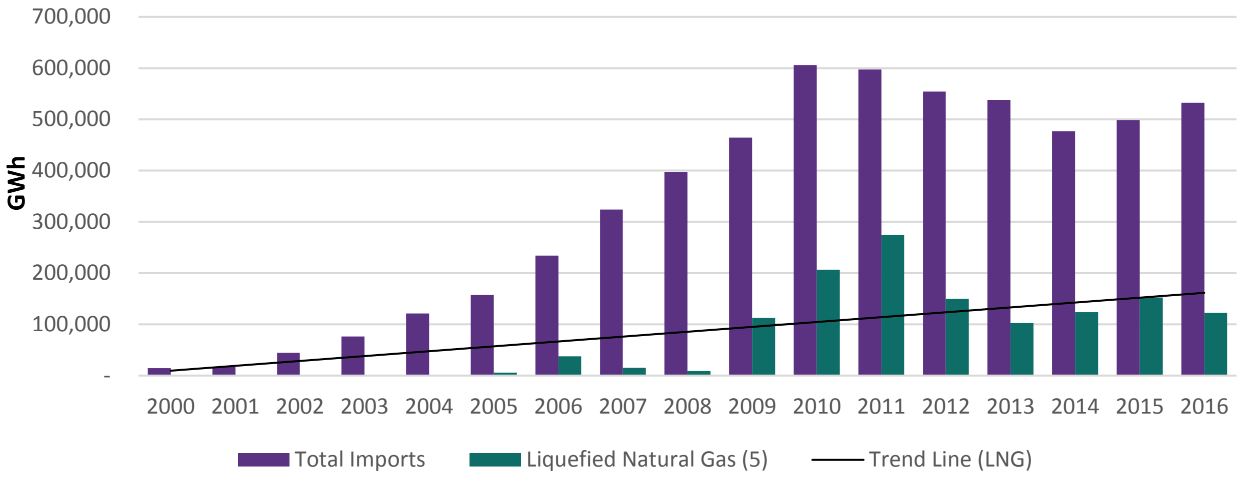
LNG Import Terminal	2012	2013	2014	2015	2016
	GWh				
Dragon (Milford Haven)	1,819	968	3,326	8,014	4,079
Isle of Grain (Isle of Grain)	38,196	15,664	13,808r	14,224r	22,152
South Hook (Milford Haven)	110,082	85,989	106,776	130,169	96,079
Teesside GasPort (Teesside)	-	-	-	-	-
Total	**150,097**	**102,620**	**123,910**	**152,406**	**122,310**

Source: BEIS 2017

Table 3-1 above highlights the Welsh and English import terminals based in the south of both nations. It also also shows some of the fluctuation driven by the supply and demand trends and dynamics identified above. Figure 3-3 below shows that long term there has been modest growth in LNG imports, despite fluctuations.

Figure 3-3 Natural Gas and LNG Imports (2000 – 2016)

[33] Industry source 2017
[34] See Isle of Grain website 2017
[35] The FT report that this investment is being made with the confidence of the facility contributing to energy security, the locations providing greater flexibility as LNG supplies increase, LNG infrastructure coming down in cost, liquidity in the LNG market getting deeper, growth in LNG trade volumes globally and flexibility of US supplies: https://www.ft.com/content/25121f3a-ec7c-11e6-930f-061b01e23655



LNG has seen some volatility in imports since 2011 due to increased demand from Japan (driven by the Fukushima disaster (and the suspension of energy production from the other Japanese nuclear power plants) and other LNG market dynamics. Looking longer term, there has been an increased importation of LNG in the UK. Whilst the UK continues to import most of its natural gas from Norway, the use of LNG has risen since 2005 and in 2011 made up almost 50% of imports. This should be seen in an economic context, but also highlights a trend of increased imports of LNG in the UK.

Stolt-Nielsen and their development planned in Rosyth are well placed to take advantage of the growing demand. Whilst the proposed development is small scale (starting at 10,000m3), it has the potential to expand and serve other demand markets. Stolt Nielson have identified a potential market of 442,000m3 over 5 years in Scotland and the North of England in the short term with a focus upon ship to ship, terminal to ship and truck to ship bunkering.

- **Statutory Independent Undertakings -** Scotland has five Statutory Independent Undertakings (SIUs) for gas supplies that are operating gas networks not connected by pipeline to the rest of the network. Four use Liquefied Natural Gas (LNG) and one uses Liquefied Petroleum Gas (LPG). Campbeltown, Oban, Wick and Thurso have SIUs supplied with LNG by road tanker from Isle of Grain. The fifth SIU, Stornoway, uses LPG. There are around 7,500 gas customers in the four affected SIUs, mainly domestic. Approximate demand from the SIUs is around 2,500,000 m3 and as coastal sites, they appear be well suited to LNG supply by sea.

Transport Costs
The transport costs of LNG by road vary. Estimates vary between less than 5% to over 30% of total costs. Within the UK it is estimated that LNG costs for Scotland can include upto £2,500 per LNG vehicle shipment.

Transportation (by road ad sea) is a significant portion of the cost of LNG (over 50% in some cases) and often it is not economical to transport by road over 500 miles from a plant, making the journey between Kent/Wales and Scotland a factor to greater adoption of LNG. Furthermore, this journey is also made lengthier by safety requirements for LNG road transport (no transportation in tunnels). Imports of LNG in the UK take around 2 days to get to Scotland by road.

- **Cost of Delivery -** The cost of delivery for gas supplies from the point of entry to the system through to end consumers is becoming increasingly important. Where gas is available, and in future, there may be greater diversity in supply sources to Scotland, and requirements for an increasing flow from the South to the North Scotland. In the absence of an LNG terminal in Scotland.

3.4. Scotland LNG Terminals

There exists in Scotland, a range of LNG infrastructure including; a gas vehicle refueling hub in Lockerbie, cryogenic tank facilities at Grangemouth and new developments proposed at Rosyth and the Orkneys. The opportunities for LNG in Scotland have been recognised by investors, specifically Caledonia LNG (in Orkney) and Stolt-Neilson (in Rosyth):

- **Caledonia LNG** (ExxonMobil, Babcock International Group, Bernhard Schulte Shipmanagement (BSM), Calor and Orkney Islands Council) is developing the infrastructure, storage and technical support needed to enable the supply of LNG for both marine and land-based applications.
- **Stolt-Neilson** has recently announced its intention to construct a Small-Scale LNG (SSLNG) terminal at Rosyth on the Firth of Forth, with the intention of supplying LNG to the north of England and Scottish markets. Total investment is estimated at £80-100 million including:
  - £ 30-40 million Scotland LNG Terminal
  - £ 30-40 million 7,500m3 LNG Carrier
  - £ 10-20 million On-site Customer Facilities
  - £ 4-10 million retrofitting/conversion of existing Diesel and Heavy Fuel facilities
  - £ 2-6 million Transportation assets (Trucks, ISO containers, etc.)[36]

The potential investments in Rosyth and by Caledonia LNG are representative of the opportunities for LNG. It is proposed that Rosyth will support bunkering, road transport use, and feed gas to the Orkney facility. These facilities are complementary, with Orkney providing a demand that Rosyth can meet, rather than being supported direct from the Isle of Grain. If demand grows there will be opportunity for others (see Section 4). However, the initial investments proposed by Caledonia LNG and Stolt-Neilson will give them first mover advantages (and some disadvantages), providing them with the opportunity to exploit cost and market advantages before other firms.

3.4.1. LNG supply

The future growth prospects for LNG appear to be positive based on current trends around energy use, diversification and low carbon targets. Going forward, low energy prices tend to reduce future supply whilst high prices reduce demand for energy but boost supply. However, there are some concerns about the continuation of global LNG market trends which could impact upon new infrastructure investments. These concerns are mainly around supply and demand for LNG:

- There are concerns that the current supply of LNG significantly exceeds demand; recently this has led to low prices. Low prices can stimulate demand but the response to the low prices has been limited and it is expected by several commentators[37] that the market may remain oversupplied into the mid-2020s[38] or later. This uncertainty leads to challenges in financing projects.
- Shell identifies that new LNG demand is offsetting growth in supply, mitigating oversupply concerns. This demand is particularly in new markets where LNG supplies have been replacing declining domestic gas production.
- Global LNG export capacity is projected to increase 32% by 2020 as LNG construction projects come online[39]. This will add to the export capacity but traditionally companies planning to build LNG export plants needed customers to sign longer term contracts to give financiers enough assurance of revenues to justify the loans for the projects.
- The above sections highlight characteristics which impact upon supply and demand for LNG. The supply of LNG is also impacted by geopolitical factors. UK imports of LNG have dipped in recent years due to Japan seeking increased levels of LNG following the Fukushima accident.
- Many new LNG buyers are facing uncertainties in their domestic gas markets related to factors such as the global economy, gas exploration, or electricity and gas markets. These uncertainties would lead to importers and buyers increasingly preferring shorter-term supply contracts of around five years, compared to traditional longer-term deals that usually run for around 20 years.

The above represent some of the features and uncertainties within the global LNG market. The future of the global LNG supply and demand dynamics has led to some uncertainty over investments. However, there are several additional trends which could impact upon LNG in Scotland:

- The increasing costs of accessing oil deposits, the low cost of LNG and a general worldwide environmental demand for less environmental damaging sources of energy has resulted in an increase focus on LNG with its reduced CO_2 emissions compared to other fossil fuels (see Section 2).

[36] Stolt-Neilson 2017
[37] See for example see LNG or Gas industry reports from Shell, McKinsey Energy Insights and PWC.
[38] IEA - International Energy Agency October 2017
[39] IGU (2017) 2017 World LNG Report, available at: https://www.igu.org/sites/default/files/103419-World_IGU_Report_no%20crops.pdf

- Changes to contract lengths to meet the evolving needs of importers and final destination buyers, including shorter-term and lower-volume contracts could be advantageous to LNG investors in Scotland.
- New markets are being sought driving different investments. Despite the oversupply of LNG to the market there are a range of LNG projects across the world which are diverse in their technology, location and structure; a mix of brownfield expansions, modular mid-scale projects, floating LNG projects and the more traditional greenfield onshore terminals.

It is expected that fast growth in worldwide LNG demand will eliminate any LNG surplus and as a result delayed projects could become part of a “second wave” of LNG expansion. The global supply of LNG currently out paces demand, due to:

- A significant number of LNG export terminals that went to final investment decisions in the early 2010’s, are now starting to deliver LNG to the world markets.
- The development of horizontal fracking techniques and the rapid monetisation of shale gas deposits particularly in the USA.
- The USA federal authorities licensing energy exports.

The future uncertainty about supply and demand, and long lead in times for construction have led to some delay over the next ‘generation’ of LNG export terminals. These are expected to be planned and developed in Canada, Mozambique, Tanzania and Mauritania/Senegal.

Qatar, currently the world’s largest producer of LNG, is planning to increase production by 30% to meet the threat to its position from the likes of Australia and the US. As such, the LNG market may see further uncertainty over supply investments, but with low prices of LNG, potential LNG import infrastructure is likely to see further expansion across the globe, specifically in small scale LNG. Small scale LNG infrastructure is seen as the potential growth market, offering lower risk to investors. Small scale LNG allows a more flexible market response and the technology is evolving. This has seen increasing rates of return on infrastructure and quicker construction timelines.

4. LNG Demand

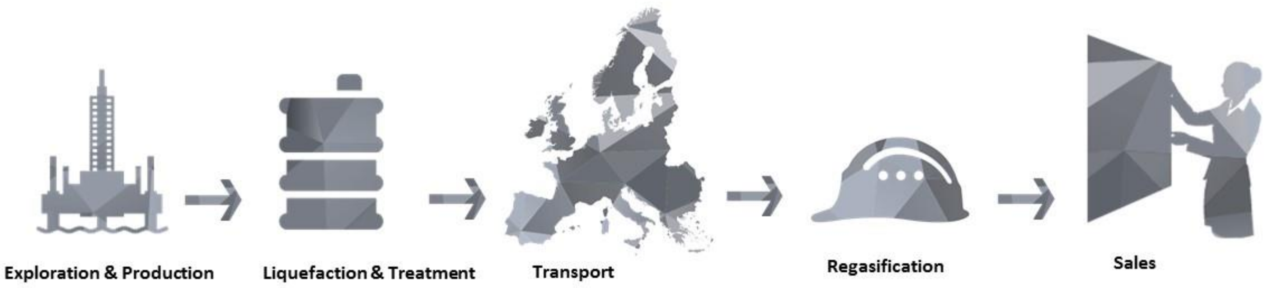
Potential sources of LNG are vast, and the long-term prospects are positive for the LNG industry. This section explores the potential demand and highlights the points within the LNG value chain, and the various sources of demand which could drive LNG demand in the future.

We provide figures for demand for 2025 (Medium-term) and 2040 (approx. 20 years from the report date).

4.1. LNG value chain

To understand LNG demand, it is helpful to present the LNG value chain. The value chain is shown below (Figure 4-1) and in the following we assess the Scottish potential for the different stages.

Figure 4-1 LNG Value Chain



- **Exploration & Production:** Following exploration and production from onshore or offshore fields, natural gas is transported by pipelines to a liquefaction facilities.

- **Liquefaction & Treatment:** At the liquefaction facilities, it is pre-treated and cooled to -161°C (-259°F) at which point it becomes a liquid (at around 1/600th of its original volume)

- **Transport:** The liquefied natural gas is loaded into specially constructed ocean-going vessels with cooling systems and insulation to keep the gas cool.

- **Regasification:** LNG is transported by ship to regasification plants (often close to the end destination); where a heating process converts the liquid to its gaseous form. At regasification utilities, cryogenic storage tanks are used to enable a more regulated flow of gas into the pipeline / transmission system since vessel arrival is only periodic (e.g. bi-monthly). Storage tanks can also be used to cover peak demand.

- **Sales:** Finally, the gas is fed into pipeline grids or packaged into trucks and sold to distributors or directly to power producers, large industrial consumers or other consumers.

Across Scotland there would be a focus upon the latter stages of the LNG value chain; Transport, Regasification and Sales. Clearly, the current distribution arrangement of LNG leads to additional costs for Scottish clients, Estimates of costs of transport upon LNG final user costs by road range between less than 5% to over 30% of total costs. Within the UK it is estimated that LNG costs for Scotland can include £2,500 per LNG vehicle shipment in the UK. However, the LNG industry is increasingly flexible and technology developments mean that different aspects of the value chain are becoming increasingly efficient, and are starting to offer a range different investment scales.

We explore the main areas of demand below which include: marine, road transportation, power generation, and industrial and residential uses. We also highlight other potential demand sources which have been raises during this project. We summarise this overall demand at the end of the section[40].

[40] The section outlines some potential scenarios for LNG demand which are outputted as cubic metres per year. This standardises the information presented and allows comparisons to be made.

4.2. Marine

The introduction of MARPOL (Marine Pollution) marine emission regulations in 2012 has forced ships operating within the North Europe, Baltic Sea, North Sea, English Channel and US and Canadian Emission Control Areas (ECA) to either use low sulphur fuels, limit sulphur emissions by using a scrubber, or use alternative fuels. While these regulations currently focus on the reduction of Nitrogen Oxide (NOx), Sulphur Oxide (Sox) and particulates (see Section 2), the use of LNG can also reduce CO2 emissions by 25 to 30 percent in general, compared to diesel or heavy fuel oil powered vessels[41]. Since 2015 the North Sea and Baltic Sea have been designated Sulphur Emission Control Areas (SECAs) with ships trading there having to use fuel oil on board with a sulphur content of no more than 0.10%. All ships operating on these seas need to comply.

LNG already has a 6% market share of the global marine fuel market and around 439 ships use LNG currently[42]. Within Scotland, the number of vessels using LNG is unknown but not considered to be a large number. An increasing number of vessels are seeking to retrofit LNG (where diesel engine is adjusted or replaced and that an LNG tank can be installed on the ship) and more new vessels will have LNG or dual fuel capabilities. Only certain ships are suitable for an LNG retrofits (e.g. some do not have space). Most ships have an average lifetime of 20-30 years and many vessels will not be replaced in the coming years but those that are will have LNG retrofitting options.

As a result, a small but increasing number of vessels are being built with dual fuel engines, so increasing the demand for LNG as a marine fuel, and LNG bunkering facilities. Demand for LNG bunkering is expected to grow rapidly[43] and has seen recent growth in the past 5 years[44] from a low base. However, with a typical investment repayment period for ships of 20-30 years the natural replacement of older ships with new LNG powered vessels would be slow, but the introduction of the MARPOL regulations and the possibility that some existing vessels can be retrofitted is all expected to lead to a more rapid increase in the demand for LNG bunkering services.

The most suitable vessels are those that undertake short trips. But with a working life of 20-25 years many will not be replaced by new ones before 2030. However, Transport Scotland and ferry operators are planning for new vessels to have LNG technologies and the increasingly strict emission policies and further technology efficiencies could see ships adopting LNG quickly. Two new LNG vessels have been ordered by Transport Scotland and CMAL at a cost of £97million for both, with an expectation that they enter service in the second half of 2018. CMAL has long term plans to continue to invest in LNG and with more than 35 vessels there are likely to be more investments, although timescales are currently uncertain.

The availability of LNG on trade routes is vital for encouraging ship-owners to invest in dual fuel engines. Ports such as Rotterdam and Antwerp are proactively leading the way having introduced LNG bunkering capability in 2012, and many other major ports in Europe (e.g. Marseille) are planning to provide this capability.

The cruise market in Scotland has ambitions to increase the number of cruise passengers to over 1 million by 2030. Cruises often fuel at their starting point but increasingly larger cruise vessels on longer journeys need to 'top up'. There are also increasingly more LNG fuelled cruise ships being on order. In Australia cruise ships visit Port Hedland which is advertised as "industrial sightseeing" but in fact the vessels are primarily looking to bunker.

Although this document is location neutral, the use of marine LNG is likely to be underpinned by geographical characteristics with geography driving where vessels bunker and operate. Rather than reviewing the total marine transportation demand we focus upon one the Clyde Scottish Marine Region[45] since investments at Rosyth and the Orkney Islands would be well placed to meet demand elsewhere in Scotland. The following is a simplified estimate of the possible LNG demand on the Firth of Clyde 2025 and 2040.

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[41] Marine Insight's 10 Noteworthy LNG-Powered Vessels, available: https://www.marineinsight.com/tech/10-noteworthy-lng-fueled-vessels/
[42] IGU (2017) 2017 World LNG Report, available at: https://www.igu.org/sites/default/files/103419-World_IGU_Report_no%20crops.pdf
[43] Aronietis, R., Sys, C., van Hassel, E. et al. J. shipp. trd. (2016) 1: 2. https://doi.org/10.1186/s41072-016-0007-1
[44] Ship & Bunker News (2016), available at: https://shipandbunker.com/news/features/industry-insight/742644-lng-bunker-fuel-weathering-the-oil-price-storm
[45] Scottish Marine Regions Order 2015

Demand: Marine Transport

In the following, one scenario of the many possible for LNG demand from marine transport on the Firth of Clyde, West Coast of Scotland is calculated for illustrative purposes only.

Assuming

- The number of arrivals and bunkering's at Clydeport remains constant into the future
- A typical vessel is represented by the "Isla Bella" launched in 2015 and the world's first LNG power container ship, with a typical bunkering requirement of 400m3 / bunkering
- Cruise Ships – The majority of cruise ships will bunker taking 2,000 m3/ bunkering. However, bunkering will not just occur in Scotland[46].
- Ferries - The two CMAL LNG ferries would bunker on the Firth of Clyde every week taking on 100m3/bunkering. Additional ferries will be added in the future
- Other marine covers other marine vessels, shipping fleets (short journey, leisure and commercial vessels)

Therefore	**Other**	**Cruise**	**LNG Ferries**
No. Annual of arrivals at Clyde port (2016)	1200	70	100
Percentage Bunkering (say)	10%-20%	75%-90%	100%
Average Bunkering requirement m^3	400	1,500	100
Percentage using LNG (say 2025)	10%-20%	20%-30%	100%-150%
Percentage using LNG (say 2040)	20%-40%	40%-60%	150%-200%

2025 Total volume of LNG required (annual) = 30,500 – 62,500 m^3
2040 Total volume of LNG required (annual) = 56,100 – 115,000 m^3

It is concluded from the above that the trend in using dual fuel vessels will continue to grow, resulting in increased demand for LNG bunkering and therefore a need for LNG bunkering capability. The overall scale of demand for Scotland will be larger than the above. For example, demand in the Firth of Forth could be similar but will be largely addressed by the Stolt-Neilson's LNG facility, and therefore is not modelled.

An important factor in future demand is the Vessel Replacement and Deployment Plan (forthcoming) by Transport Scotland which will outline the number of vessels to be replaced and ordered. It has also been highlighted in research that hydrogen as a fuel alternative is being explored through the partnerships between universities[47], the Scottish Government and private firms which could change (in the long term) the profile of vessels and demand for LNG.

4.3. Road transportation

There is no strategic or industry consensus as to which technologies should be taken forward for low carbon vehicles. There is also little clarity around the need for upgrades to infrastructure or the national grid because of increased demand for electricity. The drive for doing so appears to be consistent with increased demand for energy to power electric vehicles. However, initiatives such as smart metering, demand management and other low carbon technologies could reduce the need to make investments or changes. Overall, the general trend appears to be for cars to be electrified. However, larger vehicles have no leading technology and LNG could become the dominant fuel type.

At the moment, LNG trucks are less suitable for long-haul, heavy-freight distribution journeys which limits the size of the possible vehicles that can adopt LNG (e.g. HGVs). A big barrier to LNG in vehicles is the lack of LNG infrastructure in the UK. There are a limited number of LNG stations which forces LNG trucks and ships to adjust their routes, which can lead to extra kilometres. As the LNG infrastructure improves this barrier might be addressed but it could remain a barrier when transporting to other countries. Dual-fuel vehicles can overcome the distance but it is likely that technological development will lead to more LNG trucks.

[46] As such LNG regasification would not just occur in Scotland but if it did then the scale of facility would need to be considered and ship to ship technologies might need exploring.
[47] See for example http://www.researchscotland.ac.uk/pst-energy.php

LNG represents an opportunity to integrate transport into systems thinking around energy. Linking heat, electricity and users (e.g. residential and transport) to single sources or shared resources. Generating electricity with LNG or using dual-fuel vehicles could see networks and future synergies and technologies developed. There are also further opportunities around the move to autonomous vehicles. These have the potential to offer efficiency and low emissions and also to connect up remote communities.

LNG with its relative high energy content is a practical alternative to diesel for road transportation. With 1.8 litres of LNG equivalent 1 litre of diesel the equivalent truck range can be achieved with an easily accommodated larger fuel tank. On this basis, a 700 to 900 litre LNG fuel tank should be capable of providing a truck with a 1,000-km range.

In May 2013, the European Commission initiated its 4 year LNG Blue Corridor project with the European Natural & bio Gas Vehicle Association (NGVA Europe) with the aim of establishing LNG as a real alternative for medium and long-distance transport. By March 2017:

- 4 primary LNG blue corridors have been established with a network of filling stations in place
- 150 heavy-duty LNG-fueled trucks are operating on the European roads, 50 more than the initial 4-year target of 100 trucks.
- 43 road transport fleet operators have opted to trial the use LNG as fuel for their vehicles.
- NGVA Europe predict that some 400,000 gas-fueled trucks will be on EU roads by 2030, which will help meet the EU goal of de-carbonising the transport sector, with a 30 percent reduction in CO2 emissions by 2030 and 60 percent by 2050.
- The LNG blue corridor project aims, by 2025, to have at least one filling stations every 400 kilometers along Europe's primary transportation routes

The Gas Vehicle Hub (GVH) currently report that in the UK there are 22 LNG filling stations with 12 available with public access and 10 with no public access. There is only 1 in Scotland at Lockerbie.

With Heavy Goods Vehicles (HGVs) having a typical investment repayment period of approximately 5 to 8 years, and the assuming the availability of suitable infrastructure, a switch to LNG powered vehicles could see a rapid increase in the number of such vehicles on the roads of Scotland.

Demand: Road Transport

In the following, one scenario of many possible for LNG demand from road transport is calculated for illustrative purposes only.

Assuming

The number of trucks in the EU and UK remains constant
The % of LNG trucks in the UK is the same in the EU
The % of UK trucks operating in Scotland remain constant

Therefore

Number heavy duty vehicles in the EU (2015/16)	= 15,000,000
Number of LNG fuelled heavy duty trucks predicted (2025)	= 300,000 to 500,000 (of 2015/16 vehicles)
Number of LNG fuelled heavy duty trucks predicted (2025)	= 2.0 to 3.3% (of 2015/16 vehicles)
Number of heavy duty vehicles in Scotland (2015/16)	= 41,000 Number
Number of heavy duty LNG fuelled trucks in Scotland (2025)	= 1,093 Number
Number of heavy duty LNG fuelled trucks in Scotland (2040)	= 20,431 Number
Assume each vehicle travels	= 82,000km / year
Assuming LNG demand per 1,000km	= 0.85m^3/1,000 km
Total volume of LNG required 2025	= 34,000 to 76,000m^3/year
Total volume of LNG required 2040	= 700,000 to 1,420,000 m^3/year

Based on the above there could be an increase in the use of LNG fuelled trucks and therefore potential growth in demand for LNG filling stations. Currently the Isle of Grain importation terminal in Kent is the only facility in the UK capable of loading LNG road tankers, for distribution to LNG filling stations. Going forward, the proposed Rosyth facility is well placed to meet demand for heavy duty vehicles in Scotland but future growth could drive the need for further facilities.

4.4. Power generation

With the cost of electrical cars predicted to reach parity with internal combustion powered cars by the early to mid-2020's, a 20-30% increase in power generation could be required to meet demand [48]. However, long term future energy demand is difficult to predict and better efficiency and changing technologies and habits could impact whether additional power generation is needed. However, in the short term, it is expected that further power generation will be needed. Electrical power generated from LNG could secure energy generation supplies and add capacity to the network, although there is preference for renewables generation.

Demand: LNG demand from Power Generation

In the following, one scenario of many possible for LNG demand from power generation in 2025/30 is calculated for illustrative purposes only.

Assuming
The demand justifies an 1,853 MW power generation capability.

Nominal power station capacity	= 1,852MW
Nominal yearly power station capacity	= 16,223,000 MWh/year
Operating efficiency	= 50%
Actual yearly power station generation	= 8,100,000 MWh/year
Actual yearly power station generation	= 8,100,000,000 KWh/year
Power per m3 of gas	= 10.73 KWh
Conversion estimate	= 43%
Electrical power per m3 of gas	= 4.64 KWh
Total volume of gas required	= 1,750,000,000 m3
Total volume of LNG required	= 2,900,000 m3/year

The Pembroke Combined Cycle Gas Turbine (CCGT) power station in Wales provides an example of the demand for LNG which could be replicated. Built with an estimated investment of £1bn and has a total generating capacity of 2,160MW, the power station generates electricity for approximately three and a half million homes. We have used 1,853 on the basis of existing power station proposals in Scotland.

The total volume of LNG required for power generation could drive demand for LNG in Scotland and would represent a shift in the industry. The demand articulated above would be dependent on the energy generation future strategies and investment. However, the closure of Torness (2031) and Hunterston B Nuclear Power Stations (2023) will reduce Scotland's electricity generation capacity if growth in renewables does not meet this shortfall.

Electricity generation has the potential to be the largest single user of LNG in the foreseeable future. A mid-sized power station which is seeking to generate 1,852 MW has the potential to be the largest single user of LNG, whilst any smaller power station (<1000MW) could also contribute to demand and potentially induce development of LNG demand and infrastructure across Scotland. There are several potential locations for power stations with those near or adjacent to port facilities providing advantages.

4.5. Industrial

There are a range of Energy Intensive Industries (EIIs) in Scotland and other businesses which utilise large amounts of gas or electricity which could benefit from utilising LNG as a heat source or using LNG to generate electricity. EIIs are defined as companies where energy costs are greater than or equal to 10% of gross value added. DECC estimates that EIIs account for roughly 50% of UK industrial energy consumption. As such, reducing this industry's reliance on fossil fuels could make a significant difference to emissions in Scotland.

EIIs include cement, ceramics, chemicals, glass, industrial gases, iron and steel, non-ferrous metals, pulp and paper, and coke and refined petroleum product industries. EIIs require certainty that energy and feedstocks will be secure and competitively priced in the medium term in order to secure future investment. Without

[48] Scottish Power, National Grid and Cambridge Econometrics have outlined between 10-30% more power generation for a move to electric vehicles. See: http://www.bbc.co.uk/news/uk-scotland-scotland-business-41373466 and https://www.carbonbrief.org/analysis-switch-to-electric-vehicles-would-add-just-10-per-cent-to-uk-power-demand.

certainty, it is likely that these sectors will decline, reducing employment, economic activity and manufacturing output.

If any EIIs in Scotland were to utilise LNG as an energy source (as heat or electricity) then the demand for LNG could increase. Some industries (e.g. ceramics) have no practical or economically viable alternative to the use of natural gas to generate high temperatures in kilns. Furthermore, several energy intensive industries (e.g. fertilisers and petrochemicals) require competitively priced sources of natural gas and other hydrocarbons as feedstocks. There is evidence of long-term LNG contracts being established in the industry. However, the industry trend is for shorter term contracts. The use of LNG by EIIs could be a driver for LNG demand which could also drive use across other sectors.

The demand for LNG from one large EIIs is presented below.

Demand: LNG demand for electricity from an EII business

Therefore	
Nominal EII capacity	= 10MW
Nominal yearly capacity	= 87,600 MWh/year
Operating efficiency	= 100%
Actual yearly power consumption/generation	= 87,600 MWh/year
Actual yearly power consumption/generation	= 87,600,000 KWh/year
Power per m3 of gas	= 10.73 KWh
Conversion rate to electricity say	= 43%
Electrical power per m3 of gas	= 4.64 KWh
Total volume of gas required	= 18.900,000 m3
Total volume of LNG required	= 31,500m3/year

There are potentially several EIIs across Scotland that may require their own power generation and where LNG could play a role. However, at this stage we estimate that the demand from industry would not drive significant LNG demand in Scotland overall. The return on investment from LNG though may be attractive and drive rapid uptake and further industry demand or interest should be monitored.

4.6. Other demand

A range of other demand sources were identified in the research process. The below section reviews the potential demand sources which exist, highlighting their potential scale and the linkages to other demand sources.

4.6.1. Residential

SGN, the organisation that manages Scotland's gas network, distributes gas to Statutory Independent Undertakings. SGN is required under licence to support the SIUs and purchase their requirements at previously determined regulated prices. These include Independent Networks in Stornoway, Wick, Thurso, Oban and Campbeltown which are not connected to the National Transmission System, but are instead supplied with natural gas by road tankers. Other fuels are also used in communities but the coastal location of the SIU's mean they are well suited to be supplied by LNG by sea.

There are also other residential gas network areas. Data published by Scottish House Conditions Survey estimates that 16% of households (396,000) in Scotland are off the gas grid[49]. Excluding Orkney, Shetland and Eilean Siar (Western Isles), the local authorities with the highest proportions are Highland (61%), Argyll & Bute (49%) and Aberdeenshire (40%).

Table 4-1 Scotland Local Authorities with over 35% of households not on the gas grid

[49] Off-Grid Energy An OFT market study October (2011)

Local Authority	Domestic gas meters (thousands)	Estimated number of households not connected to the gas network (thousands)	Estimated % of households not connected to the gas network
Eilean Siar (Western Isles)	-	13,000	100%
Orkney Islands	-	10,000	100%
Shetland Islands	-	10,000	100%
Highland	40,000	62,000	61%
Argyll & Bute	20,000	20,000	49%
Aberdeenshire	62,000	42,000	40%
Dumfries & Galloway	43,000	24,000	36%

Source: DECC 2015

Across Scotland there are 396,000 households not connected to the Gas Network in Scotland whilst Ofgem highlights that the average Household uses 12,0000 KWhs of Gas per year[50] . There are 7,500 households which are covered by the SIUs and the size of the off-grid market shows the potential LNG market could be much larger, although some off-grid housing is in urban areas.

An estimate of demand for domestic use is highlighted below.

Demand: Residential

Number of households not connected to the gas network	= 396,000
Average household usage of gas	= 12,000 kwh
% converting to LNG	= 50%
Total demand per year	= 2,376,000,000 kWh/year
1 m^3 of gas energy content	= 10.73 kWh
Gas to LNG	= 600
Actual LNG required	= 370,000 m^3/year

This represents a strong market for LNG but it is also fragmented. The take up of LNG would be dependent on technology, individual will (and investment), funding and capacity within residential buildings and available infrastructure. There are some risks in using LNG in residential properties but the industry in general has a good safety record, although careful planning would be required for more concentrated residential areas. The actual scale of demand from residential is unknown due to several variables and uncertainties, although the potential size of the market is highlighted by the straightforward calculation.

4.6.2. Agriculture, food and drink

The demand for LNG could be driven by agricultural industrial processes (as heat or electricity in raw material manufacturing), transport (e.g. lorries, tractors, etc) and use of natural gas as a product in plastic, fertilizer, anti-freeze, and fabrics. Utilising LNG could allow significant reductions in costs for these activities. However, it would also require infrastructure upgrade or investment in new technology. There is little academic or industry literature on the impact of LNG upon the agriculture industry, many reports instead highlighting the different uses rather than sectoral impacts.

Industrial feedstock (e.g. manufacturing of chemical products) is another potential source of agricultural demand. Although no significant demand has been identified at this stage, it could constitute an area of future growth.

The Scottish Government has in the past supported agricultural businesses to install small scale renewable energy capacity to reduce emissions and improve business viability. The Agri-renewables strategy from Scotland also highlights how energy installations should be integrally linked to energy efficiency as part of the overall shift towards a low carbon economy. The strategy highlights renewable technologies as being most

[50] Ofgem 2017

effective in terms of cost, carbon emissions reduction and reduced energy bills when combined with energy efficiency measures.

LNG also has the potential to play a role in the estimated 27,000 agricultural businesses and 51,896 farm holdings in Scotland. The whole agricultural sector needs to find a balance between increased intensification of agricultural production and climate change impacts. The changes expected in the agricultural sector as a result include stronger collaboration, stimulating greater innovation and adaptation to climate change impacts, reducing carbon impacts in logistics and distribution networks and prioritising resource efficiency.

At the moment opportunities for LNG exist primarily in certain sub-sectors of the agricultural sector. Across rural Scotland, the Food and Drink Sector is intertwined with agricultural production. Given the importance of this sector to the Scottish Economy (£3.65 billion in 2012), there are likely to be specific areas where LNG could be utilised, one of which includes the Scottish whisky industry.

The proposed Rosyth LNG facility is working on a joint project to bring LNG to Scottish breweries and distilleries which are not on the existing natural-gas grid. Given that the whole whisky industry utilises over 3 billion KW/h per annum and the remote location of many firms and the relative energy intensiveness of the activities is driving energy investments, LNG could play a further role as an energy provider to distilleries.

It is estimated that natural gas accounted for 54% of the whisky industry's total primary energy use in 2010 and the vast majority (87%) of the heavy fuel oil used in the industry was at malt distilleries where the gas grid is not accessible due to their relatively remote location.

The 102 malt distilleries in Scotland could be a focus for LNG use, as their remote locations frequently preclude access to the gas grid. The whisky industry in general is focused upon reducing emissions and alternative energy technologies such as biomass, solar and wind are increasingly being adopted by producers. There are also opportunities from distillery by-products to be captured and used for energy production (using their own methane for use or grid injection). This could limit LNG take up.

Demand: Whisky Production

The Scottish Whisky industry is a major consumer of electricity, in 2010 54% of which was from natural gas, with an objective of making more use of renewables

Total production per year (litres)	= 61,000,000,000
Average electricity demand per litre	= 0.367kwh
% converting to LNG	= 50%
Total demand per year	= 11,193,500,000 kWh/year
1 m3 of gas energy content	= 10.73 kWh
Gas to electricity conversion efficiency	= 43%
Gas to LNG	= 600
Actual LNG required	= 4,024,459 m^3/year
Number of malt and grain distilleries	= 108
Average LNG demand	= 37,263 m^3/year/distillery

There is a potential demand for road and sea transportation for LNG which could service the food and drink logistics sector. There is also potential for the 2,000 Scottish fishing vessels and agricultural vehicles to utilise LNG fuels. However, our research has identified that demand from these areas is uncertain and potentially small. We cover the road transport and marine demand above.

4.6.3. Other demand considerations

A couple of other considerations have been identified in the review of demand:

- **Bio-LNG:** LNG production from bio-LNG plants is increasingly being explored. Bio-LNG comes from biogas (produced anaerobic digestion). It provides an opportunity for circular economy processes and sustainable sources of LNG production. Biogas is one of the cheapest and cleanest biofuels (e.g. emits negligible NOx or particulate matter when burnt). It is methane rich and creates a situation whereby LNG reduces its carbon emissions (Bio-LNG can be carbon negative) further, but can produce other challenges (e.g. competition for food or land use).

Producing biogas from anaerobic digestion is proven and the potential exists in Scotland for further infrastructure to be developed. Northern Ireland has developed a small-scale commercial unit to produce liquefied biomethane from biogas via anaerobic digestion from dairy farm waste[51]. Any development of a similar plant in Scotland could see a local LNG supply, stimulating the increased take-up of LNG. For example, the Gothenburg Biomass Gasification Plant with a 20MW first phase and a second phase of 80-100MW capacity is expected to initially supply 5,000 cars or 400 buses a year and a Phase 2 could supply between 80,000 and 100,000 cars.

- **Hydrogen:** Throughout the research process hydrogen has been highlighted as a potential alternative fuel source which could deliver further benefits to the economy and emissions reduction. Hydrogen as a low-carbon energy source could be used for replacing oil as a transport fuel or natural gas as a heating fuel. Hydrogen is attractive because whether it is burned to produce heat or reacted with air in a fuel cell to produce electricity, the only by product is water.

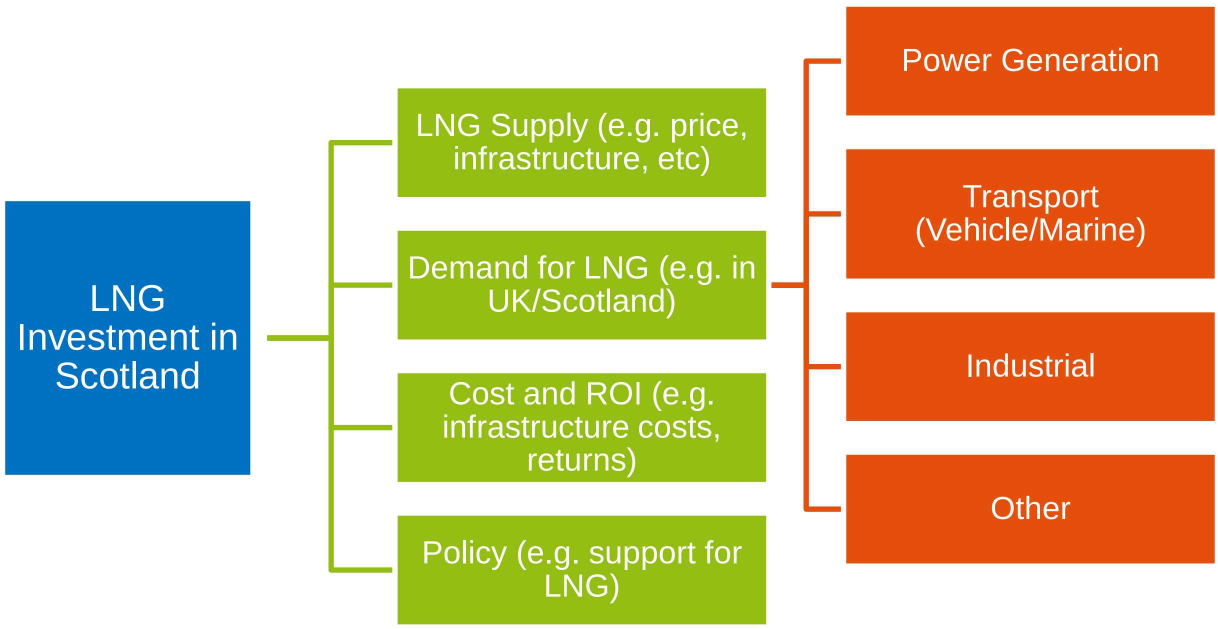
  Hydrogen could also be useful as a way to store renewable energy from intermittent sources – for example, when the wind is blowing but there is not high demand for electricity. In this context, it is an alternative to large-scale batteries or other storage systems. Hydrogen also contains almost three times as much energy as natural gas. However, hydrogen is not a fuel, but a way of storing or transporting energy. There are also technological barriers and safety concerns which need to be overcome before hydrogen can be used more commonly.

Academic evidence highlights the benefits and possibilities from utilising hydrogen as an energy source[52]. Of particular interest is the energy content and the lack of emissionsIt is suggested that further comparative assessment research is undertaken to assess how hydrogen compares to other energy sources, how it could play a role in Scotland's energy demand and meet the energy demand in the future.

4.7. LNG Demand Summary

The below diagram highlights a simplified structure of the key drivers for LNG Investment in Scotland. It highlights the key importance of demand for LNG, but also other factors including supply, costs of investment and support.

Figure 4-2 Drivers of Investment for LNG in Scotland



[51] See report here: https://www.gasworld.com/northern-ireland-to-get-first-ever-bio-lng-plant/2010670.article
[52] See for example, http://tsrc.berkeley.edu/sites/default/files/Lipman_GHG_2011_0.pdf and http://agronomy.emu.ee/vol10Spec1/p10s102.pdf

Source: Atkins 2017

LNG providers will only invest in LNG if they are confident that LNG has a future in Scotland. The planned and existing LNG infrastructure in Scotland (and the UK) provides some certainty and confidence for investors. Furthermore, the positive policy across Europe supports further LNG infrastructure investments. The end users of LNG and their decisions to use or switch will determine how fast the LNG market will develop in Scotland. The shipping industry has already seen switches to LNG driven by policy and there could be future shifts in other industries (e.g. transport, manufacturing) if policy directs or influences how energy use is taken up.

The scenarios for LNG demand in the previous section could significantly alter if energy infrastructure is fast-tracked, tougher emission regulations for vehicles and ships are introduced, and positive price developments of gas occur. However, at this moment, the use of LNG in Scotland is small but growing. Businesses and the public sector will need to invest to be able to fully benefit from the advantages that LNG offers

In totalling the above demand, future LNG demand in Scotland could see a maximum total demand for up to 4,700,000 m3 per year. This demand is above and beyond the demand currently proposed to be serviced by facilities in Rosyth and the Orkneys. Stolt Nielson have identified a potential market of 442,000m3 in Scotland (over 5 years) and the North of England in the short term with a focus upon ship to ship, terminal to ship and truck to ship bunkering. The initial investments made at these locations will give them first mover advantages with emergent demand. This will provide them with the opportunity to exploit cost and market advantages before other investors; allowing them to meet more of the predicted demand and therefore reduce the scope for new investors.

From the demand assessment, it is apparent that power generation and road transportation are key drivers for demand. Should individual major energy users convert to LNG, they would need; on site storage, a means of re-gasification and be capable of being resupplied by ship. We assess the LNG transportation and regasification options which could be explored in the next section.

There is also a temporal aspect to demand which is subject to uncertainties and difficult to forecast. Nevertheless, timescales for the above are important. Demand could grow quicker, slower, or in line with the timescales presented in the demand estimates. For example, the shipping industry's adoption of LNG vessels is one area where uptake could be more rapid than anticipated[53]. Similarly, recent investments in LNG infrastructure by energy suppliers like Calor could support further adoption of LNG by the commercial vehicle market[54]. Given the scale of demand for power generation, any change to timescales for this development would have a substantial impact upon total demand.

The demand assessment should be considered as indicative of the potential size of the relative markets for LNG.

[53] For example, the Sea Europe (2017) Market Forecast Report.
[54] See report here: https://www.gasworld.com/calor-brings-uk-lng-station-toll-to-nine/2010731.article

5. LNG transportation and regasification

This section outlines the transport and regasification options which could be explored in Scotland to meet the demand for LNG identified in the previous section. If total LNG demand is to reach 4,700,000 m^3/y and with nominal LNG carrier capacity of 125,000m3 this equates to approximately 37 deliveries per year. The demand is in addition to the current demand being met by facilities in Rosyth and the Orkneys.

We present the transportation and regasification infrastructure options below for a new terminal in Scotland but note that the industry could develop in several ways, with expansion of Rosyth potentially able to meet some (or more) of the demand or several areas across Scotland developing small scale LNG import terminals.

A new LNG terminal in Scotland will need to meet requirements around gas demand, have flexibility for potential expansion (as demand is expected to increase but also to address uncertainty) and capacity or phased development.

5.1. LNG Carriers

LNG carrier vessels are a key part of company business models. There are examples of vessels being shared between locations (where regular shipments are not needed). This is one of the proposals for Rosyth which will reduce costs and highlights the flexibility of small scale LNG.

The principal dimension of selected LNG Carriers is summarised below (Actual dimension may vary by +/- 10%):

Table 5-1 LNG Carriers

Description				Q - Flex	Q- Max
Containment	Moss Tanks	Membrane Tanks	Membrane Tanks	Membrane Tanks	Membrane Tanks
Capacity (m^3)	125,000	140,000	177,000	216,200	267,000
Displacement (t)	99,000	100,000	120,000	141,000	175,000
Length (m)	274	280	298	315	345
Beam (m)	42	43	46	50	55
Laden Draught (m)	11.3	11.4	11.8	12	12

Source: PIANC WG 121 Harbour Approach Channel Design Guidelines (Ref 121)

Analysis shows that the clear majority of LNG carrier fleet is over 125,000m^3 capacity, while in the future new build LNG carriers are likely to be larger (between 160,000m^3 to 267,000m^3 vessels).

The transportation of LNG requires stringent safety and resilient infrastructure. LNG needs to be kept at very low temperatures in an unstable liquefied state. However, LNG Carriers have some of the best safety records for all maritime vessels. There are also stringent tests for officers and crews and vessels should be maintained meticulously, and renewed frequently.

5.2. LNG regasification options

Three principal operating methods can be used for the regasification of LNG. The scale of demand outlined in the previous section suggests that the following regasification options could be suitable for infrastructure in Scotland:

- Onshore Storage and Regasification
- Floating Storage and Regasification (FSRU) Vessel
- Floating Storage and Regasification Barge (FSRUB)

The characteristics and operational requirements of each of the above are briefly discussed in the following section along with a fourth hybrid option, Gravifloats (or similar).

5.2.1. Onshore storage & regasification

With an onshore storage and regasification process, LNG is initially pumped from the LNG Carrier via cryogenic pipe lines to above ground storage tanks and is only re-gasified immediately prior to send out. The key issue being a suitable location for the storage tanks and re-gasification facilities. The location of the storage tanks and regasification facilities will dictate head loss losses and heat gain in the cryogenic pipes which in turn will determine the requirement for booster pumps and fix the location of the cryogenic tanks.

Onshore storage tanks for LNG would typically have double skinned containment, comprising a concrete external tank with a steel inner tank and insulation in between. Ground heating under the tanks is required to prevent the tanks freezing the ground and causing problems.

Onshore regasification of LNG can be under taken by many methods including:

- Heaters using a closed-loop heating medium;
- Submerged combustion vaporisers using combustion as a heat source;
- Sea Water vaporizers returning chilled sea water via an outfall;
- Heating towers with intermediate water and supplementary heaters;
- Gas turbine generators; and,
- Steam turbine generator.

The relative merits of these systems are outside the scope of this study.

The principal factor regarding to construction of an onshore re-gasification terminal is securing a long-term supply contract. As a reliance on short term economic conditions may result in a stranded asset. A long term contractual commitment would be required to construct such an on-shore facility

5.2.2. Floating storage and regasification unit (FSRU)

From a current global fleet of only 25 vessels, the market is dominated by Excelerate with 7, Golar LNG with 7, and Hoegh with 6. FSRU vessels are either classified as ships or offshore installations. Ship design adheres to worldwide LNG trading operations, dry docking and international marine safety standards. Most FSRUs are classified as ships to provide the flexibility to operate either as an FSRU or LNG tanker.

5.2.3. Floating storage and regasification barge (FSRB)

The development of FSRBs is still in its infancy; they are being developed to allow small volumes of LNG to be delivered to markets not normally accessible to a FSRU or where the building of an onshore facility is not economically. Characteristics of FSRB will vary but indicatively the characteristics are highlighted in Table 5-5:

Table 5-2 FSRB Characteristics

Description	Characteristics
Capacity (m^3)	25,000 – 30,000
Length (m)	80 – 150
Breadth (m)	30 - 40
Draught	5 -10
Gas send out rate (t/hr)	50
Gas send out pressure (bar)	16

Source: TGE Marine Gas Engineering (Ref 103) Wartsila (Ref 104)

From available literature, the following conditions are also suitable for FSRBs:

- In situations where an onshore tank facility is difficult to build.
- If regulatory permits to build onshore are difficult to obtain.

- When the water is too shallow for FSRUs and large-scale LNG carriers.
- Where a temporary solution is needed while more permanent facilities are being developed.
- When limited demand cannot support a large fixed facility or a conventional large-scale FSRU.
- When flexibility is demanded and adapting to changing market conditions is essential (e.g. capacity can quickly be increased or equipment relocated and sold).

The storage capacity of a FSRBs is more aligned with the immediate opportunities available in Scotland.

Figure 5-1 Indicative FSRB (Ref 104)

Source: Sembcorp

5.2.4. Gravifloat

Gravifloat[55] represents a variation of a FSRB and is a marketed by a subsidiary of Sembcorp Marine (Gravifloat should be considered as representative of such systems, other suppliers may have similar technologies). It is a new technological innovation. Gravifloat designs and patents, a range of flexible modularised near shore floating gravity based LNG Terminals including re-gasification options. They are reported to be potentially more cost effective than traditional FRSU / FSRB operations.

It is not apparent from publicly available information if a Gravifloat solution has ever been deployed, but several potential advantages are apparent:

- It can be readily relocated, if market conditions require;
- Modular construction and operation, allows for a ramping up in capacity;
- Fabrication is in the controlled environment of a shipyard;
- The facility can be tested and substantially commissioned at the point of fabrication allowing quick and easy on-site commissioning;
- The re-gasification equipment can be mounted on the Gravifloat; and,
- The storage capacities of the Gravifloat is potentially up to 90,000m^3 .

[55] Gravifloat is presented as indicative of the emerging technologies for small scale LNG. Other technologies are could be available and should be explored.

Figure 5-2 Gravifloat LNG receiving terminal (Ref 105)

Source: Sembcorp

5.2.5. Regasification process

LNG is stored in the tanks and sent to vaporisers which warm and regasify the LNG. The main types of vaporisers used in the LNG industry are Open Rack Vaporisers, Submerged Combustion Vaporisers, Intermediate Fluid Vaporisers and Ambient Air Vaporisers[56].

FSRUs, FSRBs and Gravifloat options can be capable of 3 types of regasification processes:

- Closed Loop – The FRSU boilers are used to heat fresh water circulated through LNG vaporizers in a closed loop.
- Open Loop – The FSRU draws in seawater which is circulated through LNG vaporizers in an open loop.
- Combined Loop – The FSRU draws in seawater, heats it using steam from the boilers and circulates it through the LNG vaporizers.

5.3. Additional infrastructure

In addition to the above transportation and regasification facilities, additional LNG infrastructure could be required across Scotland. This is likely to be shaped by the source of demand. For example, for new power generation powered by LNG there will need suitable sites and connectivity to gas and the electricity grid.

One area where LNG could make a difference is in road transport. The ambition to create LNG Blue Corridors' in order to create a road network with LNG stations every 400 km in Europe could see requirements for additional infrastructure. This could in turn drive LNG demand in Scotland. The use of LNG fuelled buses and trucks could reduce both the concentration of pollutant emissions and noise in urban areas

Infrastructure requirements resulting from transport infrastructure growth could include gas refuelling stations, dedicated depots, and connectivity to import terminals. LNG would be delivered by tanker trucks from an import terminal to the service station. There are currently few accessible stations whilst increasingly fleet operators are looking at semi-private refuelling facilities. Other options include mobile filling stations or semi-mobile stations which can be temporary solution or integrated into long-term infrastructure.

Given the range of potential infrastructure requirements, assessing the infrastructure needs requires further research as it is dependent on demand developments. In addition to the built infrastructure, additional soft infrastructure around policy and Government support is also necessary. This is broad in its remit but could include workforce development (e.g. skills development), working with the EU around standards for LNG infrastructure, agreeing common technical specifications and assessing cross border transport operations. In

[56] GIIGNL Study Group - LNG Process Chain (date unknown)

addition to this, policy or government decisions could support the industry by reducing delivery restrictions (areas or peak hours), addressing transmission charges, overcoming planning conditions and highlighting the possibility of LNG to different users.

5.4. Summary

Based on the above analysis, there is potential for a FSRB and Gravifloat (or similar) or other floating terminal solutions to be investigated further in Scotland[57]. The use of a FSRB, Gravifloat (or similar) or the construction of an on-shore facility will be determined by the demand and financial viability of the various opportunities identified for LNG in Scotland. However, some of the financial considerations include:

- There is uncertainty around Gravifloat operational and construction costs as there are few examples of this being utilised. However, it is marketed as a cost competitive alternative.
- An FRSU can be hired at an indicative cost of say US$ 100,000 per day, plus a mobilisation/demobilisation cost (actual costs will vary significantly depending on availability),
- Alternatively, an FRSU could be purchased/constructed and dedicated to this project at an approximate cost of US$ 250M (180,000m^3). If the commercial environment for the importation of LNG into the UK changed the vessel could be relocated to other location / projects.
- Timescales for developments can be long. Permitting can take between 12-18 months with planning and design before that and construction making the overall schedule around 3.5 years to get started.

Onshore cryogenic storage tanks, would cost approximately US$ 100M (150,000m^3) and re-gasification facilities would also add further significant cost. Such fixed assets would have little value if the UK LNG import economics changed and they may become a stranded asset.

5.4.1. Indicative investments

As a result, to assess the approximate scale of investment for LNG infrastructure, the following costs in Table 5-3 are identified for a FSRB[58]. There is uncertainty to this information due to the variable technologies, locations and end user costs. As a result, these figures, whilst indicative, should be used with caution.

Table 5-3 Indicative Investments

Area	Cost	Assumption
Construction		
Modifications to site infrastructure	£40,000,000	Changes to existing port infrastructure, jetties or other[59]. Figures based on previous work.
Gas Storage	£260,000,000	This assumes several gas storage facilities at £90million each as well as connecting infrastructure and safety considerations.
Regasification facility	£210,000,000	FRSU purchase rather than hiring.
Loading, Onshore interface/infrastructure facility	£30,000,000	Additional facilities including transport, storage and offices.
Operation		
Operating costs including: • Staff • Maintenance • Technology	Operating expenditure calculated as 2.5% of CAPEX per year.[60]	
Total		
Construction	£648,000,000	Includes contingency of 20%

[58] At this stage we are focusing upon the costs for FSRB as Gravifloat technology has less information available on costs to inform this high level assessment.
[59] Jetties can be expensive and at around £6,000 per metre of Cryogenic cable, lengthy jetties can be expensive. However, they can provide benefits including deep water access, safety and logistical benefits
[60] Oxford Institute for Energy Studies (2017), The Outlook for Floating Storage and Regasification Units (FSRUs)

Area	Cost	Assumption
Operation	£21,060,000	Includes contingency of 30%

Source: Various including Atkins' experience. Note: Costs exclude the consumption of LNG to generate heat and power for the regasification process.

The timescales to develop a LNG project can range from 18-40 months depending on planning permissions, technology and financing. New build FSRUs typically take 27-36 months although some facilities can be reassigned from other areas (e.g. where new infrastructure has been created) which speeds up the process.

Funding for much of the infrastructure identified above would come from inward investment or existing commercial entities seeking to exploit the opportunities of LNG in Scotland (and the north of England). The role of regulation and the public sector in LNG infrastructure is largely around enabling infrastructure investment (e.g. through the planning process). However, bodies like Ofgem, SGN and National Grid also play a role in influencing what investments are made, identifying connections that could be strengthened, collaborating on transmission costs and identifying where investment would support the best interests of customers and enable value for money.

6. Impact and delivery

There is a clear positive economic contribution from the energy sector in Scotland. Latest figures show that the energy sector in Scotland employs 51,000 people and generates £16.4 billion GVA[61]. As a result of this, the sector's future growth, transition and progress is of importance to policy makers, investors and industry groups.

The previous sections highlight how LNG provides further opportunities to decarbonise the economy, support the transition from coal and provide well paid, sustainable jobs to local communities in Scotland. This section explores the potential impact of LNG investment in Scotland, highlighting the potential economic impact by drawing upon available information on the sector and related studies in the LNG and energy sector.

> Stolt-Nielsen is developing a 10,000m3 LNG terminal and distribution facility in the Port of Rosyth. Stolt-Nielsen will source LNG via its 7,500m3 LNG carrier from mainland Europe/UK and store the LNG in the Scotland LNG Terminal where LNG will be distributed across Scotland and Northern England by rail and truck.
>
> Total investment is estimated at £80-100 million with an employment impact that includes the potential for 130 professional workers during construction (40 technical and engineering positions and 90 highly skilled construction jobs). It is anticipated that employment during operation of the terminal and other facilities will create 113 professional workers (77 technical jobs and 36 other jobs).
>
> Source: Stolt-Nielsen 2017

6.1. Economic impact from LNG

There are few UK studies of the local or national impact of the LNG sector upon the economy within academic or industry literature[62]. Many studies look at the market potential of LNG for local or national areas. There are more studies which explore wider energy or port sectors but do not disaggregate data to identify those elements of the economy which are driven by LNG.

There is more information about the LNG industry's economic impacts from other countries. However, this also has limitations, use of Australian or American data on the industry would not be comparable to the UK due to the focus upon supplying LNG rather than consuming. We present some of the most relevant case studies below.

Table 6-1 Economic Impact Case Studies

Location	Economic Impact
Milford Haven, Wales[63].	Milford Haven is one of Europe's largest importation ports for LNG handled through South Hook LNG and Dragon LNG terminals. A study by the Milford Haven Port Authority on the economic impact, highlights the port's importance to the local economy in terms of economic activity, jobs, wider supply chain and intangible benefits. The report does not break down the impact of the port in terms of LNG[64]. However, it highlights that the contribution of the port in terms of jobs is 3,808 (and wider contribution of 5,703 jobs to the Welsh economy), with the Port contributing £412million GVA to the Welsh Economy. The report highlights the importance of the port, despite environmental, wider economic and locational challenges. The port contributes a high proportion of high value jobs (high skill and highly paid) to the local economy. However, the wider area features GVA per capita levels which are lower than the national average. The report also highlights the importance of LNG to port activities and employment. However, it also highlights risks to the energy sector and

[61] Scottish Government Economic Data (2017) The oil and gas sector contributes a large proportion of total output and employment with the GVA at £13.1 billion and the UK oil & gas employment at 375,000 with approximately 45% in Scotland.
[62] A study for the European Commission highlighted that LNG regasification and transportation in Europe can see high rates of return and investment incentives for facilities shows positive economic impact.
[63] Port of Milford Haven
[64] The authors of the report were contacted for further information.

	how a decline in this sector could have major negative effects on the local and national economy.
Netherlands[65]	A study by PWC on the potential of small scale LNG and the economic impact upon the transport sector for the Dutch Ministry of Economic Affairs. This work highlights the economic growth potential, specifically jobs, economic contribution and wider infrastructure connectivity from small scale LNG. The report prepared in 2013 highlights how small-scale LNG is now in the market development phase (characterised by a large amount of uncertainties). After gradual growth via early industry adaptors, the market is expected to grow substantially after 2020. The drivers for LNG are identified as industry take-up, policy, fuel prices and competition. The report highlights the challenge for the industry in that "LNG is a suitable fuel for transport companies, as it can support long-distance travel on a constant base. Currently, LNG is only adopted on a limited scale" The report also highlights that demand could grow and provides different scenarios around growth, including low LNG demand growth, growth in line with current trends and clean growth (high growth). The report highlights the economic potential with around 8,000 job years will be added due to investments in infrastructure, and trucks and vessels and an estimated potential economic impact of c.€2.7bn on GDP related to direct investments of c.€1.5bn. The report also identifies further potential economic positives from bio-LNG production and take-up from the transport sector.
Shannon, Republic of Ireland	A range of benefits are identified in a report for Shannon LNG[66] (owned by the Hess Corporation) on the economic impact of the Shannon LNG project to Ireland. The main benefits which are highlighted from the project include: • Impact on the economy. • Tax/exchequer impacts • Competitive gas prices though increased supply into the market • Security and diversity of supply • Benefits in the electricity market, though improving the economics of electricity generation • Environmental benefits, through encouraging a switch from other fossil fuels. The report highlights the potential benefits of LNG investment in Shannon and Ireland which include conservative estimates of contributions to the economy of €1.35 billion (which excludes potential economic benefits to lower prices and environmental benefits). The work also estimated benefits to the Irish Government's Exchequer of €410 million and highlights the role of LNG in Ireland in linking up the global market for natural gas. The report also identifies security, diversity of supply, supply disruption and price rise mitigations. It also highlights that Shannon will be impacted by short term socio-economic dis-benefits but there will be significant economic benefits in the long-term.

This range of studies highlights the economic benefits which can be gained from LNG investment. In a review of existing literature, the most comparable and relevant studies for what is being proposed in Scotland are the studies in The Netherlands and Shannon, Ireland. Both studies highlight some further parallels and learning points around strategy, process and maximising economic impact and delivery.

6.2. Potential economic impact in Scotland

The studies in section 6.1 provides estimates of the potential economic impact Scotland could experience from LNG investment. However, there are several uncertainties around any future infrastructure in Scotland, not least location and scale of investment.

As a result, the analysis below presents an indicative economic impact assessment which draws upon several approaches to estimate economic impact. The analysis uses a range for job and GVA impacts which provides

[65] PWC (2013), The economic impact of small scale LNG: https://www.rijksoverheid.nl/documenten/rapporten/2013/09/02/the-economic-impact-of-small-scale-lng

[66] DKM, Shannon LNG– Economic Benefits to the Irish Economy Final Report (2008)

an indication of how LNG infrastructure could contribute to the economy. The analysis assesses the gross rather than the net impact, which means jobs and benefits created may not solely benefit Scotland.

Table 6-2 Potential Gross Economic Impact

Theme	Calculation	Impact
Jobs	The cost of construction (section 5.4) is divided by construction company revenue by employee (£257,000[67]) to estimate construction phase employment person years. Although the construction phase would last up to 3 years, it is standard practice to divide by 10 to obtain full time equivalent (FTE) jobs. As a result, the person years are divided by 10 years to obtain the FTE. Experience from other projects shows that peak construction employment could be around 800 people. For operational jobs, the operational costs of operating the LNG plant per year (section 5.4) are divided by FTE jobs per £million of operating costs (approximately 8)[68]. This standard approach within desk based economic impact studies is utilised where high-level information or limited information is available.	250 FTE Construction phase jobs. 150 FTE Operational phase jobs.
	Projects of a similar scale across Europe, including examples in Ireland and the Netherland provide a guide for the levels of investment, expected jobs and benefits that Scotland can expect. Utilising examples of LNG investments and previous projects) the levels of investment and jobs expected to be created were factored against the potential LNG investment (construction and operation) to provide an assessment of employment in Construction and Operation. This was reassessed against the size of potential investment expected in Scotland. Investments in an FSRU and LNG terminals range greatly in terms of employment created and economic output. For example, in Cork, Ireland an FSRU with £350 million investment created 100 jobs[69] whilst the Shannon €500 million proposal is expected to create around 450 (construction and operation jobs). As such, we have reviewed the potential scale of investment and jobs in line with these (and other examples) and identified a range of estimates on construction and operation figures.	200 FTE Construction phase jobs. 175 FTE Operational phase jobs. 350 FTE Construction phase jobs 100 FTE Operational phase jobs.
GVA	GVA figures are calculated utilising employment figures derived above with GVA per worker figures for construction and gas workers for Scotland: • £44,000 per job (for Construction Sector) • £167,000 per job (for Oil and Gas)[70]	£11 million GVA following construction and first year of operation (and £25 million GVA per annum) £8.8 million GVA following construction and first year of operation (and £29.2 million GVA per annum)

[67] Calculated from construction industry employment and project cost figures for the UK (Atkins analysis 2017)
[68] Calculated from employment outcomes and existing energy projects for the UK (Atkins analysis 2017)
[69] Texas to White gates referenced
[70] Available from ONS and Scottish Government data.

		£15.4 million GVA following construction and first year of operation (and £16.7 million GVA per annum)
	Estimates of GVA are based on activity and scale of demand from similar projects[71]. GVA estimated utilising existing project information on project size (m3) and costs are factoring up using ratios from similar projects against proposed LNG demand in Scotland.	Potential for £13.4 million GVA following construction and first year of operation (and £24.7 million GVA per annum)

Source: Atkins 2017, BEIS and Atkins research.

The analysis shows that the potential employment impact could create between 200 and 350 temporary construction jobs and between 100 and 150 operational jobs from investments in LNG[72]. The investments articulated in section 5 have the potential to be modularised which means that investments could pause, grow further or be utilised elsewhere.

The analysis above suggests that there is also potential for LNG infrastructure to deliver up to £38 million GVA activity to Scotland's economy. A large proportion of both jobs and GVA would be for the local area in which the infrastructure is located. Both employment and economic activity impacts highlight the benefits from expanding LNG infrastructure in Scotland, which would contribute to National productivity (£127 billion GVA) and if infrastructure was based in one or two sites, make a difference to the local economy.

The above calculations are only a narrow element of the economic benefit that LNG can deliver. The environmental, new market and spill-over benefits that LNG could deliver are not captured. In this assessment these benefits could, on the basis of existing evidence, be as significant.

One complication to economic impact is that construction of FSRUs (and other infrastructure) can be undertaken abroad (in shipyards, etc). However, there are aspects that can be constructed within Scotland and as such, the above assumes a positive scenario for construction of FSRU infrastructure in Scotland[73]. However, as with all construction and infrastructure projects there is the possibility that there will be elements constructed abroad and with technical staff from outside of Scotland and the UK.

6.2.1. Potential direct, indirect and induced effects

To provide a potential scale of the indirect benefits, we use multipliers devised for Scottish Government to "model the impact of hypothetical economic events"[74]. This approach is straightforward but the findings of this assessment should be treated as broadly indicative at this early stage as there are still many unknowns. However, this analysis provides an indication to the increases in employment or economic activity throughout the Scottish economy which could result from an increase in employment/economic activity, from investments in LNG.

Table 6-3 below identifies potential indirect and induced effects in terms of jobs and GVA for the wider economy.

Table 6-3 Gross Employment and GVA Multipliers

Impact Type	Employment Multiplier (Type 2)	Indirect effect.
Employment	1.8 (Construction) 1.9 (Gas)	Between 310–370 further indirect and induced jobs for the Scottish economy.
GVA	1.9 (Construction) 1.6 (Gas)	A further £23.9 - £24.8 million GVA in wider indirect and induced activities.

Source: Scottish Government Input/Output Tables 2014 – Atkins Analysis. Type 2 Multiplier – calculates indirect (supply chain) and induced (re-spent income) effects minus direct).

[71] Shannon LNG project is expected to generate €30 million per annum GVA benefits.
[72] The employment analysis uses FTEs to highlight overall employment scale. Construction is likely to last up to 3 years whilst analysis for operational FTE is calculated on basis of 10 years of operation.
[73] To construct an onshore terminal can see employment of between 800-1,000 people.
[74] Scottish Government Input-Output Tables, available at: http://www.gov.scot/Topics/Statistics/Browse/Economy/Input-Output

The variance in indirect effects shows the uncertainties inherent at this level of detail and the unknowns around investment. When undertaking an economic impact assessment, it is also common to analyse the net additionality of impacts, including leakage (the benefits generated by LNG investment which are lost to other areas' or countries' economies) and displacement (the net impacts created by the investment are reduced due to economic activity moving from other areas). These figures are gross and do not show the net impact for Scotland's economy. To do so, there would need to be application of deadweight, displacement, leakage, substitution and optimism bias to calculate potential net impact on the economy. As such, the figures above must be considered in the context of this analysis not being undertaken. However, where further detail emerges, this can be calculated and analysed in more detail.

6.3. Wider economic benefits

There is an increasing focus upon wider economic benefits within private or public-sector investments, particularly related to infrastructure. This is in part because of the narrow focus of business case and economic analysis within Government investment decision making processes and frameworks. Below we highlight some of the wider economic benefits of LNG investment which have been identified through the research, noting their potential for LNG investments in Scotland.

6.3.1. Sector impacts

Investment in LNG is broadly seen as positive for the wider energy sector. Investment will provide further employment opportunities and potential agglomeration benefits that can support the oil and gas and wider energy sector. There could be some competitive dis-benefits but cumulatively the impacts are expected to be positive, given the complementary activities. Outside of the energy sector, other sectors could benefit including: engineering and manufacturing; transport; and professional services. They may benefit from labour market linkages or cost reductions associated with LNG. There may be some dis-benefit to tourism (of importance to certain areas' economic plans) or agriculture through disruption and landscape impacts caused by shipping, vehicle movements or further industrial development. However, negative impacts can be mitigated by solutions focused around location, landscape and design.

6.3.2. Skills and transferability

The LNG sector has a strong overlap with other energy sectors. This provides a potential opportunity for transfer of experience and skills across sectors, helping to safeguard jobs in the wider energy sector and also create new ones. This is already a focus of activity for other energy sub-sectors like renewables and could align with the decommissioning and wind turbine testing.

This research has highlighted that workers involved in the LNG industry are often highly skilled. Furthermore, construction workers often must be specially trained or skilled in constructing power infrastructure.

Table 6-4 below highlights the occupations which likely to be key to LNG infrastructure construction and operation. These employment areas could form the focus of future employment and skills initiatives (retraining/transition or upskilling).

Table 6-4 Potential Employment Areas for LNG

Construction phase	Operational phase
Carpenters, labourers and construction trades	Production Operations
Welders and fitters	Operational performance improvement analysts
Mechanical and electrical engineers	Instrumentation engineers and technicians
Geotechnical engineering	Gas process operators
Control and Instrumentation engineers	Telecom engineers and technicians
Project managers	Health and safety officers
Production Operations	Inspection engineers and technicians
Marine construction trades	Marine operation, Shipping and Port terminal
Operations engineers	Electrical process engineers and technicians
Administration, Legal and Human Resource	

Construction phase	Operational phase
Environmental engineers	
Security	
Scientists (chemists, physicists and metallurgists)	
Design engineering	

Source: Various LNG Industry papers, socio-economic projects and previous projects (Atkins)

Several of the occupations in Table 6-4 are listed within industry literature on skills shortages in the UK (and Scotland) and therefore any new investments should consider how the labour market can meet the employment or skills needs. More broadly, the energy sector currently faces skills gaps and there are also emerging skills gaps in countries that supply LNG. This could demonstrate a further constraint and challenge to maximising benefits from LNG investments.

Wages for many of the occupations involved in LNG importing have higher than average wage levels which could further drive benefits for local economies. Furthermore, this high wage and added value employment aligns with economic growth strategies and contribute to transforming Scotland's economy into one that is "future‑proofed, high‑tech and low carbon"[75].

Two other aspects that are clear from the research is that industry sector experience is often highly important to employment prospects and so is knowledge of safety procedures. Together these two areas can form the basis of requirements for training, education and employment initiatives for LNG in the future.

6.3.3. Inclusive growth

There are many building blocks of inclusive growth, but the overarching principle is for more people to contribute to and benefit from economic growth. Inclusive growth is of particular relevance to infrastructure development and major projects that are seeking additional benefits beyond job and GVA outcomes. Investment in LNG could secure wider benefits beyond employment and GVA.

Working with different stakeholders and collaborating with the private sector is important to the success of inclusive growth. LNG projects in other countries have seen local workers hired to build and operate facilities. If a LNG project was to be taken forward there would be opportunities to support education and training initiatives targeted at local communities, community cohesion and targeted work with deprived communities could unlock further benefits from investment. Another positive move is that the development and implementation of initiatives in the areas of procurement and employment are often positive steps which could support investment in energy infrastructure.

Deprivation in rural and remote communities, as well as fuel poverty (see below) is a concern for policy makers and LNG investments could make a difference to deprived communities. Although complex, the siting of LNG infrastructure could provide advantages to local communities, although quantifying demand and funding infrastructure upgrades could complicate inclusive growth ambitions.

6.3.4. Fuel poverty

LNG also has a potential role in reducing fuel poverty, although some of the advantages are uncertain and dependent on market trends continuing[76]. There is a link between homes not using natural gas and the incidence of fuel poverty. There are approximately 845,000 (34.9%) households which are defined as being in fuel poverty[77]. The Scottish Government has committed to eradicating fuel poverty and any future energy supply issues which increase costs could have far-reaching issues.

Residences in fuel poverty can be reliant on heating oil or other expensive energy sources. Importing LNG could supply more homes with natural gas, providing a cost-effective alternative. There are particular advantages in supplying remote communities with natural gas. Small scale LNG could provide a flexible resource to generating electricity or heat for households and also help make energy supply more secure, to avoid large fluctuations in cost. However, as section 3.4.1 on LNG supply highlights, although costs are

[75] A Nation With Ambition: The Government's Programme for Scotland 2017-18
[76] A household is in fuel poverty if, in order to maintain a satisfactory heating regime, it would be required to spend more than 10% of its income on all household fuel use.
[77] Scottish Government - new draft fuel poverty strategy, including a new definition (2017)

expected to remain low there are uncertainties for prices beyond 2025. Furthermore, switching a home to LNG could be expensive for individual users[78].

6.3.5. Land use

LNG infrastructure has the potential to utilise existing industrial areas as well as expand into new areas. The construction and land disturbance required for energy infrastructure can alter land use and harm local ecosystems by causing erosion and fragmenting wildlife habitats and migration patterns. Distribution facilities for LNG may need to see sites cleared, pipelines build, and access roads created. The construction process can cause erosion of dirt, turbulence to waterways and release of harmful pollutants. However, in some cases existing brownfield sites can be used which minimises disruption.

6.3.6. Health impacts

Natural gas is a fossil fuel, though the emissions from its combustion are much lower than those from coal or oil. LNG has the potential to reduce emissions, particularly where other fossil fuels are being used.

The Road to a Healthier Future (2015)[79] outlines the role that natural gas can play in reducing transport and industry emissions. LNG, as part of a future energy mix, could therefore play an important role in reducing human health impacts from air pollution. From an economic perspective, the economic benefits of improved health from improved air quality could lead to reduced costs for the NHS in Scotland.

As a result, it appears that LNG has the potential to contribute to health and emissions targets by reducing greenhouse gas emissions[80] and reducing costs for the NHS in Scotland. It is reported that air pollution is responsible for more than 2,000 deaths in Scotland each year and costs NHS Scotland up to £2bn annually[81].

LNG suppliers also market LNG as having significantly less health and safety risks than oil based fuels. Given the impact that vehicle (and specifically diesel) emissions have on air quality, LNG has the potential to contribute to addressing public health concerns. This has an economic benefit on reducing healthcare budgets around respiratory illness. A further economic benefit could be observed on transport connectivity. There is a lack of evidence on the direct and indirect health impacts of LNG and further research is needed to explore the potential benefits.

6.3.7. Strategic

There is a strategic and political dimension to LNG which is best highlighted in the work in Shannon, Ireland but also in other places in the world (e.g. Chile). Investments in these countries highlight how LNG can encourage a better energy mix and support energy security. In Scotland (and the UK), this can mean reduced reliance on nuclear or coal fuels with an energy source that can address peak demand issues. However, there remains a risk in reliance on other countries LNG supplies. Geo-politics, economic risks and other events could impact upon LNG supply and demand.

6.4. Economic development delivery

This section outlines specific areas of strategic delivery which have been identified in the research and require further exploration. These should be considered in the context of LNG infrastructure investments in Scotland.

Table 6-5 Economic Development Actions

Theme	Comment
Maximising opportunities out of investments	Any proposed investment in LNG could be maximised for the benefit of communities in Scotland. This requires coordinated efforts by local areas, businesses, investors and decision makers to ensure that people are prepared, opportunities are highlighted (e.g. through procurement) and barriers to involvement are reduced.
Exploring skills synergies	There are clear overlaps between skill needs in LNG and other sectors in Scotland. The successes experienced in these sectors can be built upon in LNG and lessons

[78] There are some safety issues too which need to be overcome, particularly in more dense housing areas.
[79] The Road to a Healthier Future (CAFS) is to provide a national framework which sets out how the Scottish Government and its partner organisations propose to achieve further reductions in air pollution and fulfil our legal responsibilities as soon as possible.
[80] North Ayrshire Environmental Sustainability & Climate Change Strategy 2017-2020
[81] Health Protection Scotland (2014): http://www.hps.scot.nhs.uk/resourcedocument.aspx?id=1743

Theme	Comment
	learnt from skills challenges faced. There is potential for skills to also drive inward investment and better linkages with areas or countries with strong LNG infrastructure.
Site suitability	Any LNG investment should consider the suitability of local sites and the merits of different locations in investing in, seeking to attract investors or providing support to investing organisations. LNG investments favour existing industrial marine side locations with access to road. This research process has identified that certain locations and features of certain sites in Scotland are well placed for encouraging investment of LNG in Scotland, particularly those with existing maritime infrastructure, electrical or gas network connections and good accessibility.
LNG demand	The demand for LNG that exists locally, nationally and beyond is growing but there remains a level of demand yet to be realised. There remain barriers at a global level but also at a Scotland and local level which can be assessed and overcome. At a strategic level, these include policy positions or policy led tools (e.g. public procurement) to support uptake of different energy types or to encourage investments in certain infrastructure (e.g. ferries).
Scale of infrastructure	The extent and scale of LNG infrastructure can unlock different benefits to the economy: Small scale LNG can start to connect up demand and also support others in realising its potential. Large scale investment may utilise one or two large demand sources but also encourage others to explore the capabilities of LNG. The scale of infrastructure needs to be appropriate for the demand, whilst communication plays a key role in highlighting the potential.
Innovation	New investment can drive innovation, which in turn can enhance economic returns for Scotland. In relation to LNG, the developments in bio-LNG, small scale LNG and gas transfer technologies could be supported and provide further examples of innovation for Scotland to explore becoming a world leader in and gain additional benefits from.

7. Study conclusion

Demand for LNG as fuel for transportation is expected to increase rapidly, but from a very low base. The introduction of emissions restrictions within the European maritime Emissions Control Area has prompted a move to LNG or dual fuel powered ships, as demonstrated by CMAL ordering two LNG powered ferries that are currently under construction at Ferguson Shipyard on the Firth of Clyde. However, the first bunkering of a LNG power vessel using a purpose designed and built LNG bunker vessel, i.e. Ship to Ship bunkering, only occurred in June 2017. While in the UK the first ever LNG bunkering of a ship only occurred at the Port of Immingham in August 2017 using road tankers, from the Isle of Grain terminal in a Truck to Ship operation. The adoption of LNG powered vessels will, in part, be dependent on the availability of the appropriate bunkering infrastructure.

While the use of LNG in road transport has been promoted by the EU's LNG blue corridor projects for over 4 years, there remain only 22 LNG fuelling station in the UK only one of which is on Scotland. However, road transport with its relative short payback period does have the potential to see a rapid conversion to LNG.

The Government of Scotland in its "Scottish Energy Strategy" has the aim of moving to a low carbon economy, and by 2030 having over 50% of Scotland's heat, transport and electrical needs supplied from renewable sources. In addition, the Scottish Government has committed to no further nuclear power under current technologies, which combined with the decommissioning of Hunterston B in 2023, and the decommissioning of Torness in 2031 will leave a significant gap in Scotland's power generation capability, which could be filled by a LNG gas powered power station. Into this mix should also be added the potential of large industrial users of energy / gas to be supplied with LNG, such as distilleries. As a result, this report highlights that there is potential demand for further LNG trans-shipment facilities to be located in Scotland.

Investment in LNG could unlock many new jobs (up to 350 gross temporary construction jobs and up to gross 150 operational jobs) and contribute to productivity growth through a further GVA (up to £38 million gross GVA contributions annually including direct and indirect) to the economy. This does not include the wider benefits that LNG could unlock around health, transition for employment and respond to fuel poverty ambitions.

8. Actions and recommendations

We have identified a series of broad action areas which would support the future assessment of the benefits of expanding the LNG sector in Scotland. These are indicative and highlight areas of focus if the benefits of using LNG or investment is determined to be advantageous. The following are identified as broad actions and recommendations for Scottish Enterprise and other stakeholders (e.g. Scottish Government) to assess and take forward:

- Consider the need for specific research on energy generation (LNG Power Station) utilising LNG, exploring in more detail capacity and capability for LNG use in the context of the Scottish Government Energy Strategy.
- Assess and consider further the environmental impact of the LNG value chain in comparison to other fuels.
- Explore whether National Development designation through the National Planning Framework (NPF) could support further LNG infrastructure in areas and unlock sustainable economic growth.
- Utilise information from this report and any other LNG research to inform emerging government strategy (e.g. shipping strategy).
- Assess in more detail the potential industry users of LNG.
- Further explore the innovation and economic opportunities from LNG use in marine and land based transport, domestic and industrial settings
- Consider provision of support, where appropriate, to areas seeking LNG investments, identifying their specific constraints; labour market, infrastructure (e.g. pipeline) etc and solutions to challenges.
- Review and identify the new infrastructure needed to enhance the LNG prospects in Scotland. This should focus on whether the infrastructure required to support LNG could also be used for hydrogen.
- Assess how investments in the existing gas networks or transport infrastructure could support LNG take-up.
- Assess the potential for further bio-LNG take-up or technologies, including exploration of examples in Northern Ireland and Sweden.
- Review and identify the infrastructure needed to enhance the LNG prospects in Scotland. For example, assessing how investments to the gas networks or transport infrastructure could support LNG take-up.
- Assessment of potential for further bio-LNG take-up or technologies, including exploration of examples in Northern Ireland and Sweden.

Appendix

A.1. Additional Tables

Table -1 Gas storage sites and import/export facilities

Owner	Site	Location	Space (Billion m^3)	Approximate maximum delivery (Million m^3/day)	Type	Status *(2)*
Operational storage						
Centrica Storage Ltd	Rough	Southern North Sea	3.30	41	Depleted field	Long
Scottish and Southern Energy & Statoil	Aldbrough	East Yorkshire	0.30	40	Salt cavern	Medium
E.ON	Holford	Cheshire	0.20	22	Salt cavern	Medium
Scottish and Southern Energy	Hornsea	East Yorkshire	0.30	18	Salt cavern	Medium
EDF Trading	Holehouse Farm	Cheshire	0.02	5	Salt cavern	Medium
Humbly Grove Energy	Humbly Grove	Hampshire	0.30	7	Depleted field	Medium
Scottish Power	Hatfield Moor	South Yorkshire	0.07	1.8	Depleted field	Medium
EDF Energy	Hill Top Farm	Cheshire	0.05	12	Salt Cavern	Medium
Storenergy	Stublach	Cheshire	0.20	15	Salt Cavern	Medium

Source: Gas storage sites BEIS 2016

Figure 8-1 Worlds First purpose built LNG bunkering vessel Engie Zeebrugge

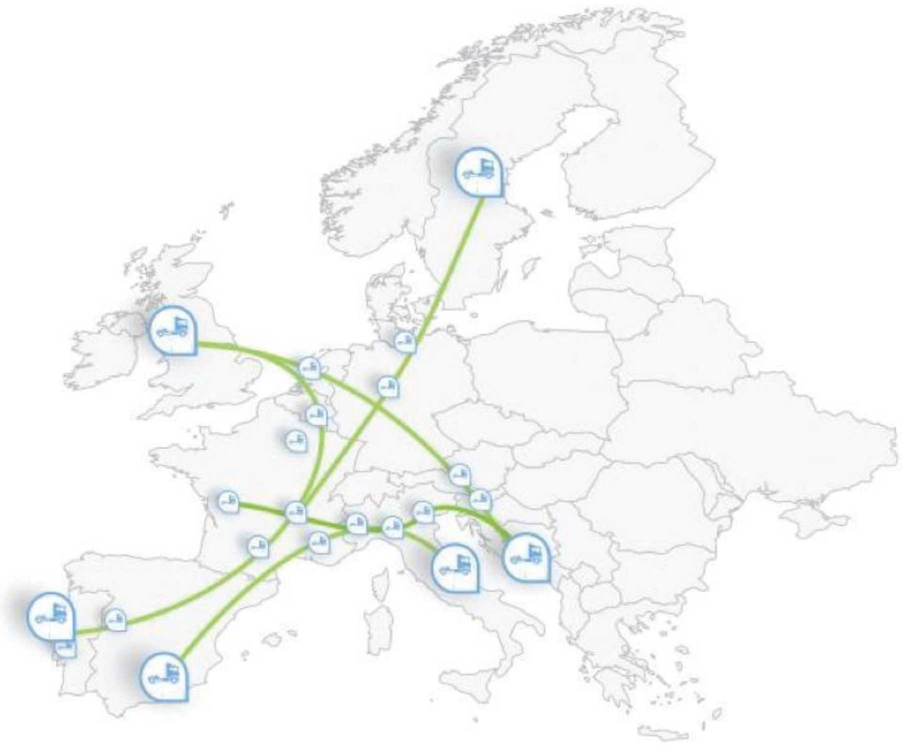
Source: LNG World NEWs

Table A-2 LNG Bunkering vessel - Engie Zeebrugge

Description	Dimension
Gross Tonnage (t)	7,403
Length (m)	107.6
Beam (m)	18.4
Draught (m)	17
LNG Capacity (m3)	5,000

Source: LNG World NEWs

Figure 8-2 European LNG Blue Corridors



Source: http://lngbc.eu/

Figure 8-3 QFlex LNG Carrier Mesaimeer (Maritime News Ref 105)

Source: LNG world News

Selected FSRY vessel dimensions are given in the following tables.

Table 8-3 Excelerate – FSRU's Typical Dimensions

Description	Excelsior Class	Explorer Class	Experience Class
Capacity – Nominal	138,000	150,900	173,400
Capacity - Cargo	135,930	148,637	170,800
Length (m)	277	290	294.5
Beam (m)	43,4	43.4	46.4
Laden Draught (m)	11.52	11.6	11.5
Ballast Draught (m)	9.2	9.5	9.4
Build	2005 -2006	2008-2010	2014
Regasification MMcuf/day	400 – 690	500 – 690	400 - 800

Source: Down the pipeline - A Lansdale (Re 08)

Table 8-4 Golar – FSRU's Typical Dimensions

Description	Golar Winter	Golar Eskimo	Golar Igloo
Capacity – Nominal	138,000	160,000	170,000
Length (m)	277	280	292
Beam (m)	43	43	43
Laden Draught (m)	11.7	11.5	11.0
Build	2004	2014	2014

Source: Down the pipeline - A Lansdale (Re 08)

Table 8-5 Hoegh – FSRU's Typical Dimensions

Description	Neptune	Hoegh Gallant
Capacity – Nominal	145,130	170,000
Length (m)	283	294
Beam (m)	44	43
Laden Draught (m)	11.5	11.4
Build	2009	2014

Source: Down the pipeline - A Lansdale (Re 08)

Figure 8-4 FSRU Excelsior (Ref 102)

Source: LNG news

A.2. References for Demand Calculations

The following sources of information were used to inform the estimation of demand for Scotland:

- UK Admiralty Chart
- UK Admiralty Tide Tables
- Harbour Approach Channel Design Guidelines - PIANC
- Recommendations for the design and assessment of marine Oil and Petrochemical terminals - PIANC
- Design of Small to mid-scale Marine LNG Terminals - PIANC
- LNG World Shipping June 2016
- Down the pipeline - A Lansdale
- International Gas Union World LNG Report 2017 IGU
- The Economic impact of small scale LNG PWC
- LNG The fuel of the Future - A Campbell
- The development of LNG bunkering facilities in North European port - S Wang and Professor T Notteboom
- Still a strong case for small scale LNG - Poyry
- Scottish Energy Strategy The future of energy in Scotland - Scottish Government
- Low Carbon Truck and Refuelling Infrastructure Demonstration Trial evaluation – Final Report to DfT - Atkins
- Proposed Liquid Natural Gas (LNG) Import Terminal Rosyth - Fife Council
- Scotch Whisky Industry Environmental Strategy Report 2012 - Scotch Whisky Association
- Department of Transport Statistics
- PD Ports
- Excelerate
- TGE Marine Gas Engineering
- Wartsila
- Maritime News
- Open Maps
- European Blue Corridors
- Gas Vehicle Hub

A.3. Additional Information

A selection of milestone in the adoption of LNG bunkering are presented below:

- 13th December 2012 – The barge “Argonon” becames the first vessel to bunker LNG (Truck to Ship or TTS) at the Port of Antwerp, Belgium
- 9th August 2016 – The “Ternsund” became the first sea-going vessel to bunker LNG (TTS) in the Port of Rotterdam, Netherlands.
- 15th February 2017 – Agents acting for Stolt-Neilsen submitted a formal request for a EIA screening opinion under the Town and Country Planning (Scotland) Regulations for a proposed LNG import terminal at Rosyth (Scotland). This facility is reported to be planning for 10,000m3 to 15,000m3 LNG storage capability and an estimated annual throughput of 61,000m3 after 5 years of operation, supplying local industry, ferry and shipping companies and remote domestic LNG facilities
- 16th June 2017 – The Port of Zeebrugge, Belgium, became the first port to offer regular Ship To Ship (STS) LNG bunkering. When the world’s first purpose built LNG bunkering ship Engie Zeebrugge re-fuelled two vessels owned by NYK lines, Opening the possibility of simultaneous operations (simops) of bunkering and cargo loading/unloading which is not considered practical with TTS bunkering
- 24th July 2017 - The first 88t, 147m3 capacity LNG fuel tank was delivered to Ferguson Shipyard on the Clyde for incorporation into Caledonian Maritime Assets Limited’s (CMAL) and Scotland’s first LNG ferry. The first of two CMAL dual fuel 120m long ferries, the “MV Glen Sannox”, is due to enter services in late 2018. The vessels are planned to service the Ardrossan to Arran route and the Skye triangle
- 16th August 2017 - The 7,300 dwt, 110m long cement carrier “Ireland” operated by KGJ Cement become the first vessel in the United Kingdom to bunkered with LNG. The TTS LNG bunkering operation at the Port of Immingham involved multiple road tankers from the Isle of Grain LNG terminal.

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