LNG opportunities in Hunterston

Case Study & Research Study

Scottish Enterprise

21 December 2017

Contains *sensitive* information

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Conversions

Density of Liquified Natural Gas (average)		450 kg/m^3
Conversion	1 m^3	35.3145 ft^3
Conversion of Methane gas	1 ft^3	1,037 Btu
Conversion of	1 kWh	3,412 Btu
Gas Heat rate		7,900 Btu/kWh
Energy Conversion Efficiency Gas to Electricity		43%
Ratio of LNG to natural gas by volume		1:600

Units

ft^3	Cubic feet	m^3	Cubic meters
dwt	Deadweight tonnes	kg	Kilograms
h	Hour	km	Kilometres
l	Litre	kn	Knots
M	Million	kW	Kilowatt
MW	Megawatt	kWh	Kilowatt Hour
MWh	Megawatt Hour	t	Tonnes
Mft^3	Million cubic feet	bar	Barometric pressure
MTPA	Million Tonnes per Annum	US$	US Dollars
m	Meters	y	Year

Acronyms

AGR	Advanced Gas-cooled Reactor
AHJ	Authority Having Jurisdiction
ALARP	As Low As Reasonably Practical
CD	Chart Datum
CMAL	Caledonian Maritime Assets Limited’s
CO2	Carbon Dioxide
ECA	Emissions Control Area
EIA	Environmental Impact Assessment
EU	European Union
FERC	Federal Energy Regulatory Commission
FSRU	Floating Storage Re-Gasification Unit
FSRB	Floating Storage Re-Gasification Barge
GVH	Gas Vehicle Hub
IGU	International Gas Union
IMO	International Maritime Organisation
LNG	Liquefied Natural Gas
LNGC	Liquified Natural Gas Carrier
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
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
SGN	Scotia Gas Networks
SIN	Scottish Independent Networks
SOx	Sulphur Oxide
SSLNG	Small Scale LNG
STS	Ship To Ship
TTS	Truck To Ship
UK	United Kingdom

“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)

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Executive summary

This report assesses the options for Hunterston Port, on the Ayrshire coast, for Liquified Natural Gas (LNG) importation. The report assesses the market demand for LNG and the required facilities and terminals which may be required. The report also highlights some of the benefits that Hunterston and the local area could experience because of such an investment. A separate report looking at the potential for LNG in Scotland was developed to assess LNG demand and investment benefits in Scotland.

LNG is liquified natural methane gas that can be quickly and easily turned back into natural gas and delivered to homes, businesses and industry via pipelines and/or road transport. The European, UK and Scottish policy environment is broadly supportive of LNG investment, although as a fossil fuel there are concerns about its emissions footprint.

There has been an increase in the take-up of LNG in the UK, and new investments in Scotland and the north of England are being proposed to meet this demand. The demand for LNG that exists locally, nationally and beyond is growing but from a low initial point, which investors in Rosyth and The Orkneys are exploring and could exploit.

Demand is expected to be driven from different sources, primarily marine, road transport, power generation, industrial and residential use. The demand for LNG is expected to increase for the following reasons:

- The introduction of emissions restrictions within the European Maritime Emissions Control Area has prompted a move to LNG or duel fuel powered ships, as demonstrated by Caledonian Maritime Assets Limited's (CMAL) ordering two LNG powered ferries, that are currently under construction on the Firth of Clyde.
- The first bunkering of a LNG power vessel, using a purpose designed and built LNG bunker vessel, i.e. Ship to Ship (STS) bunkering, only occurred in June 2017 in Belgium at the Port of Zeebrugge. While in the United Kingdom (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 (TTS) operation. 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 remains only 22 LNG fuelling station in the UK, only one of which is in Scotland. However, road transport with its relative short payback period does have the potential to see a rapid transition to LNG.
- The Government of Scotland in its draft "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. While electricity demand is expected to increase due to a move to electrical vehicles. Scotland's. Electrical generation capacity will decrease under the Scottish Government with a policy for "no new nuclear power" under current technologies and the decommissioning of Hunterston B in 2023, and the subsequent decommissioning of Torness (in 2030, after life extension). These have the potential to leave a significant gap in Scotland's electrical power generation capability, a gap that could, in part, be filled by a LNG gas powered power station at Hunterston.

Into this demand profile, small scale residential and large industrial users of energy/gas (such as whisky distilleries) should be added and could be supplied with LNG from Hunterston.

The research considered two scenarios, based on different demand predictions:

1. A LNG terminal supporting a gas fuelled power station similar in capacity to that recently proposed (and rejected) for the Hunterston site. Along with supplying LNG to, marine vessels, road transportation and large energy users
2. A LNG trans-shipment terminal suppling LNG to, marine vessels, road transportation and large energy users.

Scenario 1 considers a Hunterston LNG terminal supporting a 1,853MW power station, and trans-shipment capability for marine and road transportation. Under this scenario the long-term commitment to gas powered electrical generation would justify the construction of onshore storage and re-gasification. Through the initial low (capital) cost of using a Floating Storage Regasification Unit (FSRU) could help spread the capital expenditure, there would be higher operating costs. LNG carriers would berth on the outer berth of the existing Hunterston jetty before transferring the LNG into the onshore storage tanks.

Under scenario 2 only a marine and road trans-shipment capability would be constructed. This option would be served by a Floating Storage Barge, holding the LNG until it could be transferred to road tankers and or marine bunkering vessels. The storage barge would be located on the inner berth at Hunterston with supply vessels berthing on the outer berth.

Investment in LNG could support economic development ambitions in North Ayrshire by safeguarding and creating jobs in the energy sector. There is the potential to maximise the opportunities from LNG investment and align investments with inclusive growth in the North Ayrshire area (e.g. local skills ambitions). The benefits to be derived from both scenarios are different with Scenario 1 likely to deliver more benefits around jobs and Gross Value Added (GVA) to the local (and national) economy:

- Scenario 1 could be between 150-240 Construction and 100-150 Operational FTE jobs to be created for investments in LNG. There is also potential for this to deliver up to £33.8 million GVA activity to Scotland's economy.
- Scenario 2 could be between 70-130 and 40-90 FTE jobs (construction and operation) to be created for investments in LNG. There is also potential for this to deliver up to £21.1 million GVA activity to Scotland's economy.

LNG has been transported by marine vessels and used safely worldwide for approximately 40 years and the industry has an excellent safety record.

It is concluded from this research study that a LNG trans-shipment facility could be located at Hunterston, supporting marine operations on the Firth of Clyde, road transport in central and southern Scotland and potentially power generation near or on the Port site. The Hunterston terminal could, with suitable modification, accommodate either scenarios and support further adoption of LNG in Scotland.

1. Introduction

In August 2017, Scottish Enterprise commissioned Atkins to undertake a Market Study into the opportunities for Liquified Natural Gas (LNG), both within Scotland and in markets served from Scotland, over the next 20 years. The second element of the scope of work was to consider Hunterston as a case study for a potential LNG hub and identify the steps that would be needed to develop this location for the importation and distribution of LNG.

This document reports on the second element of the study, i.e. the assessment of the potential of the Hunterston Terminal to act as a LNG hub.

Liquefied Natural Gas (LNG)

LNG is 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 with lower carbon emissions lower than 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 techno-economic studies of infrastructure investments. It utilised both empirical and secondary data sources. The research collected secondary information and undertook consultation with individuals from Peel, Scottish Government and Local government stakeholders (including Scottish Enterprise, Transport Scotland and North Ayrshire Council), EDF Energy and industry specialists in the energy and marine consultancy. This 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. Professional judgement was used to assess demand and highlight the potential scenarios for LNG at Hunterston.

1.2. Structure of document

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

- Section 1 Introduction – This section describes what the methodology and background to the report.
- Section 2 Hunterston Port and Resource Centre (PARC) – This section describes and assesses the key characteristics of the Hunterston site.
- Section 3 Supply of LNG – Outlining the supply of LNG
- Section 4 LNG Demand – Hunterston – This section summarises the possible demand for LNG in the Firth of Clyde and its wider environment.
- Section 5 Demand Summary – This section outlines the overall demand and indicative timescales.
- Section 6 and 7 Scenarios – These sections consider various demand driven options for the development of Hunterston:
  - Section 6 Scenario 1 – LNG Importation Terminal.
  - Section 7 Scenario 2 – LNG Trans-shipment.
- Section 8 Challenges and Opportunities – This section considers the broad challenges and opportunities associated with a Hunterston LNG terminal.
- Section 9 Impact and Delivery – This section considers the economic impact of LNG infrastructure and delivery options of a Hunterston LNG terminal.
- Section 10 – Concludes the study and summarises the findings.
- Section 11 – This section recommends actions to be taken forward.

1.3. Background

As environmental concerns and emission controls become more stringent; LNG is increasingly seen as a more versatile, efficient and cleaner burning fuel than other hydrocarbons. However, LNG has a low energy density at atmospheric pressure, thus the only economic/efficient way to transport it in large quantities. This is achieved by cooling it down to minus161 degrees centigrade (-161 ^{o}C). Several ports across the world have become import terminals to serve different markets utilising LNG.

This report considers the suitability of Hunterston PARC, on the Firth of Clyde estuary (Figure 1-1) to accommodate Liquified Natural Gas infrastructure to serve demand for the fuel in Scotland. Hunterston PARC is the site of the former iron ore and coal terminal, 40 km southwest of Glasgow and close to Largs on the North Ayrshire coast which could be a possible site for importing LNG.

Figure 1-1 Hunterston PARC (view from the air)

Source: Peel Group 2017

1.4. Study limitations

There is significant uncertainty in forecasting the expected demand for LNG. This is due to the very low current usage of LNG. There is particularly low usage in the transportation sector where LNG remains in the developmental stage. In addition, significant uncertainties in: government policies, infrastructure investment, operational performance, and LNG pricing. Will all need to be better understood if forecasting reliability is to be improved. This study therefore presents possible scenarios and should not be used as the sole basis of any investment decisions.

2. Hunterston Port and Resource Centre

This section provides an overview of the Hunterston Port and Resource Centre (PARC), identifying key assets and its suitability for accommodating Liquified Natural Gas (LNG) infrastructure.

2.1. Site history

Hunterston has a long history in Scotland's industrial heritage. Constructed in 1979 to import iron ore for British Steel Corporation's Ravenscraig steel works, it was at the time regarded as one of the finest deep-water terminals in the world. The facilities were also used to complete the concrete gravity sub-structure for BP's Harding Field and the gravity platform for the Maureen Field.

With the closure of Ravenscraig in 1992, the terminal focused on the importation of coal to the power stations of Drax in Yorkshire, and Longannet in Fife. However, in 2016 the Longannet power station closed, ending coal powered electrical generation in Scotland. The subsequent conversion of Drax to burn biomass has seen the importation of bulk materials at Hunterston cease, with the loss of jobs to the area. Hunterston's coal import volumes dropped from a high of 9.4Mt to 2.4Mt in two years and operation ceased in 2016. The terminal is therefore available for and actively seeking alternative use.

Hunterston Port and Resource Centre (PARC) key features:

Dry Dock: 230m length, 150m breadth, dock floor is 12.5m below mean water mark. Water depth still 11m extending to 40m in the Clyde estuary

Jetty: A 443m long and 36m wide jetty head which extends approximately 1.6km from the shoreline to the edge of the Hunterston (navigation) channel of the Firth of Clyde

Berth:

Outer Berth: Length - 44m, DWT - 350kmt, Draft - 26m
Inner Berth: Length - 300m, DWT - 95kmt, Draft -20m

Cranes

Load capacity of crane platform (i.e. 100t/m
Loading: 2,000 tph Outreach - 31.5m
Unloading: 2 x 1,400tph, Outreach - 50m, Airdraft: 49.3m
Simultaneous unloading / loading / reclaim

Source: Peel Ports 2017

Figure 2-1 Hunterston

Source: OpenMaps 2017

2.2. Site context

Hunterston PARC is located approximately 40km southwest of Glasgow on the Firth of Clyde estuary. It is located in the district of Fairlie and forms part of Clydeport, operated by Peel Ports. The existing coal handling facility includes a large jetty with two large cranes at 72m in height, a control tower, elevated conveyors, several large coal loaders, a coal storage area and a rail freight loading area which is connected to the storage area by a covered conveyor that crosses the A78.

Adjacent to the site is:

- Hunterston A, Nuclear Power Station, a two-reactor 180MW Magnox station that is currently being dismantled; and
- Hunterston B, Nuclear Power Station, with two Advanced Gas-cooled Reactors (AGR) generating approximately 1,000MW. The station is expected to continue generating electricity until 2023.

2.2.1. Settlements

There are a small number of settlements close to Hunterston PARC including Largs, the towns of Seamill and West Kilbride, Portencross, Crosbie and Fairlie. The village of Millport is located on Great Cumbrae Island to the north west of Hunterston Port.

2.2.2. Natural environment

The nearshore habitats consist of sands, and sandy gravels, whilst made ground is reported offshore of the main construction yard. In terms of wildlife, waders and wildfowl numbers are reported and are most prevalent in the nearshore environment adjacent to the Nuclear Power Station sites.

Any proposals for LNG infrastructure would have to demonstrate that there would be no adverse effect on the integrity of the Southannan Sands a Site of Specified Scientific Interest (SSSI) near to Hunterston port. Site design will have to minimise impact on the SSSI and propose mitigation (or compensation measures) where necessary.

2.3. Site access and capacity

2.3.1. Vessel size

The Hunterston terminal can accommodate on berth extremely large vessels. For example, the terminal can accommodate the world’s largest construction vessel the “Pioneering Spirit” which is a twin-hulled vessel of 382 m length and 124 m width wide and at maximum draft displaces nearly 1,000,000dwt.

2.3.2. Land access

Hunterston PARC benefits from multi-modal connectivity, with low cost rail and road options linking the site with central Scotland and beyond.

Road access to Hunterston PARC from the Glasgow / Edinburgh conurbation is via the following routes:

- The A78 coastal road from Glasgow via Port Glasgow, Greenock and Largs directly to the site entrance;
- The A737 from Glasgow to its junction with the A78 just north of Irvine and then back up the coast to Hunterston; and
- The A760 at Lochwinnoch which joins the A78.

These roads are classed as Trunk roads and are overseen by Transport for Scotland. The road connections to and from Hunterston appear capable of supporting a road-based transportation supply chain delivering LNG to filling stations within southern and central Scotland and northern England.

Hunterston PARC’s dedicated automated rail loading station offers economic efficiencies and environmentally friendly transportation for imported bulk materials. The site has a lower rail / vehicle loading area with access to the national rail and, via haulage, to the motorway network.

Hunterston has direct rail access to the UK rail network via ‘local routes’ to either Glasgow or Troon and to regional and national destinations thereafter. Prior to its closure, bulk trains delivered coal to Drax power station in Yorkshire. Subsequently, nuclear waste has been transported by train to Sellafield in Cumbria. The capacity and safety of these rail connections for transport of LNG will need to be assessed.

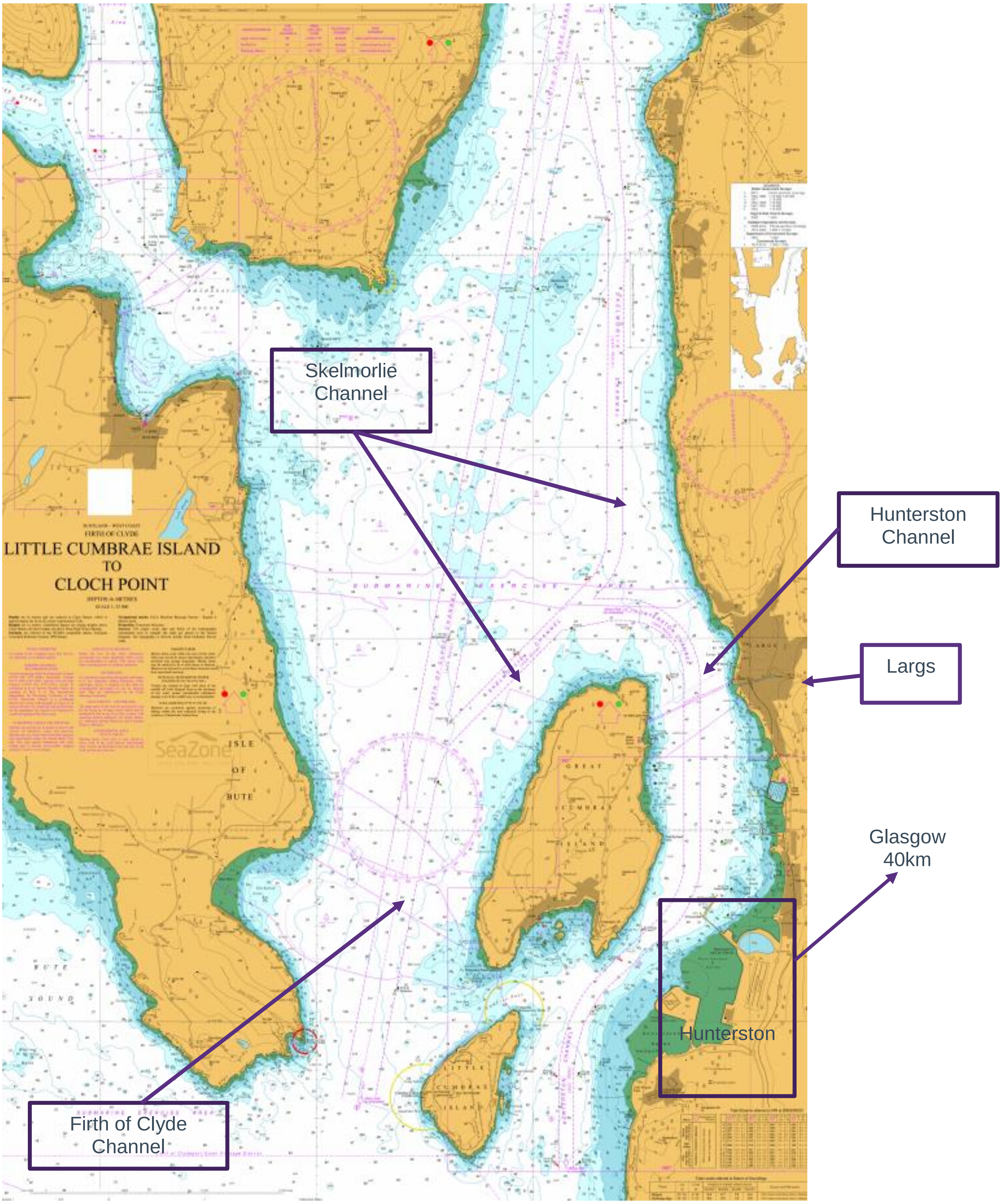
2.3.3. Marine access

The approaches to the Firth of Cyde, Hunterston channel and Hunterston PARC are presented in extracts from Admiralty Charts 1907 and 1867 (Figures 2-2 and 2-3).

The transit of LNG vessels to and from the Hunterston facility along the Firth of Clyde would require careful preplanning, multiple tugs, pilotage, and approval of the Authority Having Jurisdiction (AHJ). Vessels would approach the Hunterston Terminal from the Firth of Clyde via the Hunterston Channel. The Channel has a water depth greater than 20m throughout, and over 30m throughout except for small intrusions at Fairlie Roads (the area between Hunterston and Great Cumbrae Island), and is therefore suitable for LNG vessels. However, the Hunterston and the Skelmorlie channel (the northern connection between the Hunterston channel and the Firth of Clyde), with an approximate width of 270m are classed as narrow under International Maritime Organisation (IMO) International Regulations for Preventing Collisions at Sea. Therefore, appropriate procedures should be adopted

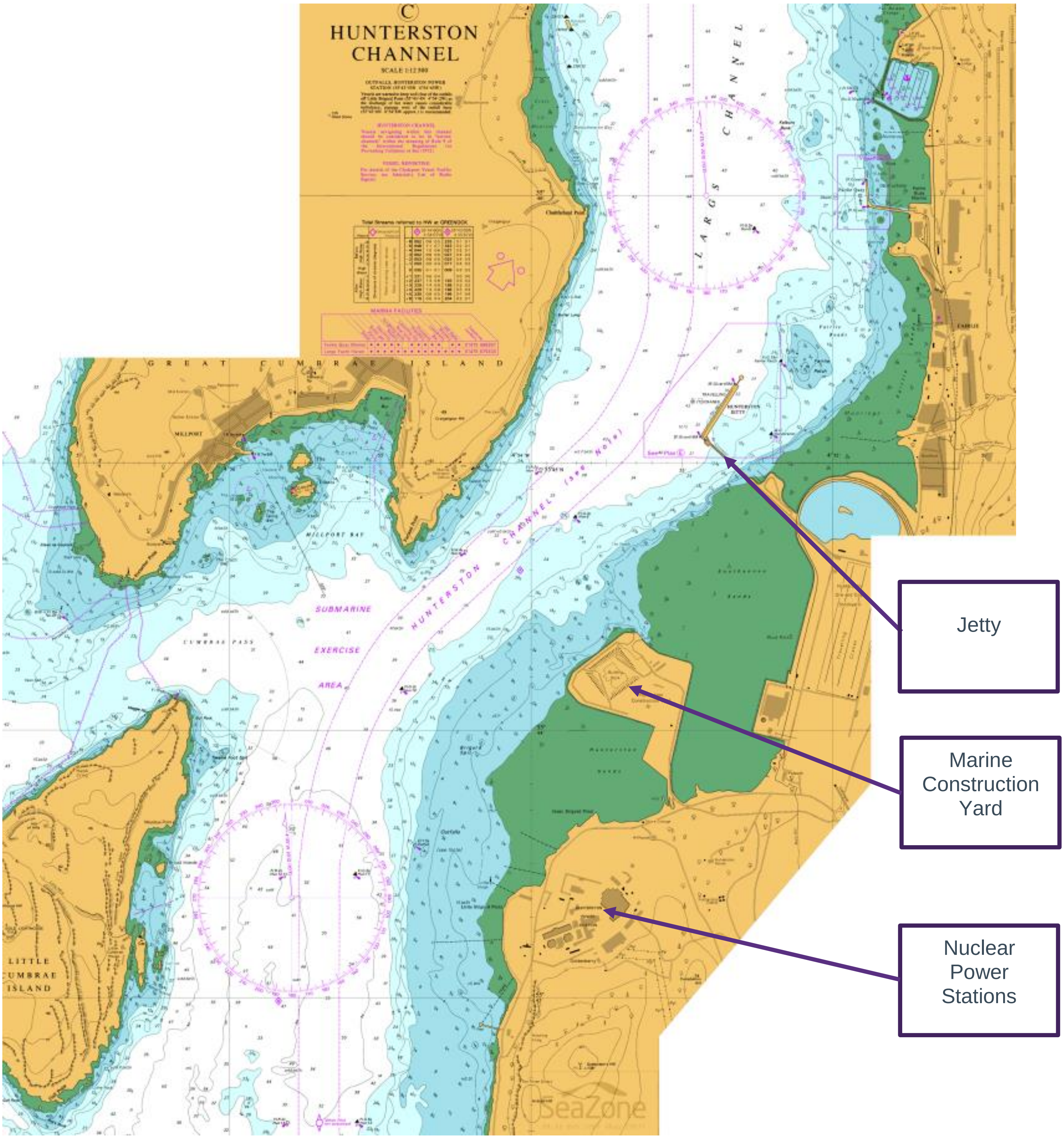
As the channels are well marked and were intended for use by bulk carriers up to 350,000dwt, even the largest LNG carriers should be capable of safely accessing the Hunterston terminal. However, further consideration should be given to the effects of wind on the largest LNG carriers.

Figure 2-2 Firth of Clyde Channel



Source: United Kingdom Hydrographic Office 2017

Figure 2-3 Hunterston Channel (Ref 02)



Source: United Kingdom Hydrographic Office 2017

2.3.4. Jetty

The outer Hunterston Jetty, at 440m length and with potentially 26m water depth (although currently likely to be slightly less due to material lost overboard at the quay edge), can accommodate the largest Liquified Natural Gas Carrier (LNGC) vessels.

The inner berth with minor dredging works can accommodate typically smaller LNGC's of 70,000dwt. With significant dredging, the inner berth could accommodate LNGC's of 170,000dwt and therefore could accommodate typical LNGCs of approximately 125,000dwt. The jetty access trestle represents a risk to LNGC's accessing the inner berth which will need to be managed.

Figure 2-4 Hunterston Jetty

Source: United Kingdom Hydrographic Office 2017

2.4. Safety

The design and construction of a LNG terminal is subject to stringent safety standards and controls which are required to reduce risks to as low as reasonably practical (ALARP). Strict controls are imposed to limit the possibility of spillages, limit the volume of spilled, and eliminate sources of ignition, which together minimises the risk of a spillage of cryogenic liquid followed by an ignition or rapid phase transition. Controls typically include a minimum exclusion zone around the LNG marine product transfer facilities in which no sources of ignition may be present. A Qualitative Risk Assessment (QRA) is one of the requirements to be undertaken before Hunterston can be considered for the trans-shipment of LNG. The extent of the exclusion zone can be determined based on the vapour dispersion from the largest credible leak and/or following a QRA, which would include a hazard analysis, risk assessment and preparation of risk contours.

2.5. Gas transmission

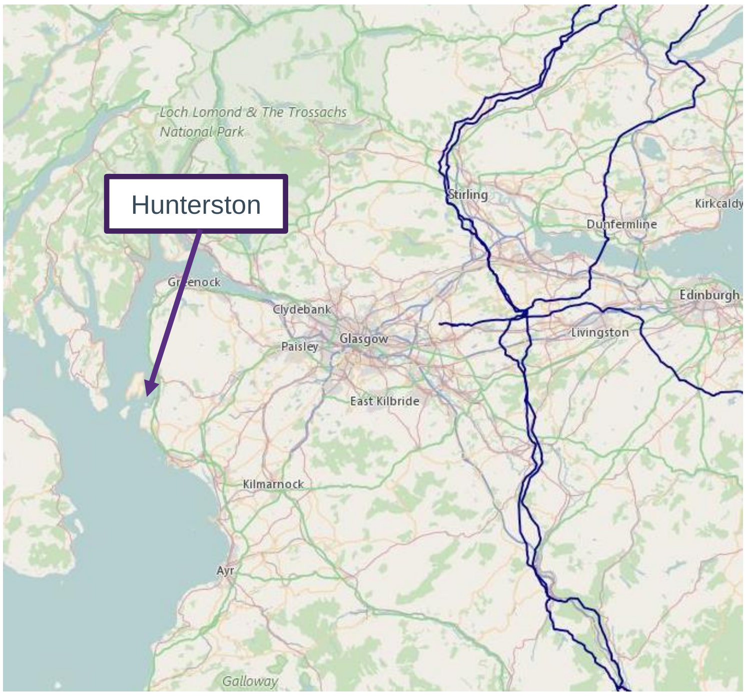
For a LNG storage facility constructed at Hunterston a high-pressure connection to the National Grid high pressure gas pipeline, would have several obvious advantages including:

- An ability to feed gas into the National Grid at times of high demand
- An ability to extract gas to supplement supply to, for example a power generation facility

The location of the high-pressure gas pipeline is shown Figure 2-5, as can be seen the pipe line is located to the east of Glasgow. The distances and terrain are within the capabilities of the Oil and Gas industry to install a high-pressure connection. However, further work will need to explore the connection possibility. Another point to note is that the economic case for such a connection would be difficult to justify. On the basis of supplying gas into the United Kingdom's (UK's) high pressure gas pipeline network alone, as other locations within Scotland and the UK are better located. Such as the Teesside Gas Port, in north England is already directly connected to the national transmission network, and within Scotland a terminal located on the Firth of Forth would require a significantly shorter new pipeline.

Gas is available in the North Ayrshire area at domestic pressures, and an option to supply gas from Hunterston into the local network at low pressure could be investigated, although the financial justification would need to be made.

Figure 2-5 High Pressure Gas distribution network west and central Scotland



Source: National Grid 2017

Hunterston is believed to have an existing gas connection which is almost 40 years old and connects to the network near to Dalry. This pipeline could be upgraded or used to back feed the local domestic system at low pressure (which would raise questions about economic viability). Further work is needed to explore this connection, its condition and suitability for upgrading. Assessing the cost of connecting Hunterston to the gas network would require further feasibility work to be undertaken as costs can vary between £500,000 per mile to several million depending on geology, disruption and techniques.

Hunterston has good connectivity to electrical power transmission lines. The electricity network could provide an opportunity to connect with the national supply network, especially when Hunterston B is decommissioned (2023). This would require engagement with EDF and assessment of the technical options.

2.6. Site suitability/validation

This initial review has found the Hunterston PARC facility is suitable for a LNG importation and distribution terminal. Further work, focusing on electricity or gas connectivity and port infrastructure will be needed to scope out the precise suitability. Our review also highlighted that existing and planned LNG projects in Scotland have reviewed Hunterston's potential but rejected it in favour or alternative sites. It is also worth considering feedback from investors around weaknesses in the port infrastructure and connectivity (to motorway network and gas networks).

3. Supply of LNG

Increasing costs of accessing oil deposits[1] and a general worldwide demand for less environmental damaging sources of energy has resulted in an increased demand for Liquified Natural Gas (LNG). LNG is considered by many as a transition or bridging fuel to a low carbon emission future with its reduced emissions (of Nitrous Oxides (NxO), Sulphuric Oxide (SO_X) and Carbon Dioxide (CO_2)), and its current price competition and relative abundance, compared to other hydrocarbons fuels,

Table 3-1 shows that LNG has one of the lowest greenhouse gas emissions when compared with other fossil fuels. Solar and wind have emissions that are significantly lower than all fossil fuels. Despite this positive nature, 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 3-1 Total GHG (CO_2, CH_4 and N_2O) 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

At the time of writing, the price of LNG is low as global supply of LNG currently outpaces demand for the following reasons:

- A number of LNG export terminals that commenced construction in the early 2010s are now starting to deliver LNG to the world markets.
- The development of horizontal fracking techniques and the rapid monetisation of shales gas deposits particularly in the USA. The USA federal authorities are licensing energy exports which is further growing the supply market.
- The maturing of the LNG market from long term contracts to more immediate ('spot') requirements which is changing how investors and buyers engage the market.

The number of new LNG export facilities that have commenced construction in more recent years is limited, and the expectation is that by the early to mid-2020's demand will again outstrip supply. Therefore, due to the long lead in times, the major oil and gas producers are starting to plan the next generation of LNG export terminals, in areas such as Canada, Mauritania/Senegal, Mozambique and Tanzania etc, while 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.

It is therefore expected that LNG will remain an economically competitive energy source for the foreseeable future but price rises in the future could occur.

3.1. UK Supply

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 Liquified Natural Gas Carriers (LNGC). The South Hook Terminal has five

[1] Whilst this is generally true, the oil and gas industry is very responsive to cost reduction.

cryogenic storage tanks, each with a working capacity of 155,000 m^3. While the re-gasification plant can deliver the equivalent of 15 MTPA of LNG to the UK National Transmission System (NTS)

- **Dragon LNG Terminal** near Milford Haven in Wales has a single LNG berth capable of accommodating the largest LNGC. The Dragon LNG Terminal has two cryogenic storage tanks, each with a working capacity of approximately 160,000 m^3. While the re-gasification plant can deliver the equivalent of 6 MTPA of LNG to the UK NTS
- **Grain LNG Terminal** 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 m^3 of LNG storage capacity. While the re-gasification plant can deliver the equivalent of 15 MTPA of LNG to the UK NTS, the terminal also has a truck and vessel reloading capability

A fourth LNG import terminal, Teesside Gas Port, was operated by Excelerate Energy from 2007 to 2015, the terminal included a 138,000 m^3 Floating Storage Re-Gasification Unit (FSRU), which has since been relocated. The site is currently owned by Trafigura who have declared their intention to put the terminal back into service by mid-2018 at a cost of approximately £30m. The terminal is located close to the UK NTS and potential industrial users.

Historically the National Grid has operated a series of LNG liquification and regasification plants around the UK including at Glenmavis in Scotland, for supporting the NTS. However, the last of these facilities, Avonmouth closed in 2016. In addition, it was announced in 2017 that the UK's largest natural gas storage site (70% of the total UK gas storage capacity), Rough, off the East Coast of Yorkshire has reached the end of its design life and is to close once the existing gas is extracted.

3.2. Scotland LNG Terminals

The opportunities for LNG in Scotland have been recognised by other 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. Infrastructure is expected to be developed on the basis of LNG supply opportunities being identified.
- **Stolt-Neilson** have recently announced their 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 £76-116 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, containers, etc.)[2]

The employment impact of the Rosyth facility is expected to include the creation of 130 professional worker jobs during construction and 113 permanent professional worker jobs.

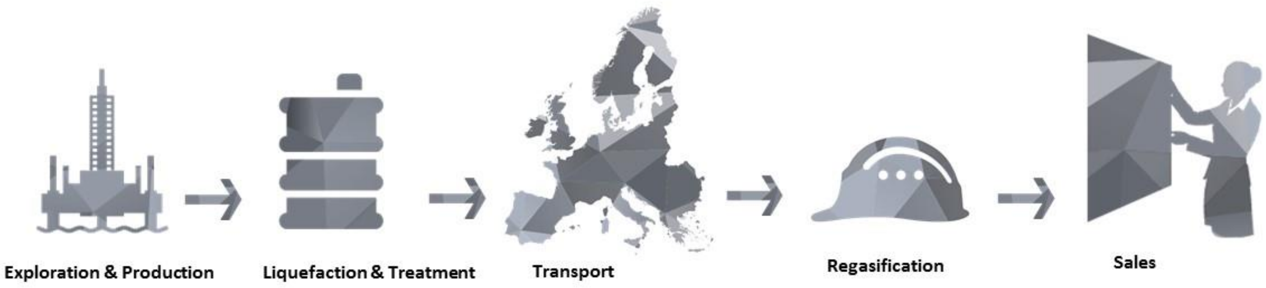
Stolt-Neilson considered various sites in Scotland for a SSLNG Terminal including Hunterston, before settling on Rosyth. A range of reasons were behind their decision, including financial and technical. The initial investments made by Caledonia LNG and Stolt-Neilson will give them first mover advantages (and some disadvantages), providing them with the opportunity to exploit cost and market advantages before other firms.

[2] Stolt-Neilson 2017

4. LNG Demand – Hunterston

To understand the Liquefied Natural Gas (LNG) demand for Hunterston, the LNG value chain sets out the stages between extraction and use (Figure 4-1).

Figure 4-1 LNG Value Chain



Stage 1: Exploration & Production - Following exploration and production from onshore or offshore fields, natural gas is transported by pipelines to a liquefaction facilities.

Stage 2: Liquefaction & Treatment - At the liquefaction facilities, gas is pre-treated and cooled to -161°C (-259°F), at which point it becomes a liquid (with around 1/600th of its original volume).

Stage 3: Transport - LNG is loaded into specially constructed ocean-going vessels with cooling systems and insulation for transport.

Stage 4: Regasification - At regasification plants (often close to the LNG end destination), a heating process converts the liquid to its gaseous form. The energy requirements for regasification are approximately 850 kWh per ton of LNG[3]. 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), and can also be used to cover peak demand.

Stage 5: Sales - The gas is fed into pipeline grids or packaged into trucks and sold either to distributors or directly to power producers, large industrial consumers or other consumers.

The focus of this study is upon the latter stages of the LNG value chain: Transport, Regasification and Sales. Any change to these stages in Scotland could enhance the current distribution arrangement of LNG. Where additional cost for clients in Northern England and Scotland arise from the need to transport gas from terminals in England or Wales. The section below considers the principal demands for LNG as applicable to a terminal located at Hunterston. These are:

- Marine fuel, bunkering;
- Road transportation, to both public and private users;
- Power generation; and
- Other such as, large industrial users of energy, independent domestic gas networks (e.g. Scottish Independent Networks, etc)

Each demand area presents calculations on potential demand for 2025 (Short to medium-term and in line the Scotland 2030 Programme) and 2040 (Long term horizon – approximately 20 years from the report date).

Each demand area is presented in terms of cubic metres (m^3) of LNG to highlight capacity required, infrastructure needed and broad scale of demand.

[3] It is highlighted by several academic papers that theoretically a proportion of this can be recovered using efficiency processes. See http://iopscience.iop.org/article/10.1088/1742-6596/547/1/012012/pdf for example.

4.1. Marine

A small but increasing number of vessels (estimated at 450 worldwide[4]) are being built with LNG or duel fuel engines, increasing the demand for LNG as a marine fuel and the demand for LNG bunkering facilities across the world.

This is underpinned by increasing recognition amongst ship operators of the need for, and benefits of, reducing marine vessel pollutant emissions. Marine vessels are predominantly fuelled using bunkering fuel which is either “Distillate”, “Residual” or a mixture of the two termed “Intermediate”[5]. These represent the lower or residual products from the distillation of crude oil and therefore contain a relatively high proportion of Sulphur Oxide, compared to other crude oil products. This makes marine vessels proportionally high polluters of sulphur oxide.

The introduction of International Convention for the Prevention of Pollution from Ships (MARPOL) marine emission regulations, aimed at preventing and minimising both accidental and operational pollution from ships, will force ships operating within the Northern European (Baltic Sea, North Sea, English Channel), and the USA and Canadian Emission Control Areas (ECA) to either use low sulphur fuels, limit sulphur emissions (by using a scrubber), or use alternative fuels.

The use of LNG as ship fuel could reduce sulphur oxide (SOx) emissions by 90-95% and Nitrogen Oxide (NOx) by 80%[6]. Although MARPOL regulations focus on the reduction of Sulphur Oxide (SOx), Nitrogen Oxide (NOx) and particulates, use of LNG could offer the added benefit of reducing CO2 emissions of vessels by 20-25%[7].

In Scotland two new LNG vessels are being ordered by Caledonian Maritime Assets Limited (CMAL)/Transport Scotland at a total cost of £97 million. The first 88t, 147 m^3 capacity LNG fuel tank for Scotland’s first LNG ferry was delivered to Ferguson Shipyard, on the Clyde, for incorporation into Caledonian Maritime Assets Limited’s (CMAL) vessel.

There is thus a long-term commitment to LNG from CMAL and Transport Scotland. With more than 35 ferry vessels operating in Scottish Waters, further investment to convert or replace is expected. With a typical investment repayment period of 20-30 years, the natural replacement of older ships with new LNG powered vessels will be slow, although the introduction of the MARPOL regulations and the possibility that some existing vessels can be retrofitted is expected to lead to a more rapid increase in the demand for LNG bunkering services.

The availability of LNG on a trade routes is vital for encouraging ship-owners to invest in duel fuel engines. Ports such as Rotterdam and Antwerp are proactively leading the way, having introduced LNG bunking capability in 2012, and many other ports are planning to provide this service.

The following is a simplified estimate of the LNG demand on the Firth of Clyde between 2025 and 2040.

[4] Deloitte (2015) LNG at the crossroads, identifying key drivers and questions for an industry in flux.
[5] Distillate fuel is composed of petroleum fractions of crude oil that are separated in a refinery by a boiling or distillation processes. Residual fuel is the fraction that did not boil, sometimes referred to as ‘tar’ or ‘petroleum pitch’.
[6] As reported by Elenergy (2017) available here: https://www.elengy.com/en/lng/lng-an-energy-of-the-future.html
[7] Costs and Benefits of LNG as Ship Fuel for Container Vessels (2015) Man Diesel.

Marine Demand Estimate: Example of possible LNG demand from Marine Transport 2025 / 2040

In the following, one scenario was chosen (out of the many possible) for LNG demand from marine transport on the Firth of Clyde. The below is calculated for illustrative purposes only:

Assuming

- The number of arrivals and bunkerings at Clydeport remains constant
- A Typical vessel is represented by the "Isla Bella", the world's first LNG power container ship, launched in 2015, with a typical bunkering requirement of 400m3 / bunkering
- Cruise Ships – The majority of cruise ships will bunker on their routes, taking around 2,000 m3/ when bunkering. However, bunkering will not just occur in Scotland[1]
- Ferries - The two CMAL LNG ferries would bunker on the Firth of Clyde every week, taking up 100m3/bunkering. Additional ferries will be added in the future
- 'Other marine' comprises other marine vessels, shipping fleets (short journey, leisure and commercial vessels)

Therefore	**Other**	**Cruise**	**LNG Ferries**
Number of Annual of arrivals at Clyde port (2016)	1200	70	100
Percentage Bunkering (approximate year)	10%-20%	75%-90%	100%
Average Bunkering requirement m^3	400	1,500	100
Percentage using LNG (2025)	10%-20%	20%-30%	100%
Percentage using LNG (2040)	20%-40%	40%-60%	150%-200%

2025 Total volume of LNG required (annual) = 18,000 – 40,000 m^3
2040 Total volume of LNG required (annual) = 56,100 – 115,000 m^3

It is concluded from the above scenario presented that the trend in using duel fuel vessels will continue to grow, resulting in increased demand for LNG bunkering and therefore a need for a LNG bunkering capability to serve the Firth of Clyde ports. Hunterston, located on the Clyde estuary, would therefore be a logical location for receiving and storing the LNG.

4.2. Road transportation

The potential for LNG use in road transport is uncertain due to low current levels of uptake, as well as technological (e.g. incomplete combustion of methane) and infrastructural constraints (e.g. lack of refuelling options) on adoption. The transport industry is testing a range of different fuels and technologies, with the development of battery powered trucks and dual fuel vehicles also backed by investors. One key driver is air quality designations in cities, with charges expected in parts of Edinburgh, Glasgow, London and other urban areas with poor air quality.

LNG is well suited for long distance, heavy duty trucks that cover tens of thousands of kilometres per year and have a replacement period of just 3-5 years[8]. LNG, with its relative high energy content, is a practical alternative to diesel for road transportation. With 1.8 litres of LNG approximately equivalent to 1 litre of diesel, the equivalent truck range can be achieved with an easily accommodated larger fuel tank. On this basis, a 700-900 litre LNG fuel tank can provide a truck with a 1,000-km range. Furthermore, the regularity in replacing HGVs could see stronger LNG uptake than is currently observed.

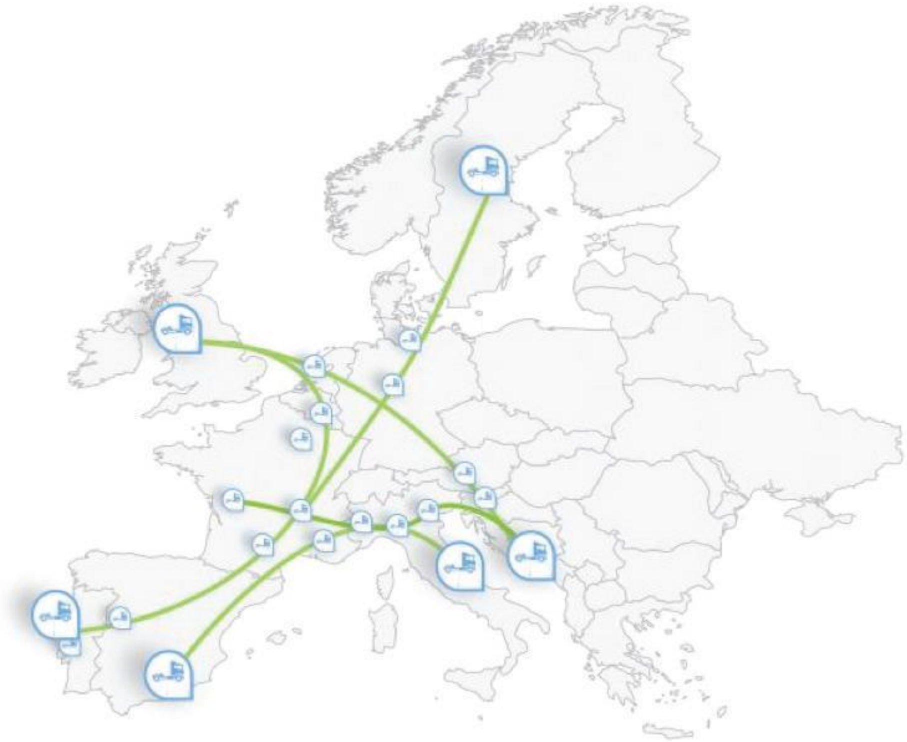
In May 2013, the European Commission and European Natural & bio Gas Vehicle Association (NGVA) initiated a 4 year LNG Blue Corridor project with the aim of establishing LNG as a real alternative for medium and long-distance transport. By March 2017 the project had seen:

- 4 primary LNG blue corridors established in Europe with a network of filling stations in place;
- 150 heavy-duty LNG-fueled trucks operating on European roads, 50 more than the initial 4-year target of 100 trucks; and
- 43 road transport fleet operators opting to trial the use LNG as fuel for their vehicles.

[1] 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.
[8] Pöyry LNG Study (2015)

NGVA predicts that some 400,000 gas-fuelled trucks will be on EU roads by 2030, which will help meet the EU goal of de-carbonising the transport sector to achieve a 30 percent reduction in CO_2 emissions by 2030 and a 60 percent reduction by 2050. The LNG Blue Corridor project aims to have at least one filling stations every 400 kilometers along Europe’s primary transportation routes by 2025 (see Figure 4-3 below). This aligns with other policies around reduction in petrol and diesel vehicles. The LNG Blue Corridor represents significant growth from the current 22 LNG filling stations in the UK (12 with public access and 10 with no public access), including just one in Scotland (at Lockerbie) reported by the Gas Vehicle Hub (GVH).

Figure 4-2 European LNG Blue Corridors



Source: http://lngbc.eu/

With a typical investment repayment period of 5 to 8 years for Heavy Goods Vehicles, and 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.

Road Transport Demand Estimate: Example of possible LNG demand from Road Transport 2025 / 2040	
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 EU is the same in the UK	
The % of UK trucks operating in Scotland	
Therefore	
Number heavy duty vehicles in the EU (2015/16)	= 15,000,000 Number
Number of LNG fuelled heavy duty trucks predicted in the EU (2030)	= 400,000 (Blue Corridor prediction)
Number of LNG fuelled heavy duty trucks predicted in the EU (2030)	= 2.6% (of 2015/16 vehicles)
Number of heavy duty vehicles in Scotland (2015/16)	= 41,000 Number
Number of heavy duty vehicles in Scotland (2015/16) % of EU	= 0.27%
Number of heavy duty LNG fuelled trucks in Scotland (2025)	= 25 - 50 Number
Number of heavy duty trucks in Glasgow area (2025) = 50%	
Number of heavy duty LNG fuelled trucks in Glasgow area (2025) = 12 - 25 Number	
Assume each vehicle travels	= 82,000km / year
Assuming LNG demand per 1,000km	= 0.85m^3/1,000 km
Number of LNG fuelled heavy duty truck in EU (2040)	= 50% (of 2015/16 vehicles)
Total volume of LNG required in Glasgow area 2025	**= 1,000 to 2,000m^3/year**
Total volume of LNG required in Glasgow area 2040	**= up to 400,000 m^3/year**
Note	
1/ Assumes the number of Trucks in Europe remains constant	
2/ Growth in the number of heavy duty LNG vehicles is based on existing numbers extrapolated through the 2030 Blue Corridor prediction	

There is therefore potential for a significant increase in the use of LNG fuelled trucks and thus in the 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, and with LNG tankers not permitted to use tunnels (i.e. the northbound crossing of the River Thames by the M25 at Dartford), there exists an opportunity to supply LNG to road transportation in the north of England and Scotland which could be seized at Hunterston.

4.3. Power generation

The closure of Torness and Hunterston B Nuclear Power Stations, in 2030 and 2023 respectively, will reduce Scotland's electricity generation capacity. On the other hand, demand is expected to remain at similar levels in the future[9] and developments with electrical cars could see a 10-30% increase in electrical power generation required[10]. This excess demand could be met with LNG electricity generation.

The following scenario estimates LNG demand from power generation assuming the justification (e.g. electrical power generation and financial) for the Ayrshire Power Ltd (2010) Multi-Fuel Power Station at Hunterston remain valid at 1,852MW.

[9] Future Energy Scenarios – National Grid available at: http://www2.nationalgrid.com/uk/industry-information/future-of-energy/future-energy-scenarios/

[10] Scottish Power, National Grid and Cambridge Econometrics have outlined between 10-30% more power generation to account 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.

Power Generation Demand Estimate: Example of possible LNG demand from Power Generation

In the following one scenario of many possible for LNG demand from power generation at the Hunterston PARC in 2025/40 is calculated for illustrative purposes only.

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

Therefore

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 rate to electricity	= 43%
Electrical power per M3 of gas	= 4.64 kWh
Total volume of gas required	= 1,750,000,000 m^3
Total volume of LNG required	= 2,900,000 m^3/year

Based on previous planning applications for a power station proximate to Hunterston Port and Resource Centre (PARC), a mid-sized power station which seeks to generate 1,853 MW could be located near to Hunterston. 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.

A proposal for a smaller power station (<1000MW) would also contribute to demand and potentially induce development of LNG demand and infrastructure across Scotland (where demand could not be met by existing and planned LNG infrastructure in Rosyth and England/Wales).

4.4. Industrial

There are a range of Energy Intensive Industries (EIIs) in Scotland and other businesses which could benefit from utilising LNG as a heat source or 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 and lime, ceramics, chemicals, glass, industrial gases, iron and steel, non-ferrous metals, pulp and paper and refined petroleum product industries. There is no reliable source of information for EIIs employment and firm data in Scotland. EIIs rely upon medium term security and competitively priced energy and feedstock to secure future investment.

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. The use of LNG by EIIs could be a huge driver for LNG, and could also drive use across other sectors as user adopt or recognise benefits.

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

Industrial Demand Estimate: Example of possible LNG demand from a large industrial user	
Therefore	
Nominal power station capacity	= 10MW
Nominal yearly power station capacity	= 87,600 MWh/year
Operating efficiency	= 100%
Actual yearly power station generation	= 87,600 MWh/year
Actual yearly power station generation	= 87,600,000 kWh/year
Power per m^3 of gas	= 10.73 kWh
Total volume of gas required	= 8,200,000 m^3
Total volume of LNG required	= 13,700 m^3/year

Should individual major energy users convert to LNG, they would need on site storage and a means of re-gasification and resupply by ship.

4.5. Other demand for LNG

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

4.5.1. Residential

Scotland Gas Network (SGN) is Scotland's gas distribution network provider and is required under licence to support the Scottish Independent Networks (SINs) 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. Their coastal location makes them well suited to marine LNG supply.

There are also residential gas network areas. Data published by Department for Energy and Climate Change estimates that 16% of households in Scotland are off the gas grid (396,000). In North Ayrshire, there are 4,000 (7% of all), and other nearby local authority areas (e.g. South Ayrshire) have further households which are not connected to the gas network. There are 7,500 households which are covered by the SIUs. The potential LNG market served from Hunterston could range from a national high of 396,000 households which are not connected to a low of 30,000 households. The below provides an estimate of the potential range of residential demand.

Domestic Demand Estimate: Example of the potential uses of domestic household not connected to the gas network	
National (High)	
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
Local (Low)	
Number of households not connected to the gas network	= 30,000
Average household usage of gas	= 12,000 kWh
% converting to LNG	= 75%
Total demand per year	= 270,000,000 kWh/year
1 m^3 of gas energy content	= 10.73 kWh
Gas to LNG	= 600
Actual LNG required	= 50,000 m^3/year

The domestic take up of LNG is uncertain; residential areas using LNG could adapt although requirements such as modern and energy efficient appliances, combined heat and power units and condensing boilers may prove expensive or prohibitive for users.

4.5.2. Agriculture, food and drink

Increased agricultural 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 enable significant reductions in the costs of these activities. However, it would also require infrastructure upgrades and investment in new technology. There is little academic or industry literature on the potential of LNG upon the agriculture industry, many reports instead highlighting the different uses rather than sectoral impacts.

Industrial feedstock (e.g. manufacturing of a number of chemicals and 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. In the future, there may be further support for businesses to adopt LNG. The estimated 27,000 businesses and 51,896 farm holdings in Scotland need to find a balance between commercial success, increased intensification of agricultural production and climate change impacts.

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

Opportunities for LNG are concentrated in certain areas of the Agricultural industry namely distribution and manufacturing. Across rural Scotland, the Food and Drink Sector is intertwined with agricultural production. Given the importance of the Food and Drink sector to the Scottish Economy (£3.65 billion in 2012), there are likely to be specific sub-sectors where LNG could be utilised, such as Whisky.

4.5.3. Whisky

The 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. The remote location of many whisky distilleries, consolidation, and the relative energy intensiveness of their activities – the industry uses 3,367,178,455 kW/h of energy per annum - drive energy investments, in which LNG could play a further role. There are approximately 20 whisky distilleries (only handful in the lowlands but many more in Campbelltown, Islay and in the Highlands) on the West Coast of Scotland that are accessible to Hunterston (by road or sea).

The 102 malt distilleries in Scotland could be a focus for LNG use. These accounted for 87% of the heavy fuel oil used in the industry in 2010, 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. This could limit LNG take up.

Industrial Demand Estimate: Example of Whisky Production

Total production per year	= 61,000,000,000 litres
Average electricity demand per litre	= 0.367kWh
% converting to LNG	= 50%
Total demand per year	= 11,193,500,000 kWh/year
1 m^3 of gas energy content	= 10.73 kWh
Gas to LNG	= 600
Actual LNG required	= 1,740,000 m^3/year
Number of malt and grain distilleries	= 108
Average LNG demand	= 16,100 m^3/year/distillery

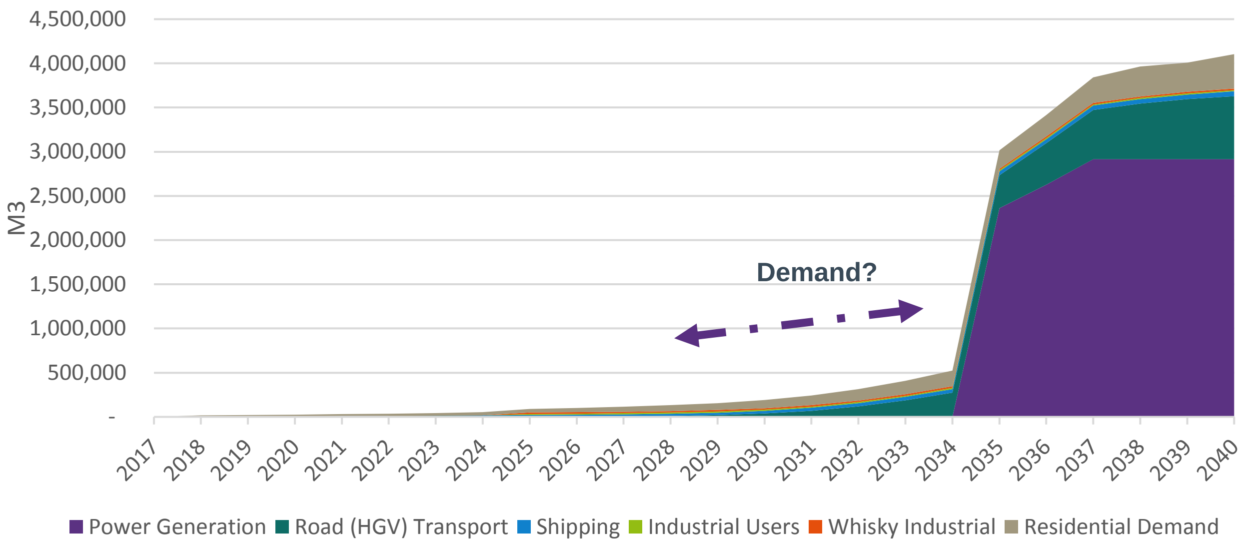
As highlighted in previous sections, there is a potential demand for LNG from road and sea transportation. This has some overlap with the food and drink logistics sector with distribution, transport of raw material and farming or fishing. As a result, there is also potential for the 2,000 Scottish fishing vessels and agricultural vehicles to utilise LNG fuels. However, demand from these areas is uncertain.

5. LNG Demand - Summary

The previous section outlined several possible scenarios for the future Liquefied Natural Gas (LNG) demand in the West of Scotland. It is apparent that LNG power generation, if required, would be the dominant source of demand, with marine LNG bunkering and the supply of LNG to road transport filling stations as secondary demands.

Figure 5-1 shows how demand could grow against the timescales presented in the demand estimates. Given the scale of demand for power generation, any change to timescales for this development would have a substantial impact upon total demand.

Figure 5-1 Indicative Future Demand



Source: Atkins 2017

There is a temporal aspect to demand which is subject to uncertainties and difficult to forecast. Nevertheless, temporality remains important. The above analysis should be considered as indicative of the potential size of markets for LNG and not relied upon for investment decisions

Presented is a likely scenario assuming work progressing on a new power station within standard timescales over the next 20 years. However, demand across all areas could rise significantly quicker, leading to requirements for more LNG infrastructure. For example, the shipping industry's adoption of LNG vessels is one area where uptake could be more rapid than anticipated[11]. Similarly, recent investments in LNG infrastructure by energy suppliers like Calor could support further adoption of LNG by the commercial vehicle market.

The decommissioning of Hunterston B in 2023 and Torness in 2030 could lead to a gap in energy supply. At the moment, Nuclear makes up 35% of all electricity generation in Scotland[12] and therefore LNG development may be brought forward to plug this gap, although the planning process and construction could take several years.

Future demand in West of Scotland (as presented above) could be met by existing LNG facilities in Scotland until approximately 2028-30, when the demand would need to be met by new or larger LNG facilities. When LNG facilities are built at Rosyth, this facility will be well placed to meet this demand in the short-term. Demand for LNG in Scotland would also be driven by major power stations, industrial users and larger residential demand. The indicative demand presented above is based on current trends and assumptions regarding forecasts and the development of a power station.

[11] For example, the Sea Europe (2017) Market Forecast Report.
[12] Scottish Government, Energy Statistical Bulletin 2017, available: http://www.gov.scot/Resource/0051/00514475.pdf

Following the review of demand, two development scenarios in table 5-1 are considered which would enable the Hunterston site to meet this demand:

Table 5-1 Scenarios

Scenario	Detail	Demand
1 - Importation Terminal	• 1,000 MW LNG Power Station • The marine transhipment of LNG to support - Ship to Ship (STS) LNG bunkering of marine vessels in the Firth of Clyde - The distribution of LNG to isolated domestic users - The distribution to large industrial users • The supply of LNG road tanker to support - TTS LNG bunkering of marine vessels in the Firth of Clyde - Commercial/private LNG filling stations - Commercial transportation users - The distribution to large industrial users	Up to 3,515,000 m^3/y (as displayed above)
2 - Trans-shipment Terminal	Scenario 2 is as per scenario 1 but without the Power Station and therefore: • The marine transhipment of LNG to support: - STS LNG bunkering of marine vessels in the Firth of Clyde - The distribution of LNG to isolated domestic users - The distribution to large industrial users • The supply of LNG road tanker to support: - TTS LNG bunkering of marine vessels in the Firth of Clyde - Commercial/private LNG filling stations - Commercial transportation users - The distribution to large industrial users The terminal would be a Small-Scale LNG (SSLNG) terminal acting as a hub to the distribution of LNG in west and central Scotland	Up to 615,000 m^3/y (without the power demand in the above chart)

These scenarios are elaborated in the sections below, which outline the infrastructure which could be adopted and developed for Hunterston.

6. Scenario 1 – LNG Importation Terminal

This section explores the infrastructure requirements for a Liquefied Natural Gas (LNG) Importation Terminal at Hunterston and the suitability of the site for meeting the demand articulated in Scenario 1.

6.1. LNG demand

Based on the high-level demand analysis in section 3, the total demand in 20 years at a LNG Terminal in Hunterston that supports power generation and trans-shipment could be:

LNG Demand Marine = 56,100 to 115,000 m3/y
LNG Demand Road Transport = 400,000 m3/y
LNG Demand Power Generation = 2,900,000 m3/y
LNG Demand Other (estimate) = 100,000 m3/y
Total Demand = up to 3,515,700 m3/y

With a nominal Liquefied Natural Gas Carrier (LNGC) capacity of 125,000 m^3 this equates to approximately 28 deliveries per year or one approximately every 2 weeks. To accommodate vessels the design of a LNG terminal at Hunterston would need to meet the following considerations:

- Operational - Target markets and volumes of gas;
- Operational - Short term vs long term vision for the terminal; and,
- Development phasing – Is the facility to be built for full capacity or phased development.

6.2. LNG transportation - LNGC

Looking to the future, the size of LNGC is anticipated to increase, which will have implications for the facilities and infrastructure at Hunterston. The principal dimensions of selected LNGC's are summarised in the table below:

Table 6-1 LNGC dimensions

Description	Existing vessels			New generation	
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) Actual dimension may vary by +/- 10%):

The clear majority of LNGC fleet exceeds 125,000m^3 capacity, while in the future new build LNGCs are expected to be larger at up to 180,000m^3. These are well within the berthing and mooring capacity of the Hunterston Terminal as outlined in section 2.

6.3. LNG Storage and Regasification Options

Once the LNG is delivered to Hunterston there are three principals options for its storage and regasification, which are:

- Onshore Storage and Regasification;
- Floating Storage and Regasification (FSRU) Vessel; and
- Floating Storage Unit and separate Regasification Unit.

LNG that is to be transhipped to marine vessels or road trucks will be cryogenically stored before being re-loaded on to the vessels, or loaded on to road tankers. LNG used for power generation will be cryogenically stored before being re-gasified and used in a gas fired power station.

The characteristics and operational requirements of each storage and regasification option are discussed in the following section.

6.3.1. Onshore Storage & Regasification

With an onshore storage and regasification process, the LNG is pumped from the LNGC via cryogenic pipe lines to above ground storage tanks. LNG that is to be trans-shipped is then discharged into vessels or road tankers. While LNG to be used in power generation is re-gasified prior to send out to the power station. The key issue is identifying a suitable location for the storage tanks and re-gasification facilities. Locating the storage tanks and regasification facilities close to the berth would be preferred.

Large 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 heave.

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 favouring the construction of an onshore storage and re-gasification is securing a long-term supply contract so that the large capital costs can be spread over a reasonable long payback period. Therefore, provision of a LNG terminal and a gas fired power station are explicitly linked and, in turn, a new gas fired power station would require a long-term commitment from the government to purchase the electrical power generated.

The Hunterston site has sufficient space to accommodate both the LNG cryogenic storage tanks and re-gasification facilities. Assuming a 125,000 m^3 LNGC and a minimum 5-day contingency storage (in case LNG delivery is delayed), a nominal onshore storage capacity of 170,000 m^3 is required. This could be achieved with a single tank or several smaller tanks.

6.3.2. Floating Storage and Regasification Unit (FSRU)

FSRUs combine LNG storage with vessel-mounted re-gasification, thus eliminating the need for substantial onshore facilities. The current global FSRUs fleet, as reported by International Gas Union (Ref 09) in 2017, consists of only 25 vessels, with the market dominated by Excelerate and Golar LNG with 7 vessels each, and Hoegh with 6.

Selected vessel characteristics are provided in the following tables.

Table 6-2 FSRUs Typical Dimensions

Owner	Excelerate	Excelerate	Golar	Golar	Hoegh	Hoegh
Class or name	Excelsior Class	Experience Class	Winter	Igloo	Neptune	Gallant
Capacity – Nominal	138,000	173,400	138,000	170,000	145,130	170,000
Capacity - Cargo	135,930	170,800				
Length (m)	277	294.5	277	292	283	294
Beam (m)	43,4	46.4	43	43	44	43
Laden Draught (m)	11.52	11.5	11.7	11.0	11.5	11.4
Ballast Draught (m)	9.2	9.4				
Build	2005 -2006	2014	2004	2014	2009	2014
Regasification MMcuf/day	400 – 690	400 - 800				

Source: Down the pipeline - A Lansdale (Re 08), Golar and Hoegh web sites

Figure 6-1 FSRU Excelsior

Source: excelerateenergy.com (2017)

The principal advantage of a FRSU operation is the speed of deployment and the ability to off-hire the FSRU if it is no longer required. On the other hand, the cost of daily hire constitutes a significant cost.

At Hunterston one configuration would be to berth the LNGC on the outer berth, of the jetty, and the FSRU on the inner berth, with the LNG pumped in-between.

There are 3 principal options for re-gasification using a FSRU:

- 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; and
- Combined Loop – The FSRU draws in seawater, heats it using steam from the boilers and circulates it through the LNG vaporizers.

The Hunterston site, from initial inspection, is considered a suitable location for both the LNGC and FSRU.

Assuming a 125,000m^3 LNGC and a minimum 5-day contingency storage, as before, a nominal FSRU storage capacity of 170,000m^3 is required. This is compatible with the current range of FSRUs.

6.3.3. Floating Storage and separate Regasification Unit

The third option would be to use a moored LNGC as a Floating Storage Unit / facility (FSU) on the inner berth, with LNGC deliveries to the outer berth and a separate re-gasification unit located either onshore or mounted on a pontoon, potentially towards the root of the existing jetty. The FSU capacity would be comparable with the FSRU storage outlined above.

The Hunterston site, from initial inspection, is considered suitable for a FSU and land based or separate floating regasification facility.

6.4. LNG terminal design

The following section briefly describes the principal elements of a LNG terminal supporting a power station and trans-shipment centre at Hunterston Port and Resource Centre (PARC):

Berths - Onshore storage and re-gasification will only require a single berth for the LNGC. However, if the facility is to use an FSU/FSRU for the storage of LNG, this vessel would effectively be permanently moored to the jetty. Two configurations are possible. Firstly, the FSRU moors to the inner berth and the LNGC to the outer berth, thus utilising two berths. Alternatively, the FSRU moors to the outer berth and the LNGC moors against the FSRU.

Use of both the inner and outer berths would be options and as a consequence, the jetty would not be available for the unloading of alternative products such as iron ore or coal. A second berthing structure could therefore be required.

Ideally a jetty or unloading facility would normally comprise an unloading platform, berthing and mooring dolphins and an access trestle. On the unloading platform the product handling and safety equipment, such as unloading arms and product transfer pipe work are mounted. The unloading platform ideally should be independent of the berthing dolphins to minimise the risk of damage to sensitive equipment and pipework from movement of the structure resulting from vessel berthing impacts.

At Hunterston the jetty and unloading facility and the berthing structure would be integral, owing to exiting configuration. Therefore, the topside equipment and pipework would have to be carefully designed to accommodate any movement of the structure.

Dredging (berthing pocket)- The water depth at the existing jetty is sufficient for the LNGC and FSU/FSRU, however additional dredging would be required to locate the FSU/FSRU on the inner berth.

Mooring and Berthing Dolphins - If the existing jetty is to be utilised, additional mooring and berthing dolphins will not be required.

Navigation Aids - The existing marine navigation aids would need to be reviewed and may have to be upgraded. However, it should also be expected that modern berthing aids will be required on the jetty, along with the use of portal pilot units, to minimise the risk of significant berthing impacts.

Other facilities - The existing Hunterston nuclear power stations are located to the south, removed from the PARC site. Physical interaction with the power stations should be limited, though account would have to be taken of interference between circulating water systems.

If a LNG power station is constructed then it is unlikely that a LNG power station would be operational prior 2023, i.e. when the existing Hunterston B power station is currently expected to stop power generation. In this case, it could be possible to upgrade and reuse the existing grid connections.

6.5. Summary

Other options for storage and regasification beyond those examined above are available. However, limited storage capacity at Hunterston implies they are impractical for this linked LNG fuelled power generation scenario.

As outlined above, the use of a FSU/FSRU or the construction of an on-shore facility will be determined by any policy commitment to the purchase of electricity and the demand and financial viability of the various opportunities identified for LNG in Scotland. Financial considerations for Hunterston include:

- An FRSU can be hired at an indicative cost of approximately US$ 100,000 per day, plus a mobilisation/demobilisation cost (actual costs will vary significantly depending on availability), while a LNGC acting as a storage facility can be chartered for approximately US$ 80,000 per day
- An FRSU could be purchased/constructed and dedicated to this project at an approximate cost of US$ 250M (180,000 m^3). If the commercial environment for the importation of LNG into the UK changed the vessel could be relocated to other location / projects.
- Onshore cryogenic storage tanks would cost approximately US$ 100M (150,000 m^3) and re-gasification facilities would also add further significant cost. Such fixed assets risk becoming stranded in the event of a change in the UK LNG import demand.

Table 6-3 below demonstrates that if a long-term commitment (of around 10 years) to the sending out and receipt of gas is made, such as to a gas fuelled electricity power station then it will be cost effective to provide onshore gas storage and re-gasification.

Table 6-3 Scenario 1 Indicative cost summary

LNG Terminal Element	On Shore	FSRU		FSU	
	Total	Per day	Total	Per day	Total
A/ Capital Costs					
1/ Jetty modifications	£7,600,000.00		£22,800,000.00		£22,800,000.00
2/ Gas storage					
Shore	£76,000,000.00				
FSU		£76,000.00	£27,740,000.00	£52,200.00	£19,418,000.00
3/ Re gasification	£159,600,000.00				£159,600,000.00
SubTotal1	£243,200,000.00		£50,540,000.00		£201,818,000.00
B/ Operating and Maintenance Costs					
Operating Costs/yr.	£6,080,000.00		£6,118,000.00		£8,443,600.00
Maintenance Costs/yr.	£6,080,000.00		£6,118,000.00		£8,443,600.00
SubTotal2	£12,160,000.00		£12,236,000.00		£16,887,200.00
TOTAL	£255,360,000.00		£62,776,000.00		£218,705,200.00

Source: Atkins 2017 (figures worked up using US$ and multiplied by current exchange rate)

Over 5 years, the onshore, FSRU and FSU range between £240 and £300 million. After 10 years, it is cost effective to provide onshore gas storage and re-gasification.

In relation to the development of a power station to drive demand, Ayrshire Power Limited (APL), a joint venture between Peel Energy and DONG Energy, submitted a Section 36 application in 2010 to construct and operate a multi-fuel power station with Carbon Capture and Storage on part of the Clydeport site. A Public Local Inquiry by Scottish Ministers was planned. However, in June 2012 APL decided to withdraw the application for consent due to uncertainty around securing the necessary financial investment to build the power station in the foreseeable economic climate.

If the initial combined capital cost of a LNG terminal and a power station is considered too much it may be possible to spread the cost by using an FSRU or even a separate floating storage and re-gasification capability initially. This would enable revenue and electricity to be generated during an initial period prior to commencing construction of onshore LNG storage and re-gasification facilities.

7. Scenario 2 – LNG Trans-shipment

7.1. LNG demand

Based on the previous sections total demand in 20 years' time for an LNG Terminal supporting the trans-shipment of LNG would be:

LNG Demand Marine = 56,100 to 115,000 m^3/y
LNG Demand Road Transport = 400,000 m3/y
LNG Demand Other (estimate) = 100,000 m^3/y
Total Demand **= up to 615,000 m^3/y**

With a nominal vessel capacity of 37,000 m^3 this equates to approximately 10-20 deliveries per year. The storage capacity required simplistically could be approximately 2 weeks supply plus a parcel size, i.e. approximately 50,000 m^3.

With this scenario, a LNG terminal constructed at Hunterston should have the ability to reload LNG on to bunkering vessels and load road tankers, Thus the small-scale LNG (SSLNG) terminal would support the distribution of LNG throughout the West and Central areas of Scotland.

7.2. LNG Transportation - LNGC

The principal dimension of selected small to mid-size LNGC's is summarised below (Actual dimension may vary by +/- 10%):

Table 7-1 Small to mid-size LNG Carriers

Description					
Containment	Membrane	Membrane	Membrane	Membrane	Membrane
Capacity (m^3)	5,000	10,000	19,000	30,000	65,000
Length (m)	100	123	130	175	217
Beam (m)	18	21	26	29	34
Laden Draught (m)	9	9	9	9	10

Source: PIANC WG 172 Design of small to Mid-Scale Marine LNG Terminals including Bunkering (Ref 121)

For this type of operation, the LNG would be sourced from the Isle of Grain or a European terminal capable of reloading LNG, with deliveries arranged to suit demand.

7.3. LNG Storage and Regasification Options

Once the LNG is delivered to Hunterston it would be stored in cryogenic storage tanks these could be Onshore, Floating Storage Regasification Barge (FSRB); or a re-deployable, modularised LNG terminal technology like Gravifloat. From these, the gas will be trans-shipped as Compressed Natural Gas (CNG) or LNG. The characteristics and operational requirements of each of the above storage options are briefly discussed below.

7.3.1. Floating Storage Regasification Barge (FSRB)

The development of FSRB's are still in its infancy; they are being developed to allow small volumes of LNG and gas to be delivered to markets not normally accessible. Such as where the building of an onshore facility is not economically viable (as outlined in the demand for Scenario 2).

Characteristics of FSRB vary and we present some of the indicative characteristics below:

Table 7-2 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)

The storage capacity highlighted above for a FSRB is more aligned to this trans-shipment scenario for Hunterston.

An FSRB would allow for a phased development aligned to demand. Initially in this scenario a FSRB of approximately 10,000 m^3 to 20,000 m^3 capacity could be constructed on the Clyde before being located at Hunterston. The barge would then tranship LNG to road tankers and or marine bunkering vessels. When justified by demand, additional storage capacity could be added by the provision of onshore storage tankage or an additional storage barge. In addition, re-gasification capability could be added to the deck of the barge if a requirement for sending out CNG is required by the demand. In addition, any Boil of Gas (BOG) could be used for small scale power generation

Figure 7-1 Indicative FSRB

Source: Wartsila 2017

7.3.2. Regasification Option 4 - Gravifloat

Gravifloat represents a variation of a FSRB and is a marketed by a subsidiary of Sembcorp Marine (Gravifloat should be considered as representative of such system, other suppliers are available). 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 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.

It allows modular construction and operation, to allow for ramping up in capacity.

Fabrication of the facility 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.

The storage capacities of the Gravifloat is potentially up to 90,000 m^3

The Gravifloat option incorporates the LNG storage, berthing structure, and regasification capability into a single item. At Hunterston the berthing function is not necessarily required as the existing berth is readily available. However, a storage and regasification option could be tailored and located on the inner berth of the Hunterston jetty.

Figure 7-2 Gravifloat LNG receiving terminal

Source: Wartsila 2017

Fabrication of a Gravifloat (or similar solution) could take place under licence in a Clyde shipyard, and the BOG could be used for small scale power generation.

7.4. LNG terminal design

The below section describes the principal elements of a LNG terminal, with FSB/FSRB/ Gravifloat, supporting a LNG trans-shipment centre at Hunterston PARC:

Berths - A FSRB/FSB could be located on the inner berth of the Hunterston jetty, with LNG transferred across the jetty via cryogenic unloading/loading arms and pipe lines. A FSRB/FSB would permanently occupy the inner berth and the specialist LNG transfer equipment on the jetty deck would limit the use of the terminal for alternative products i.e. the jetty will not be available for the unloading of alternative products, such as iron ore or coal. If these products remain a requirement a second berthing arrangement could be developed shore wards off the inner berth.

A Gravifloat solution could be used in a similar arrangement as a FSRB, or alternatively a complete separate facility including loading/unloading platform, mooring dolphins and access way could be constructed inshore of the existing jetty.

As previously discussed LNG handing equipment and pipework is sensitive to sudden movements of the supporting structure (i.e. those caused by berthing impacts) and ideally the berth structure and loading platform should be separate. For a trans-shipment option the vessels mooring at the jetty will be considerably smaller than in Scenario 1, and while berthing velocities may be higher the total energy transmitted into the jetty is expected to be lower, and therefore any movement will be less. It is therefore expected that with careful design the LNG transfer equipment could accommodate any deck movement.

Dredging – Berthing pocket - The water depth at the existing jetty is more than sufficient for this transhipment operation.

Mooring and Berthing Dolphins - If the existing jetty is to be utilised additional mooring and berthing dolphins will not be required.

Navigation Aids - The existing marine navigation aids would need to be reviewed and may have to be upgraded. However, it should also be expected that modern berthing aids, such as approach velocity screens and Portable Pilot Units will be required as a minimum, to minimise the risk of significant berthing impacts.

Other facilities - The existing Hunterston nuclear power stations are located to the south and separate to the Terminal site. Physical interaction with these power stations should be limited.

7.5. Summary

This trans-shipment scenario offers the possibility of modular development, and therefore the possibility to grow the business in response to direct demand, rather than responding to regional expectations or ambitions.

Historical experience of small scale LNG trans-shipment operations is limited and therefore even indicative costings are of limited use. However, as the conversion of Rosyth to a small-scale LNG terminal is estimated at £35m (within an overall project cost of between £80-100 million), a rough order of magnitude of £50 to £80m could be expected. An initial high-level assessment of the scope of work required to prepare Hunterston for such a facility is outlined below:

- Regulatory and planning approval.
- Removal or securing of unused equipment on the existing jetty.
- Installation of unloading or loading arms, cryogenic pipework and control, monitoring safety and navigation equipment.
- Purchase, fabrication and hiring and installation of a floating storage barge on the inner berth.
- Construction and installation of a cryogenic pipe work and truck loading facilities.

Based on the above analysis the use of a FSRB or a Gravifloat solution would be applicable to this scenario at Hunterston.

8. Challenges and opportunities

The combination of policy initiatives (at Scottish, UK and European), technology advancements and the oversupply of LNG has contributed to the unprecedented growth in LNG adoption as an alternative energy source to petroleum products. However, the natural gas road refuelling infrastructure in the UK is also heavily weighted towards the South of England, with one facility in Scotland (Lockerbie). This is a barrier to future adoption although private investments by companies like Stolt-Nielsen are helping to overcome challenges.

The below section examines macro challenges and opportunities for LNG in Scotland and at Hunterston.

8.1. Political changes

Several political challenges could impact with how LNG in Hunterston could develop. We highlight two key points below:

- **The relationship with the European Union:** The significance of higher and continuing levels of uncertainty as a result of ‘Brexit’ are a potential economic growth, legislative and environmental risk for the LNG market. There could also be 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. It is identified that almost every level of policy making will be “turned on its head” by Brexit. As such it will not be possible for policy to continue as normal and changes can be expected.

- **Political uncertainty:** The LNG 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 one example, that have driven price spikes in LNG. These price spikes could become more dramatic in the colder months. 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.

  The diplomatic issues between Qatar and other Middle Eastern countries could see further escalation of tensions with supplies disrupted as a result (current sea routes are through waters that are still accessible). If one of the largest suppliers of LNG finds it difficult to access markets, then reliance on other imports (e.g. from Russia) could lead to political decisions, cost rises and eventually a price rise which would affect the dynamic of the LNG market. Another change is that the recent political issues in Qatar have seen Japan review contracts with Qatar to seek more flexibility.

  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 in LNG if supply is constrained and domestic prices rise.

8.2. Low carbon and new technologies

The use of LNG should be viewed in the context of a massive expansion of low carbon and renewable heat technologies across Scotland. This supports emissions reductions and offer economic opportunities to reduce costs (for industry and householders), develop products, create services and grow economic activity. Renewable technologies have also diversified Scotland’s sources of electricity and heat, to build up security of supply for the future.

LNG is a fossil fuel but in the above context is sometimes viewed as a ‘bridging fuel’. Although a fully renewable future is the ambition, the transition period sees renewables not meeting all types of energy demand, creating a gap that LNG is viewed as being able to fill.

Hydrogen has been highlighted as a potential renewable or low carbon energy source which could drive future energy generation and play a role in transportation which will eliminate or significantly reduce emissions. There is also potential for hydrogen to provide energy for electric vehicles. Hydrogen energy technology is rapidly developing addressing some storage, liquefaction and compression challenges. Costs remain uncertain, some new infrastructure costs are high (e.g. estimated $1,000,000 per mile of pipeline) but costs can be reduced by utilising existing networks. Work is ongoing looking at how networks could be retrofitted and hydrogen blended to reduce the infrastructure demands.

There have been industry commentators[13] who have identified that the strength of renewables is leading to smaller LNG investments. The low cost of renewables increases the risk on larger 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 areas of overlap (e.g. bio-LNG) which could offer further emission efficiencies. Bio-LNG which is LNG extracted from anaerobic digestion (animal waste, landfill gas, wastewater bio-gas and digester gas) could be another way for emissions reductions to be driven. The scale of the bio-LNG industry is small and although Scotland is investing in the bio-economy and biotechnology pilots, the existing infrastructure would need to adapt for further adoption.

8.3. Transmission costs

Another potential risk for new fossil fuel power stations in Scotland is high locational transmission charges which are an additional cost on top of carbon taxes. The transmission charges are designed to ensure connection to the National Grid, which vary depending on location and are more expensive the further way from London and the South East of England.

The original aim was to encourage power companies to invest in generation capacity where it is most needed and in renewable technologies. Locational charging means Scottish generators produce about 12% of UK generation but account for 40% of the transmission costs, or about £100 million per year more than generators in the South. In 2016 Ofgem outlined a new methodology for calculating what generators pay to use the electricity transmission network. However, it will still retain the locational influence to encourage generators to build as close as possible to urban areas.

8.4. Transport costs

Transportation (by road and sea) is a significant portion of the cost of LNG and in many cases, it is not economical to transport by road over 500 miles from a plant, making the journey between Kent/Wales and Scotland a risk to greater adoption of LNG.

Furthermore, the LNG road 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. The transport costs of LNG by road vary. 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.

8.5. Scotland’s energy security

The UK has become increasingly dependent on imports of energy. It is identified that unless new energy generation projects are constructed Scotland could face a significant gap in energy generation. Furthermore, developments like the closure of UK’s largest gas storage site (off the east coast of Northern England), create risks to the supply of gas in the future. 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 system are therefore critical to the future of Scotland’s energy. The following points highlight some of the considerations that policy makers will be assessing in their support of LNG:

Security and diversity: LNG raised further questions about security, given that supply of LNG from abroad can raise energy security risks. However, new gas supply or electivity generation could diversify the energy mix, improving security.

Current low capacity margins are unsustainable: Low spare capacity could create risks to Scotland’s energy system if there is also low generation availability (e.g. low wind and many transmission faults).

New generation: The low remaining generation life of some power stations is a risk with the approaching closure of nuclear electrical generation in Scotland. This has led to a planning uncertainty for energy generation although it is recognised that new generation will be needed.

Irish-Scottish Links: Several opportunities also exist around collaboration with the Irish-Scottish Links on Energy Study (ISLES): “a major initiative designed to enable the development of interconnected grid networks

[13] 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.

to enhance the integration of marine renewable energy between Scotland, Northern Ireland and Ireland". This project sees the Ayrshire Coastline being considered and suggests that the LNG industry is another area where collaboration could be explored.

Future of Nuclear: There is current opposition to the development of nuclear power (under current technologies) in Scotland. This has not created a shortage of generation capacity in Scotland since renewables and transmission capacity in England has met requirements. However, given that Scotland has its own environmental target of an 80% reduction in greenhouse gases by 2050, the opposition to nuclear means that other forms of energy generation will have to contribute to a large share of total Scottish generation.

The future closure of several power stations, including Hunterston B (in 2023) provides an opportunity for LNG. Hunterston and the port infrastructure provide significant advantages for a new gas-powered power station. There is collective support from the local authority and others for Hunterston's energy sector to continue to be based in Hunterston. Further power generation could address a shortage in capacity following 2023.

8.6. Policy & Regulation

We reviewed the relevant polices below which would impact upon proposals for LNG infrastructure in Hunterston. This follows the examples of LNG infrastructure in other countries (e.g. Norway) where support for investment is driven by local, national and European policy and support.

Scotland's Economic Strategy (2015):

Scotland's Economic Strategy[14] 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 will support this overarching goal through making Scotland 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 9 (Economic Impact).

Low Carbon Economic Strategy (2010)

The Low Carbon Economic Strategy (LCES)[15] 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 supports LNG development particularly around transforming the energy sector to be low carbon and innovative. There is further support for LNG as the strategy highlights the opportunity and support for the skills transfer from the Oil and Gas sector to renewables and low carbon innovations.

Scotland's Draft Energy Strategy (2017)

Scotland's Draft Energy Strategy[16] 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.

[14] Scotland's Economic Strategy (2015), available at: http://www.gov.scot/Topics/Economy/EconomicStrategy
[15] A Low Carbon Economic Strategy for Scotland (2010), available at: www.gov.scot/resource/doc/331364/0107855.pdf
[16] Draft Energy Strategy 2017

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"[17] including LNG. LNG technologies provide an opportunity for advances in technology, carbon benefits and flexibility of infrastructure. These are identified as potentially having a transformative impact on the use of energy in residential, commercial and transport. The transport and manufacturing/processing sectors are seen as being well placed to benefit from LNG and other new hydrocarbon technologies.

The Strategy is flexible in that it does not outline which new hydrocarbon technologies will be favoured. 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 benefit the ambitions around decarbonising (e.g. particularly manufacturing and transport). 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 is needed.

Climate Change Delivery Plan (2009)

In addition to the Energy Strategy, the "Climate Change Delivery Plan"[18] commits to an almost completely decarbonising of 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 emissions savings from the transport sector. These include measures around changes to behaviour, eco-driving, planning and the "improved fuel / carbon efficiency of cars" where LNG can 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.

Scotland's National Marine Plan[19]

The Marine (Scotland) Act 2010 provides a framework which will help balance competing demands on seas around Scotland. It introduces a duty to protect and enhance the marine environment and includes measures to help boost economic investment and growth in areas such as marine renewables. It also lays the foundations for a more simplified marine planning and licensing system.

Scotland's marine plan highlights the need for Scotland to have a "mixed energy portfolio". The Plan identifies different regions for marine planning, including the Clyde. Regional marine plans are expected to outlines how economic activities will develop across the area. Initial work on the Firth of Clyde Marine Spatial Plan[20] makes suggestions, proposes direction and highlights opportunities. Scotland's marine plan and the Firth of Clyde Marine Spatial Plan recognise the strategic importance of Hunterston as an energy hub which will stimulate development.

National Planning Policy

Investments in LNG infrastructure meet two key elements of the Scottish Planning Policy (2014):
Supporting economic growth, regeneration and the creation of well-designed places; and,
Reducing carbon emissions and adapting to climate change.

[17] Draft Energy Strategy 2017
[18] Climate Change Delivery Plan: Meeting Scotland's Statutory Climate Change Targets (2009)
[19] Scotland's National Marine Plan - A Single Framework for Managing Our Seas (2015)
[20] Firth of Clyde Marine Spatial Plan Draft (2009)

The National Planning Framework 3 (2014)[21] sets out a strategy for development, which provides a national context for development plans and planning decisions, and informs the wider programmes of government, public agencies and local authorities. LNG infrastructure and the supply of LNG to Scottish markets will support National Planning Framework 3 by facilitating the transition to a low carbon economy, particularly by supporting diversification of the energy sector. The National Planning Framework 3 is the national spatial strategy for development, which identifies developments that the Scottish Government considers to be of national importance. NPF3 identifies Hunterston as a key area for major maritime infrastructure which will benefit from "co-ordinated action and masterplanning to deliver development in the coming years".

The National Planning Framework also provides an overarching vision for Scotland's regions, highlighting key matters for local-level spatial strategies to consider. For North Ayrshire, NPF3 identifies:

The importance of linkages between Ayrshire's largest settlements, including Ayr and Kilmarnock;

The importance of Hunterston as a key national port, and a potential location for future industrial and employment use, extended operating lifespan for nuclear power production, decommissioning activity, coastal tourism opportunities and renewables.

The potential for a coordinated approach to planning for energy related and other key development as part of a coordinated action for the Hunterston area

Local Planning

The North Ayrshire Council Plan (2015-2020) establishes the Council's mission to "improve North Ayrshire for all our residents". The plan sets out five priorities including "Growing our economy, increasing employment and regenerating towns".

North Ayrshire Council is progressing work for a new Local Development Plan (LDP2), which is intended to be adopted in 2019. The emerging LDP has potential to highlight LNG storage and distribution and electricity generation (from gas) as part of the industrial uses at Hunterston. Identifying this in accordance with the Local Plan will support compliance going forward.

Previous planning policy has seen Hunterston promoted as an internationally and nationally important deep port location for the development of energy related activities, including renewable and low carbon resources, research and skills, and enhancement of Scotland's electricity grid infrastructure. LNG aligns with this but as a fossil fuel, it's relevance and importance could be limited.

The Ayrshire Growth Deal (AGD) which includes businesses and local authorities across Ayrshire is targeting over £350 million of funding from the Scottish and UK governments. This will develop several exciting projects which are related to inclusive growth. A few projects have relevance and an overlap with LNG:

- Industrial projects such as support for a Biotech Upscaling Facility could see LNG play a role in supporting
- Any LNG infrastructure needs to consider its impact (positive and negative upon) marine tourism, clearly cruises and shipping could be supported by LNG facility but landscapes may need to be mitigated.
- Transport projects are also supported and specific investments in and around Hunterston (and nearby towns e.g. Fairlie) could overcome some of the accessibility issues that Hunterston faces.

Overall the Growth Deal aims to develop further and build on the success of the area's key industries through the provision of infrastructure and support to businesses to enhance competitiveness.

8.6.1. Indicative legislative requirements

An initial assessment of the potential Regulation and Planning requirements are summarised, based on the limited information available, should the project be carried forward this list should be re-considered. For example, depending on timescales the existing Local Development Plan and any relevant Supplementary Guidance will need to be consulted.

Table 8-1 Indicative Legislative Requirements

[21] The spatial expression of the Scottish Government's Economic Strategy (2015)

Item	Legislation	Nature of Consent
1	Development Consent	Section 36 Electricity Act 1989 (as amended) – power generation >50MW
2	Town and Country Planning (Scotland) Act 1997 as amended by the Planning etc. (Scotland) Act 2006	Planning permission(s)
3	Marine (Scotland) Act 2010	Marine licence
4	Building Regulations	Building Regulation approval (if necessary)
5	Harbours Act 1964	Harbour Revision Order
6	Energy Act 2004	Safety zone notification
7	Gas storage and loading	Oil and Gas Authority
8	Crown Estates Act 1961	Lease from the Crown Estate Commissioners in respect of the seabed
9	Construction (Design and Management) Regulations 2015	F10 - Notification of Construction Project
10	Conservation of Habitats and Species Regulations 2010 etc and The Conservation (Natural Habitats, & c.) Regulations 1994 (as amended)	Environmental legislation such as European Protected Species Licence
11	The Electricity (Environmental Impact Assessment) (Scotland) Regulations 2017	Environmental Impact
12	The Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017	
13	The Town and Country (Environmental Impact Assessment) (Scotland) Regulations 2017	

9. Economic impact from LNG

The previous sections highlight how LNG could provide opportunities to Hunterston and North Ayrshire. This section explores the potential economic impact of LNG investment at Hunterston PARC, highlighting the potential economic impact by drawing upon available information on the sector and related studies in the LNG and energy sector[22].

9.1. Potential economic impact

The Scenarios presented in Section 4 and 5 provide an overview of the potential economic investments that Hunterston, North Ayrshire (and Scotland) could experience from LNG investment:

Scenario 1: Investments between £240 and £300 million.

Scenario 2: Investments between £50 and £80 million.

Across both scenarios there is potential for further investment and infrastructure to support the industry. For Scenario 1 further investment in a power station could unlock further benefits or in both scenarios onshore cryogenic storage tanks may be deemed worthwhile particularly if LNG prices remain low.

There are several uncertainties around any future infrastructure, not least the scale of investment, investors and industry trends. As a result, the analysis below presents an indicative economic impact assessment which draws upon several approaches to estimate economic impact from LNG investment. The analysis uses a range for job and GVA impacts which provides an indication of how LNG infrastructure could contribute to the economy. We provide further examples of benefits from LNG infrastructure in Appendix 2. The analysis assesses the gross rather than the net impact, which means jobs and benefits created may not solely benefit North Ayrshire or Scotland.

We do not present the impact from the power station which would add further economic impact to the local area.

Table 9-1 Potential Gross Economic Impact

Theme	Calculation	Scenario 1 Impact	Scenario 2 Impact
Jobs	The cost of construction (section 5.4) is divided by construction company revenue by employee (£257,000[23]) 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 600-800 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)[24]. This standard approach within desk based economic impact studies is utilised where	240 FTE construction phase jobs. 130 FTE operational phase jobs.	70 FTE construction phase jobs. 40 FTE operational phase jobs.

[22] There are few UK studies of the local or national impact of the LNG sector upon the economy within academic or industry literature – we outline some examples in the appendix.
[23] Calculated from construction industry employment and project cost figures for the UK (Atkins analysis 2017)
[24] Calculated from employment outcomes and existing energy projects for the UK (Atkins analysis 2017)

Theme	Calculation	Scenario 1 Impact	Scenario 2 Impact
	high-level information or limited information is available.		
	Projects of a similar scale across Europe provide a guide for the levels of investment and benefits that Scotland can expect. Utilising examples of LNG investments and previous projects) the levels of investments 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[25] whilst the Shannon €500 million proposal is expected to create around 450 (construction and operation jobs). As such, we have reviewed potential scale of investment in line with these (and other examples) and jobs to calculate a higher and lower estimate on construction and operation figures.	200 FTE Construction phase 150 FTE jobs for the operation phase.	130 FTE Construction phase 90 FTE jobs for the operation phase.
		150 FTE Construction phase 100 FTE jobs for the operation phase.	100 FTE Construction phase 75 FTE jobs for the operation phase.
GVA	GVA figures are calculated utilising employment figures derived in cells 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)[26]	£10.5 million GVA following construction and first year of operation and £21.7 million GVA per annum)	£3 million GVA following construction and first year of operation (and £6.8 million GVA per annum)
		£8.8 million GVA following construction and first year of operation (and £25 million GVA per annum)	£5.7 million GVA following construction and first year of operation (and £15 million GVA per annum)
		£6.6 million GVA following construction and first year of operation (and £16.7 million GVA per annum)	£4.4 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[27]. GVA estimated utilising existing project information on project size (m^3) and costs and factoring up against proposed LNG investments.	Potential for £10 million GVA following construction and first year of operation (and	Potential for £8 million GVA following construction and first year of operation (and

[25] Whitegate LNG Project in Cork.
[26] Available from ONS and Scottish Government data.
[27] Shannon LNG project is expected to generate €30 million per annum GVA benefits.

Theme	Calculation	Scenario 1 Impact	Scenario 2 Impact
		£22 million GVA per annum)	£16.2 million GVA per annum)

Source: Atkins 2017, BEIS and Atkins research.

As a result, the potential employment and productivity impacts for[28]:

- Scenario 1 could be between 150-240 Construction and 100-150 Operational FTE jobs to be created for investments in LNG. There is also potential for this to deliver up to £33.8 million GVA activity to Scotland's economy.
- Scenario 2 could be between 70-130 and 40-90 FTE jobs (construction and operation) to be created for investments in LNG. There is also potential for this to deliver up to £21.1 million GVA activity to Scotland's economy.

A large proportion of both jobs and GVA would be for North Ayrshire communities. The figures represent a range and highlight how, depending on investment the employment and economic activity impacts could be significant. The above analysis highlights the scale of benefits would be higher for Scenario 2 and both could deliver a boost to North Ayrshire's economy. In 2014, East and North Ayrshire's combined economy produced £1.64 billion GVA[29] with GVA per head almost 35% lower than the UK average. As such, LNG investment could deliver an economic gain.

The above calculations are also 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, based on existing evidence, be as significant.

One complication to economic impact is that construction of FSRUs (and other infrastructure) could be undertaken abroad (in shipyards, etc). As this is a limited analysis, we have assumed a positive scenario for construction of LNG infrastructure in Hunterston[30] with 100% constructed in Scotland. However, as with all construction and infrastructure projects there is the possibility that there will be leakage.

9.1.1. Potential direct, indirect and induced effects

To provide a potential scale of the indirect benefits, we highlight the multipliers devised for Scottish Government to "model the impact of hypothetical economic events"[31]. 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 into 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 7-2 below identifies potential indirect and induced effects in terms of jobs and GVA for the wider economy.

Table 9-2 Employment and GVA Multipliers

	Employment Multiplier	Indirect & Induced	
Impact Type	**(Type 2)**	**Scenario 1**	**Scenario 2**
Employment	1.8 (Construction) 1.9 (Gas)	Up to 300 further indirect and induced jobs for the local and Scottish economy.	Up to 190 further indirect and induced jobs for the local and Scottish economy.
GVA	1.9 (Construction) 1.6 (Gas)	Up to £22.9 million GVA in wider indirect and induced activities.	Up to a further £17 million GVA in wider

[28] 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.
[29] GVA estimates – ONS (2017)
[30] To construct an onshore terminal can see employment of between 800-1,000 people.
[31] Scottish Government Input/Output Tables 2017

	Employment Multiplier	Indirect & Induced	
Impact Type	**(Type 2)**	**Scenario 1**	**Scenario 2**
			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).

Again, the analysis highlights the indirect and induced benefits would be higher for Scenario 1 and could deliver a significant wider impact to North Ayrshire and beyond. Furthermore, with a power station also presenting economic opportunities further economic impact could be achieved.

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 North Ayrshire or 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.

9.2. Wider economic benefits

Wider economic benefits within private or public-sector investments, particularly related to infrastructure are of direct relevance to North Ayrshire, particularly in the context of the Scottish Government's economic strategy. 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.

9.2.1. Sector impacts

Investment in LNG is broadly seen as positive for the wider energy sector in North Ayrshire. Investment will provide further employment opportunities and potential agglomeration benefits that can support current workers and those seeking employment. There could be some competitive dis-benefits but broadly it is 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 North Ayrshire's economic plan) or agriculture through disruption and landscape impacts caused by shipping, vehicle movements or further industrial development. However, negative impacts can be mitigated by the location, landscape and design characteristics.

9.2.2. Skills and transferability

The LNG sector has a strong overlap with other energy sectors which has relevance to Hunterston (and North Ayrshire) with its current and historical strengths in nuclear power station, coal import and manufacturing industries. This provides a potential opportunity for transfer of employment and skills across sectors, helping to safeguard jobs in the wider energy sector and 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 9-3 below highlights the occupations which have identified as being key to LNG infrastructure construction and operation. These employment areas could form the focus of future employment and skills initiatives (retraining/transition or upskilling) in North Ayrshire.

Table 9-3 Potential Employment Areas for LNG

Construction phase	Operational phase
Carpenters, labourers and construction trades	Production Operations
Welders and fitters	Operational performance improvement analysts

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

Source: Various

Several of the occupations in Table 9-3 are listed within industry literature on skills shortages in the UK (and Scotland) and therefore any new investments should consider how the labour market in North Ayrshire can meet the employment or skills needs. This is of relevance given the current skills and qualification profile of North Ayrshire (e.g. 12% of the population have no qualifications). As such, challenges in the resourcing of investment and maximisation of opportunities would occur. However, this is not unusual for many areas of the UK as the energy sector currently faces skills gaps. 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.

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.

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 North Ayrshire's economic development[32] and growth strategy and contribute to transforming Scotland's economy into one that is "future−proofed, high−tech and low carbon"[33].

9.2.3. 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 relevance to infrastructure development and major projects that seek to deliver job and GVA benefits but may not secure the long term, sustainable growth that a local area needs. Investment in LNG could secure wider benefits beyond employment and GVA.

North Ayrshire Council, operators and investors can collaborate with different stakeholders to build inclusive growth outcomes of any developments at Hunterston. 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.

There is a link between homes using natural gas and the incidence of fuel poverty is also important. There are many homes not connected to the gas grid that are reliant on heating oil or other expensive energy sources. Switching to gas requires investment and innovation. As a result, LNG also has a potential role in reducing fuel poverty[34]. LNG can further play a role for isolated communities in Scotland and is already doing so in the SIUs. Approximately 36% of North Ayrshire households are defined as being in fuel poverty. Although LNG prices could rise (which would invalidate the contribution to addressing fuel poverty), the current low prices

[32] Economic Development & Regeneration Strategy Refresh North Ayrshire 2016 – 2025
[33] A Nation With Ambition: The Government's Programme for Scotland 2017-18
[34] 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.

could contribute to lower fuel prices for residents in Scotland. The Scottish Government and North Ayrshire Council has committed to eradicating fuel poverty and any future energy supply issues which increase costs could have far-reaching issues.

As a result, small scale LNG has a potential role to play. Many of the households that are fuel poor are not connected to the gas pipeline networks. 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, LNG and natural gas can also suffer from such price spikes and so this risk needs further assessment.

9.2.4. Land use

LNG infrastructure has the potential to utilise existing industrial areas such as Hunterston 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 the case of Hunterston, existing brownfield sites and facilities can be used which minimises disruption.

9.2.5. Health impacts

Natural gas is a fossil fuel, though the emissions from its combustion are much lower than those from coal or oil. For example, natural gas emits less carbon dioxide (CO2) when combusted in a new, efficient natural gas power plant compared with emissions from a typical new coal plant.

Fracking to extract natural gas broadens the health impact assessment beyond North Ayrshire & Scotland's borders. Reducing emissions from LNG requires working with technologies (e.g. CCS) and regulators to ensure that toxic and pollutants, along with methane are captured. Impacts on human health on site (e.g. in Hunterston) and at its destination can be evaluated as part of the planning and consenting process for any investment and there is potential to mitigate any further health impacts through design and mitigation.

As a result, it appears that LNG has the potential to contribute to health and emissions targets by reducing greenhouse gas emissions[35]. Furthermore, from an economic perspective, the benefits of improved health from improved air quality could lead to reduced 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[36].

LNG suppliers also market LNG as having significantly less health and safety risks than oil based fuels. LNG can utilise underground pipes to ensure safer fuel distribution. 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.

[35] North Ayrshire Environmental Sustainability & Climate Change Strategy 2017-2020
[36] Health Protection Scotland (2014): http://www.hps.scot.nhs.uk/resourcedocument.aspx?id=1743

10. Study conclusion

This report forms a case study for a wider study into the potential LNG market demand, over the next 20 years in Scotland and markets served by Scotland. This report considers the case for Hunterston, on the Ayrshire coast, as the site for a LNG importation terminal.

Two scenarios have been developed, based on different demand predictions:

- A LNG terminal supporting, a gas fuelled power station like that previously proposed for the Hunterston site. Along with supplying LNG to, marine vessels, road transportation and large energy users, such as distilleries
- A LNG trans-shipment terminal suppling LNG to, marine vessels, road transportation and large energy users, such as distilleries

10.1. Conclusions

The demand for LNG as fuel for transportation is expected to increase rapidly, but from a very low base. It is concluded from the demand assessment that there is an opportunity for a LNG trans-shipment facility located at Hunterston and supporting marine operations on the Firth of Clyde, with road transport in central and southern Scotland and power generation at Hunterston PARC.

The work highlights how two Hunterston could serve two scenarios for LNG:

- Scenario 1 considers a Hunterston LNG terminal supporting a 1,853MW power station, and trans-shipment capability for marine and road transportation. Under this scenario a long-term commitment to gas powered electrical generation would justify the construction of onshore storage and re-gasification. Through the initial low capital cost of using a FRSU could help spread the capital expenditure (at the expenses of higher operating costs). LNGC's would berth on the outer berth before pumping the LNG into the onshore storage tanks.
- Scenario 2 sees a marine and road trans-shipment capability constructed. This option would be served by a Floating Storage Barge, holding the LNG until it could be transferred to road tankers and or marine bunkering vessels. The barge would be located on the inner berth at Hunterston with supply vessels berthing on the outer berth.

The Hunterston terminal could, with suitable modification accommodate either scenarios. The benefits to be derived from both are different with Scenario 1 likely to deliver significantly more benefits around jobs and GVA to the local (and national) economy:

- Scenario 1 could be between 150-240 Construction and 100-150 Operational FTE jobs to be created for investments in LNG. There is also potential for this to deliver up to £33.8 million GVA activity to Scotland's economy.
- Scenario 2 could be between 70-130 and 40-90 FTE jobs (construction and operation) to be created for investments in LNG. There is also potential for this to deliver up to £21.1 million GVA activity to Scotland's economy[37].

In addition to the local economic benefits, LNG poses opportunities for emissions (and subsequent health) benefits for Scotland, although whole LNG value and supply chain considerations may reduce the overall benefit.

[37] The figures are gross and the large range highlights some of the uncertainties within the investment but also should be seen as the minimum investment that could be expected.

11. Actions and recommendations

We have identified a series of broad action areas which would support future expansion of the LNG sector in Scotland. These are not definitive but highlight areas of focus if further LNG investment is to be explored. The following are identified as broad actions and recommendations for Scottish Enterprise and other stakeholders to discuss, assess and take forward:

1. **Determine the deficit in Scottish electrical power generation and the demand for new power stations. Related to this it is necessary to understand in more detail if the Scottish Governments has a response to any power generation deficit and to energy security.**
2. **Promote LNG to potential end users with large (aggregate or single) demand. Raise awareness with politicians, policy makers and industry to highlight the benefits of LNG to industry, residential and transport.**
3. **Review and identify the infrastructure needed to enhance the LNG prospects in North Ayrshire. For example, assessing how investments to the gas networks could support LNG take-up.**
4. **Assess electricity and gas connectivity options and improvements which could be delivered.**
5. **Undertake a preliminary study into the planning design and construction of a LNG fuelled power station at Hunterston. There are several on-site and off-site infrastructure improvements which could be required to deliver LNG at Hunterston, we outline much of it above but a more detail assessment will be needed.**
6. **Marketing will be crucial if Hunterston is to access emerging opportunities in LNG. It will be necessary to raise the profile of the PARC to demonstrate the suitability and potential benefits to users. This has started but our conversations so far believe further work can happen.**

In addition to the above there are some specific areas of strategic delivery of LNG infrastructure which have been identified in the research and require further exploration. These are identified in the below:

Maximising opportunities out of investments - Proposed LNG investments could be maximised for the benefit of North Ayrshire's residents. This will require coordinated work by the council, 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 skills needs in LNG and other sectors that are strengths in North Ayrshire. The successes experienced in sectors like Nuclear can be built upon in LNG and lessons learnt from skills challenges faced. There is potential for skills to also drive further inward investment and better linkages with areas or countries with strong LNG infrastructure (e.g. Norway).

Hunterston PARC - There is potential for joined up work around attracting investors or providing support to investing organisations in connection to LNG. LNG investments favour existing industrial marine side locations with access to road and Hunterston PARC has significant advantages in this area. This research process has identified that Hunterston PARC is well placed for encouraging investment of LNG, particularly due to the existing maritime infrastructure, accessibility and strategic support.

LNG demand - The demand for LNG that exists locally, nationally and beyond is growing but from a low base, the required level of demand is yet to be realised. There remain barriers at a global level but also at a local level which need to be overcome. At a council 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. The two scenarios outline potential futures which could see others encouraged 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 and increasing uptake.

Innovation - Investment can drive innovation, which in turn can enhance economic returns for Peel, North Ayrshire and Scotland. In relation to LNG, the developments in small scale LNG and gas transfer technologies are examples of innovations which present opportunities to gain additional benefits from (e.g. agglomeration, research and development).

Skills - The council, investors and any other port stakeholders can play an important role around skills, training and brokerage, which are critical to ensuring local people and businesses benefit from any new jobs as well as to attracting potential investors. There is a shortage of skills in the energy sector and some overlap in terms of timescales for decommissioning Hunterston B, growth in renewables and potential LNG developments. Depending on how the energy mix develops, there are opportunities to build on existing expertise within the workforce and supply chain and to capitalise on overlaps with other energy sectors.

Appendices

Contains *sensitive* information

Appendix A. References

Table 1. Demand Calculation References

Ref	Title	Author
01	UK Admiralty Chart	UK Admiralty
02	UK Admiralty Tide Tables	UK Admiralty
03	Harbour Approach Channel Design Guidelines	PIANC
04	Recommendations for the design and assessment of marine Oil and Petrochemical terminals	PIANC
05	Design of Small to mid-scale Marine LNG Terminals	PIANC
06	LNG World Shipping June 2016	
07	Down the pipeline - A Lansdale	A Lansdale
08	International Gas Union World LNG Report 2017	IGU
09	The Economic impact of small scale LNG	PWC
10	LNG The fuel of the Future	A Campbell
11	The development of LNG bunkering facilities in North European ports	S Wang and Professor T Notteboom
12	Still a strong case for small scale LNG	Poyry
13	Proposed Hunterston Multi-Fuel Power Station. Bon-Technical Summary of Environmental Statement	Peel Energy
14	Scottish Energy Strategy The future of energy in Scotland	Scottish Government
15	Low Carbon Truck and Refuelling Infrastructure Demonstration Trial evaluation – Final Report to DfT	Atkins
16	Proposed Liquid Natural Gas (LNG) Import Terminal Rosyth	Fife Council
17	Scotch Whisky Industry Environmental Strategy Report 2012	Scotch whiskey association
18	Department of Transport Statistics	DfT
	Web sites	
101	PD Ports	PD Ports
102	Excelerate	Excelerate
103	TGE Marine Gas Engineering	TGE Marine Gas Engineering

Ref	Title	Author
104	Wartsila	Wartsila
106	Maritime News	Maritime News
107	Open Maps	Open Maps
108	European Blue Corridors	EU Commission
109	Gas Vehicle Hub	Gas Vehicle Hub

A.1. Economic Impact Examples

There are few UK studies of the local or national impact of the LNG sector upon the economy within academic or industry literature[38]. 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 the 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 takes 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 11-1 Economic Impact Case Studies

Location	Economic Impact
Milford Haven, Wales[39].	Milford Haven is one of Europe's largest importation ports for liquefied natural gas (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[40]. 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 how decline in this sector could have major negative effects on the local and national economy.
Netherlands[41]	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 undertaken in 2013 highlights how small-scale LNG is now in the market development phase (characterised by a large amount of uncertainties) and after gradual growth via early industry adaptors, the market will 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

[38] 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.
[39] https://www.mhpa.co.uk/economic-impact/
[40] The authors of the report were contacted for further information.
[41] https://www.rijksoverheid.nl/documenten/rapporten/2013/09/02/the-economic-impact-of-small-scale-lng

	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[42] (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 those 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.

[42] www.dkm.ie/uploads/downloads/Shannon%20LNG.pdf

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