HyNet CCUS Pre-FEED

Key Knowledge Deliverable

WP6: Offshore Transport and Storage

EXECUTIVE SUMMARY

The Offshore Transport and Storage Report was generated as part of the Preliminary Front End Engineering and Design (pre-FEED) study for the HyNet Industrial CCUS Project. The HyNet CCUS pre-FEED project commenced in April 2019, and was funded under grant by the Department for Business, Energy and Industrial Strategy (BEIS) under the Carbon Capture Utilisation and Storage (CCUS) Innovation Programme.

Delivery of the project was through a consortium formed between Progressive Energy Limited, Essar Oil (UK) Limited, CF Fertilisers UK Limited, Peel L&P Environmental Limited, University of Chester, and Cadent Gas Limited.

The main project objectives are as follows;

- To determine the technical feasibility of a full chain Industrial CCUS scheme comprising anchor loads from Stanlow Refinery and Ince Fertiliser Plant and storage in Liverpool Bay fields.
- To determine the optimised trade-off position between lowest initial cost and future scheme growth
- To determine capital and operating costs for the project to +/- 30% to support HMG development of a policy framework and support mechanism
- To undertake environmental scoping and determine a programme of work for the consent process

This document is one of a series of Key Knowledge Deliverables (KKD's) to be issued by BEIS for public information, as follows;

- HyNet CCUS Pre-FEED KKD WP1 - Basis of Design
- HyNet CCUS Pre-FEED KKD WP1 – Final Report
- HyNet CCUS Pre-FEED KKD WP2 - Essar Refinery Concept Study Report
- HyNet CCUS Pre-FEED KKD WP2 - Hydrogen Production Plant
- HyNet CCUS Pre-FEED KKD WP3 - Fertiliser Capture Report
- HyNet CCUS Pre-FEED KKD WP4 - Onshore CO2 Pipeline Design Study Report
- HyNet CCUS Pre-FEED KKD WP4 - CO2 Road Rail Transport Study Report
- HyNet CCUS Pre-FEED KKD WP5 - Flow Assurance Report
- HyNet CCUS Pre-FEED KKD WP6 - Offshore Transport and Storage
- HyNet CCUS Pre-FEED KKD WP7 - Consenting and Land Strategy

Over the period January 2019 to May 2020, Eni has conducted a range of technical studies to assess the feasibility of a Carbon Capture and Storage project using their existing LIverpool Bay assets. This scope of work was carried out in conjunction with the BEIS funded HyNet CCUS Innovation Project led by Progressive Energy, but funded entirely by Eni. The results of this work have been provided by Eni to Progressive Energy under licence for the purposes of providing an integrated, full chain HyNet CCUS project report.

Dave Parkin
HyNet Project Director

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CONTENTS

1.0 INTRODUCTION

1.1 Project Background

HyNet was first conceived in 2016 as an integrated Hydrogen and Carbon Capture, Utilisation and Storage (CCUS) project to deliver widespread decarbonisation benefits across the North West region, with a particular focus on 'hard to reach' sectors of the economy, such as heat, industry, transport and flexible power. Following two feasibility studies[1,2] published in 2017 and 2018, an industry consortium was formed to deliver a pre-FEED level study for the full chain HyNet CCUS scheme. This study was undertaken from April 2019 to May 2020 and was funded by BEIS and partner contributions. Partners were:

- Progressive Energy
- Cadent
- CF Fertilisers
- Essar Oil UK
- Peel
- University of Chester

In parallel, a technically linked, but self-funded study into the offshore transport and storage elements of the scheme was undertaken by Eni, current owners and operators of the Liverpool Bay Area (LBA) oil and gas assets.

The pre-FEED project has been delivered through seven integrated work packages, and this report constitutes the final over-arching summary report. Further details are contained within work package specific deliverables.

Work package structure for pre-FEED is as follows:

- Work Package 1 – Integration
- Work Package 2 – Refinery Capture
- Work Package 3 – Fertiliser Plant Capture
- Work Package 4 – Onshore Transport
- Work Package 5 – Flow Assurance

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[1] *The Liverpool-Manchester Hydrogen Cluster: A Low Cost, Deliverable Project*, August 2017, Progressive Energy on behalf of Cadent (https://hynet.co.uk/app/uploads/2018/05/Liverpool-Manchester-Hydrogen-Cluster-Summary-Report-Cadent.pdf)

[2] *HyNet North West: From Vision to Reality*, May 2018, Progressive Energy on behalf of Cadent (https://hynet.co.uk/app/uploads/2018/05/14368_CADENT_PROJECT_REPORT_AMENDED_v22105.pdf)

- Work Package 6 – Offshore Transport and Storage (undertaken by Eni outwith the BEIS funded project)
- Work Package 7 – Land and Planning

2.0 OFFSHORE TRANSPORT AND STORAGE

Over the period January 2019 to May 2020, Eni has conducted a range of technical studies to assess the feasibility of a Carbon Capture and Storage project using their existing LIverpool Bay assets. This scope of work was carried out in conjunction with the BEIS funded HyNet CCUS Innovation Project led by Progressive Energy, but funded entirely by Eni. The results of this work have been provided by Eni to Progressive Energy under licence for the purposes of providing an integrated, full chain HyNet CCUS project report.

2.1 Pre-Feasibility Summary Report

The Eni Pre-Feasibility Summary Report brings together the findings from a range of technical studies and sets out the overall project description, the baseline system configuration (with alternatives) and was written to meet the requirements of the Eni internal project Assurance Review.

The Liverpool Bay Area (LBA), with its off-shore fields of Hamilton, Hamilton North and Lennox, was identified as one of the best sites for CO_2 storage in a 2015/16 Government sponsored study[3]. These fields are approaching the end of the operative life (the cessation of production is expected to commence in 2024 and potentially earlier dependent on prevailing oil and gas prices) and their use for such application provides for the project an opportunity of possible re-use of some infrastructure, while for Eni a saving or deferral of abandonment costs.

CO_2 coming from industrial facilities in the Merseyside region will be transported via a newbuild pipeline to Connah's Quay, and from there to the coast (Point of Ayr) using an existing natural gas pipeline. From Point of Ayr a pipeline, previously used to transport natural gas inland from the fields, will be re-purposed to transport CO_2 off-shore to a process platform (Douglas) and from there to the reservoirs, where it will be permanently stored.

Phase 1 of the project considers the Baseline Scenario, where CO_2 production increases from initial 1.0 $MtCO_2$/yr in 2025 up to 3 $MtCO_2$/yr in 2029 and then remains constant. Initial system operation was defined to be in the gas free flow mode with subsequent system compression being required. A range of system configuration options were

[3] Progressing Development of the UK's Strategic Carbon Dioxide Storage Resource, Energy Technologies Institute, April 2016

assessed to provide baseline cost estimates. It was identified that subsequent growth to higher system flow rates (up to 10MtCO_2/yr) would require transport in the dense phase, and the timing of this increase in mass flow rate would influence system configuration decisions to be taken ahead of FEED.

The base assumption of the study is that all the existing facilities in Eni's scope, previously used for natural gas transport, will be re-purposed at maximum extent. This minimises development cost and risk.

2.2 Reservoir Assessment

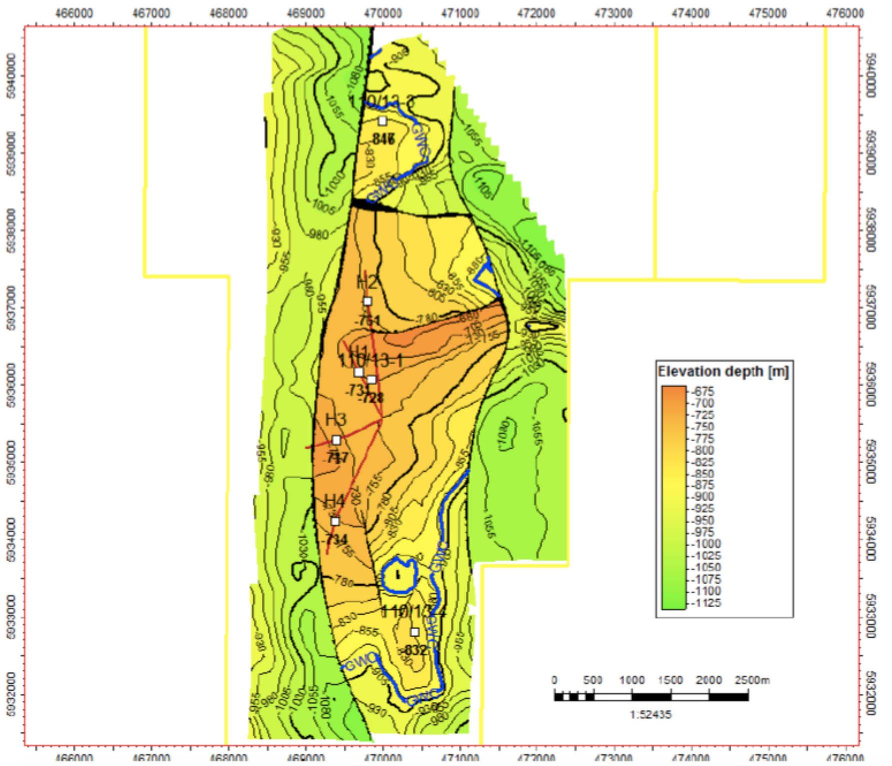
2.2.1 Reservoir Overview

Hamilton

Hamilton Field was discovered in 1990 by well 110/13-1 and the Hamilton North Field by well 110/13-5 in 1991.

The Hamilton Field structure is a simple horst block, about 10 km long and 3 km wide, with a slight dip to the East, North and South. The structure trends North-South and is cut by minor East-West and North-South faulting. All faults within the field have sand-to-sand contact and do not provide barriers to gas flow. This has been confirmed by pressure data from the development wells. The trap is provided to the North and South by dip closure. The crest of the structure at the reservoir level is at around 2300 ft TVDSS (True Vertical Depth Sub Sea) with the gas-water contact being at 2910 ft TVDSS.

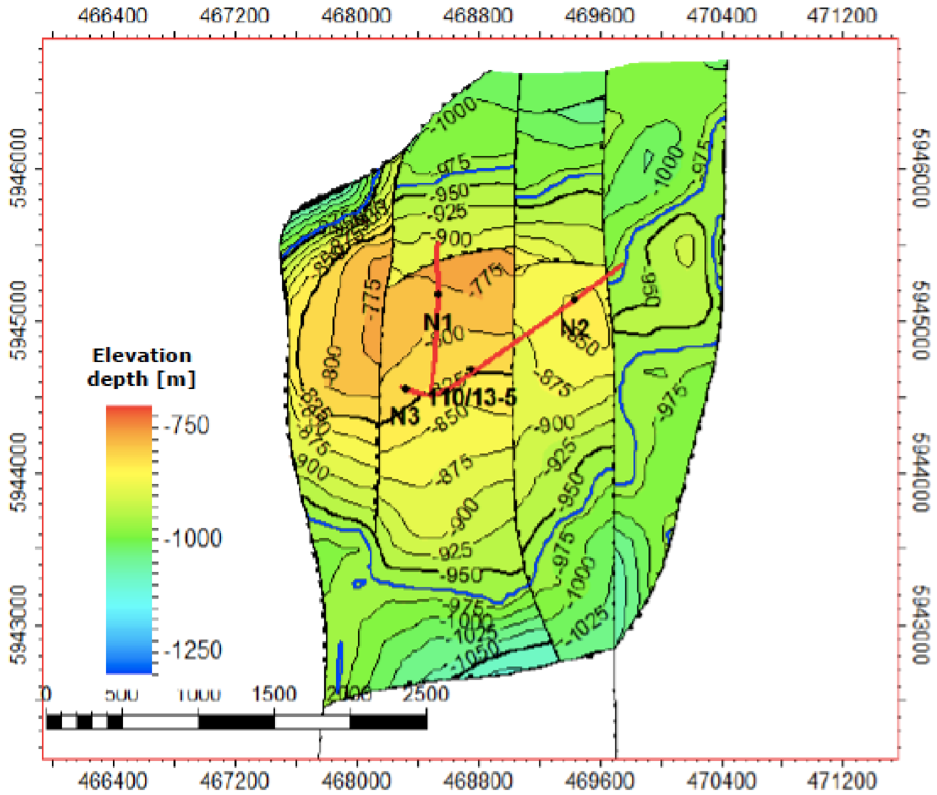
Figure 2.1: Hamilton Reservoir



Hamilton North

Hamilton North Field block lies at the Northern end of the Hamilton horst feature running through Block 110/13. It is a simple fault block 3 km long and 2 km wide with the main dip to the South. The Northern part of the field is progressively down-faulted by a set of E-W trending faults, which are antithetic to the main East-West boundary fault to the Deemster Platform. The crest of the structure at the reservoir level is at around 2600 ft TVDSS with the gas-water contact being at 3166 ft TVDSS.

Figure 2.2: Hamilton North Reservoir



Lennox

Lennox field was discovered in 1992 by exploration well 110/15-6. The well targeted a four-way dip closed structure identified on 2D seismic lines shot between 1981 and 1990. Well 110/15-6 was drilled on the crest of the structure and encountered a 744 ft gas column overlying a 143 ft oil column. The Lennox Field is divided into two panels by a large North-South trending synthetic fault. The Eastern panel exhibits faulting and fracturing associated with antithetic faulting related to the major bounding fault, whilst the Western panel exhibits little to no faulting. The crest of the structure is at c. 2500 ft TVDSS. The gas-oil contact (GOC) and OWC at initial conditions were at 3257 ft and 3400 ft TVDSS respectively. Despite the field being divided into two separate structural panels, at initial conditions the fluid contacts were continuous across the fault. The Lennox Field came on stream in February 1996. Its production life can be divided into two phases: (1) oil rim production, and (2) gas cap production, primarily during gas cap blowdown.

For all of the 3 fields the reservoir target is represented by the Triassic-aged Ormskirk Sandstone Formation. It consists of fluvial and aeolian sandstones of variable grain size. The quality of the Ormskirk Sandstone reservoir has been found extremely high with average porosities of 14-19%. The top seal is provided by the Mercia Mudstone Group which consists of a cyclic sequence of sandy mudstones and halites. The Rossall and

Mythop halites are each less than 50 ft thick and the Preesall Halite has a thickness of between 500 and 730 ft.

Figure 2.3: Liverpool Bay Reservoir Summary

	Hamilton Main	Hamilton North	Lennox
Volume in place	$124x10^6$ boe (gas)	$42x10^6$ boe (gas)	$95x10^6$ bbl (oil) $42x10^6$ boe (gas)
Production start-up	1997	1996	1996
Initial condition	97 bar, 31.6°C	106 bar, 29.4°C	115 bar, 34.4°C
Well type	2 Deviated 2 High Angle	3 Deviated	2 Deviated 4 Horizontal 8 Multi Drain Horizontal
Development strategy	Natural Depletion	Natural Depletion	Oil Rim Development w/GI Gas Cap Blowdown
Current pressure (Jan 2020)	7 bar	8 bar	22 bar
Current recovery factor (RF) (Jan 2020)	96%	97%	54% (Oil); 86% (Gas)

2.2.2 Reservoir Modelling Summary

Reservoir modelling was undertaken to assess the Baseline Scenario which sees 72MtCO_2 injected over a 25 year project life. The three LBA reservoirs, Hamilton Main, Hamilton North and Lennox are nearing cessation of production. Cumulative production as of December 2019 is as follows:

- Hamilton Main (gas): $18.3x10^9$ Sm^3 (RF 95.8%)
- Hamilton North (gas) : $6.3x10^9$ Sm^3 (RF 97.2%)
- Lennox (oil and gas): $12.9x10^9$ Sm^3 (RF 85.9%)

Separate reservoir models were built for each field (Hamilton, Hamilton North and Lennox) using up to date production data, and were history matched. To simulate injection, the reservoirs were numerically coupled to represent the manifolding of the three reservoirs (i.e. they are pressure equalised).

The identified injection strategy ensure that the three fields experience a comparable repressurisation trend during the injection period. In this “coupled scenario”, the stocked CO_2 mass results to be subdivided as follows:

- Hamilton Main: 38Mt
- Hamilton North: 17Mt
- Lennox: 17Mt

Dynamic simulations results indicate the following number of wells needed for each field:

- Hamilton Main: 4 wells
- Hamilton North: 2 wells
- Lennox: 1 well

Under current assumptions, geomechanical preliminary assessment concludes that cap rock integrity is not affected by the CO_2 injection process, as the maximum reached pressure is lower than the original reservoir pressure. Preliminary numerical modelling to predict thermal induced fractures shows that, when occurring, thermal fractures are confined into the reservoir section and do not impact on the cap rock integrity.

Geochemical studies are on-going to characterize fluids-formation rock interactions. Three cores (one for each field) have been acquired, sampling a total of 15 rock plugs on which laboratory analysis are currently being performed. The resulting composition of the sampled intervals will be the input for the static geochemical model to assess rock – formation water – injected CO_2 interaction phenomena.

While the reservoir modelling has focused on the Baseline Scenario (3MtCO_2/yr), a total storage volume assessment was undertaken to inform decisions on higher flow rate scenarios. As a reliable estimate of the fracturing pressure has not been determined due to a lack of fracture pressure measurements across the LBA basin, the upper reservoir pressure limit under CO_2 injection has been set to the initial reservoir pressure at the start of production. Storage volumes assessment are as follows:

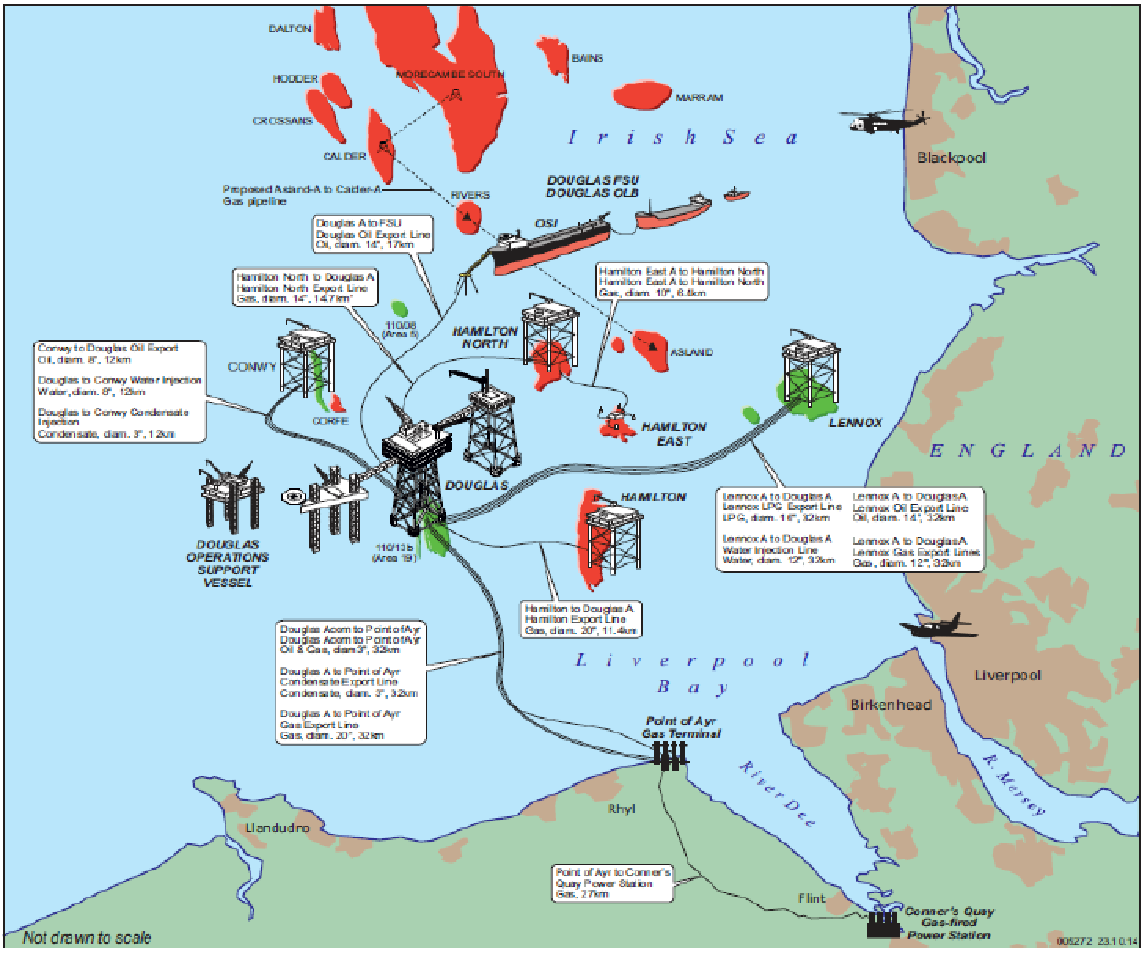
- Hamilton Main: 103Mt
- Hamilton North: 34Mt
- Lennox: 58Mt
- Total: 195Mt

While further reservoir modelling work is required in subsequent project phases, particularly looking at increased injection rates, geomechanical fault analysis and geochemical modelling, the Integrated Reservoir Study concludes that Hamilton, Hamilton North and Lennox fields are suitable CO_2 reservoir storage candidates for LBA CCS Project.

2.3 Existing Facilities Description and Lifetime Extension Assessment

Eni’s Liverpool Bay assets currently comprise a range of facilities that have been considered for re-purposing for CO_2 transport and storage. These consist of platforms, pipelines and wells.

Figure 2.4: Liverpool Bay Assets



2.3.1 Platforms

Hamilton, Hamilton North and Lennox are three fields located in the East Irish sea and are part on Eni UK's LBA asset. Each field is serviced by a separate platform, all of which are tied back to the main Douglas production platform.

The normally unmanned Lennox field has been developed by means of a simple unmanned wellhead platform with minimal facilities. Gas free flows from the Lennox platform to Douglas. There are no spare well slots on the Lennox platform.

The normally unmanned Hamilton and Hamilton North fields are developed via two not normally manned steel platforms which are remotely controlled from the Douglas platform. Each platform is equipped with well control equipment, initial processing facilities and utility systems. There are two spare well slots on Hamilton North and one spare well slot on Hamilton.

Figure 2.5: Hamilton Platform

Existing LBA platform assets are detailed as follows:

Figure 2.6: LBA Existing Platform Assets

Platform	Type	Water Depth (m)
Douglas Wellhead (DW)	Wellhead Platform	29.2
Douglas Process (DD)	Process Platform	29.2
Douglas Accommodation (DA)	Accommodation Platform Jack-Up	29.2
Lennox (LD)	Wellhead and Process Platform	7.2
Hamilton (HH)	Wellhead Platform	25.8
Hamilton North (HN)	Wellhead Platform	22.1

All offshore platforms were installed in 1995 with a design life of 30 years, with the exception of the DA platform which operated as a drilling jack-up for 12 years before being converted to a fixed installation, so the design service life is 42 years. The lifetime extension assessment concluded the following:

- DA platform: a lifetime extension can be considered, but it is not recommended. The platform is not redundant and was not designed to be a permanent installation. In case of re-use or lifetime extension diver assisted NDT are absolutely necessary on most of the leg connection in order to identify possible fatigue cracks. Increase of topside weight on this platform is not recommended;
- DD platform: a lifetime extension can be considered, since no significant damage has been found so far and results from analyses recently performed do not highlight any significant criticality as long as topside loads are not increased. NDT on fatigue prone connections shall be considered in case of lifetime extension.
- DW platform: a lifetime extension can be considered, since no significant damage has been found so far and results from analyses recently performed do not highlight any significant criticality.
- HH platform: a lifetime extension can be considered, since no significant damage has been found so far and results from analyses recently performed do not highlight any significant criticality as long as topside loads are not increased. NDT on fatigue prone connections shall be considered in case of lifetime extension. Based on the documentation, it seems that HH platform can also accommodate from 200 t to 400 t of additional permanent loads on its topside.
- HN platform: a lifetime extension can be considered, since no significant damage has been found so far and results from analyses recently performed do not highlight any significant criticality as long as topside loads are not increased. NDT on fatigue prone connections shall be considered in case of lifetime extension. Based on the documentation, it seems that HH platform can also accommodate from 200 t to 400 t of additional permanent loads on its topside.
- LD platform: a lifetime extension can be considered, since no significant damage has been found so far and fatigue life of all welded connection is always higher than 300 years. Results from analyses recently performed do not highlight any significant criticality Based on the documentation, it seems that HH platform can also accommodate from 200 t to 400 t of additional permanent loads on its topside.

HH, HN and LD platforms are all proposed to be used for the HyNet project for injection. Depending on the chosen system configuration, these platforms may require either heating or compression facilities to be installed. The lifetime assessment indicates that these platforms can accommodate the additional loads associated with these facilities. While further work is required in FEED to further analyse these platforms, the conclusion from this phase of work is that no showstoppers have been identified in the lifetime extension and repurposing of these assets.

The DA, DD and DW platforms are not necessarily required for the HyNet project, as a subsea manifold has been considered to provide the valving requirements for splitting the flow to the respective injection platforms. However, given that DD and DW lifetime extensions could be considered, the decision on whether to retain these platforms or opt for a subsea manifold will predominantly be determined by cost / benefit analysis.

2.3.2 Subsea Manifold

An option has been considered to bypass the existing Douglas complex, allowing its decommissioning and removal and replaced with:

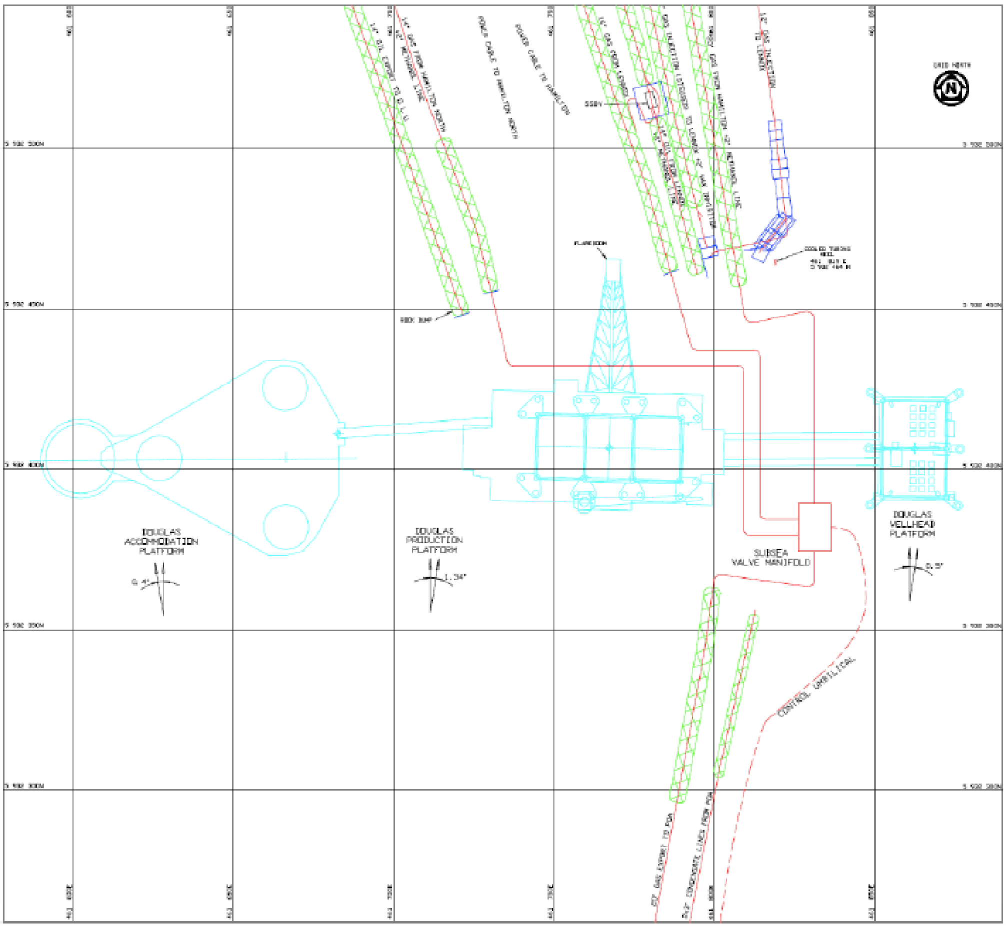
- A Sub Sea Valve Manifold (SSVM) controlled from Point of Ayr connecting existing 20” pipelines from Point of Ayr to Douglas with the existing pipelines going to Hamilton, Hamilton North and Lennox Platforms
- New pipeline spools to connect relevant pipelines with Manifold at Douglas site
- New power supply and control umbilicals network from Point of Ayr to satellite platforms that are currently controlled from Douglas complex.

The preliminary conceptual layout of the SSVM is shown in Figure 2.7 below, illustrating its connection to existing pipelines.

A schematic of the SSVM has been generated, which provides for continuation of pigging from Point of Ayr to Hamilton platform along a continuous 20in line. Two branches connect to the Hamilton North 14in and Lennox 16in lines, each of which can have temporary pig launching facilities attached to allow for pigging of these lines.

Remote control of the facility will be via an umbilical coming from Point of Ayr to a Subsea Control Module (SCM) which will provide hydraulic power to the SSVM. It may prove possible to utilise an existing 3in line from PoA to provide hydraulic pressure as a cost saving measure rather than lay a new umbilical. While no design work has been undertaken for the SSVM at this point, it is estimated to have dimensions of approximately 15m x 10m x 6m and require a mudmats shallow foundation. Estimated weight is around 250-300t in air.

Figure 2.7: Douglas Subsea Manifold Arrangement



2.3.3 Pipelines

Existing LBA pipeline assets are as follows:

Figure 2.8: LBA Existing Pipeline Assets

Pipeline Number	From	To	Purpose	Length (km)	Nominal Diameter (inch)	Design Pressure (barg)
PL852	CQY	PoA	Sales gas	26.4	24	99
PL1030[4]	PoA	DD	Gas export from Douglas	32.1	20	149
PL1039	DD	HH	Gas export from Hamilton	11.4	20	99

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[4] PL1030 also includes PL908, a short section of onshore pipeline

PL1041	DD	HN	Gas export from Hamilton North	14.6	14	99
PL1035	DD	LD	Associated gas from Lennox	32.1	16	99
PL1034	DD	LD	Oil export from Lennox	32.1	14	99
PL1036A	DD	LD	Gas production from Lennox	31.8	12	149

Eni assessed the current condition of the LBA pipelines by reviewing the Pipeline Annual Report 2017 to provide an overview of the condition, inspection results and maintenance status of each pipeline and any major pipeline activities carried out during 2017.

Eni applies a risk based approach to pipeline integrity management i.e. all the threats to the pipeline integrity are analysed, associated risks are evaluated and the appropriate risk mitigation actions are assigned. The extent and the frequency of the risk mitigation measures are driven by the risk level formally defined in the pipeline risk assessment.

The main threats to the existing Eni LBA pipeline system are corrosion (external and internal) and third party interaction and activities. The risk mitigation measures are mainly inspections, testing and corrosion management activities.

Fitness for Purpose statements are available for all pipelines from the 2017 report. PL1030 was identified has having a free-spanning section which has subsequently received rock-bagging remediation attention.

The lifetime extension assessment concluded the existing pipelines being considered in the project can be considered as candidates for requalification for possible life extension of their design life/ CO2 service use study as there does not appear to be any significant “show stoppers” and pipelines appear to be in reasonably good condition given their age.

2.4 Well Assessment

2.4.1 Basic Well Design

All of the wells are currently utilised as gas producers[5], producing from the Triassic Ormskirk Sandstone Formation. All wells utilise a similar well design with TVDs ranging

[5] Several of the current gas production wells have been converted from oil production or gas injection.

from 3150ft to 4150ft. Hamilton has 4 wells, Hamilton North has 3 wells, and Lennox has 13 wells.

Most of the wells are highly deviated or horizontal, including several multi laterals at Lennox. The wells utilise a 20” conductor, set between 460ft and 520ft MD and cemented to surface. A 13 3/8” surface casing is then set at 1686-2335 ft-MDRT (1520-2080 ft-TVDRT) and cemented to surface. Following this, a 10 ¾” x 9 5/8” or 9 5/8” production casing is set:

- Above the top reservoir for cased perforated completions (Hamilton and Hamilton North wells plus L-09), except for Lennox-01 which was side-tracked from a 9 5/8” window and has a 7” liner set above the top reservoir.
- Within the reservoir for open hole and slotted liner completions (All remaining Lennox wells)

All of the Hamilton wells plus Lennox-09 are completed with cased and perforated 7” liners with 7” tubing. Lennox-01 is completed with a cased and perforated 5” liner with 7” tubing due to the above mentioned side-track. Lennox-06 has an open hole completion with 5 ½” tubing. The remaining Lennox wells are completed with 7” x 5 ½” slotted liners with 5 ½” tubing, except Lennox-13 which has 4 ½” tubing.

It should be noted that many of the Lennox wells have had the open hole and slotted liner completions plugged with bridge plugs due to high water cut. These wells have had the tubing and production casing perforated higher up the wellbore to restore production. Several of the cased-perforated wells have had the lower perforations plugged with bridge plugs, also due to water loading.

2.4.2 Well Operations and Service Activity

Well integrity is monitored real time and uploaded to the Eni Real Time Well Integrity Tool which monitors and records a range of integrity metrics. This tracks the well integrity status as well as trends in well integrity metrics to identify higher risk areas including scheduled critical valve tests.

All well service activity is currently completed in Liverpool Bay from the Irish Sea Pioneer (4 legged jack up barge) as the platforms are small and have no crane facilities to allow purely e-line operations. It is assumed that the ISP will remain in the field during any CO_2 injection life for the purpose of well servicing. If this assumption is inaccurate, another method of well servicing will be required which may drive up well OPEX costs.

2.4.3 Well Options for Injection

A study has been undertaken to identify the available well options for injection of CO_2 into Lennox, Hamilton and Hamilton North as part of the HyNet project. The options that have been identified are:

- Use existing wells in current condition
- Workover existing wells
- Side-track existing wells
- Drill new wells

Option 1 – Well Re-Use

The first option evaluated is the reuse of the wells as is. This could be considered with no additional CAPEX. This option is however contingent on the following outstanding work scopes which will be finalised prior to the next phase of the project:

- FLUP cement study to determine the feasibility of existing cement for CO_2 storage applications
- Materials study to determine the feasibility of existing wellbore metallurgy for CO_2 storage applications
- Finalisation of pressure, temperature and injection rates.

These studies attempt to reduce risk in several areas identified as high risk areas. These are:

- Corrosion of production casing (below packer) and packer due to free water and CO_2 mixture inside wellbore
- Degradation of production liner/production casing cement from contact with reservoir fluids and CO_2 mixture
- Corrosion of production liner/production casing from contact with reservoir fluids and CO_2 mixture

A risk assessment has been drafted, pending the results of above mentioned studies. If the wells are to be re-used, an increased level of monitoring should be considered. A monitoring programme and frequency will be developed during the next phase of the project if wells re-use is selected as the preferred technical option.

Wells re-use has by far the lowest initial cost and has the added benefit of deferring well P&A (Plugging & Abandonment) expenditure to the end of field life with no additional complications to the well P&A plan. It is, however, the most uncertain option at this stage but, if further studies can demonstrate that the inherent risks can be cost-effectively mitigated, then it could prove to be the most attractive.

Option 2 – Existing Well Workover

If the ongoing studies mentioned above conclude that the corrosion of tubulars and the degradation of cement from the outside of the well is an acceptable risk, but the risk of corrosion of the production packer and production casing from the inside is unacceptable, then well workover could be a suitable solution.

The envisaged workover would remove the completion, install a suitable corrosion resistant scab liner and install a new completion. This would protect the production casing and packer area from corrosion and remove the risk of a leak to the annulus in the caprock/overburden. A risk assessment will be completed once the above-mentioned studies have been completed.

This option has the benefits of reduced cost compared to new wells or side-tracking as well as deferring well P&A costs to the end of field life. The installation of cemented scab liners however, could complicate well P&As and lead to higher overall P&A cost. The intervals for setting P&A barriers needs to be thoroughly considered in any scab liner installation design. The installation of scab liners will also reduce the well diameter across the reservoir which may limit injection rates.

Option 3 – Existing Well Side-Track

If the risk of wells re-use is deemed unacceptable and cannot be alleviated through a well workover, the reservoir can be P&A'd with a rock to rock, CO_2 resistant cement plug immediately above the production packer. Following this, it could be side-tracked and a 7" liner installed with CO_2 resistant cement extending 500-1000 ft above the reservoir through the cap rock.

It should be noted that no reservoir targets have been provided at this stage and therefore, the well trajectory has not been analysed. Final feasibility of any sidetrack is contingent on the reservoir target. A risk assessment has also been drafted, pending the results of above mentioned studies. Final reservoir target could impact side-track feasibility.

This option has the benefits of installing CO_2 resistant tubulars and cement in all fluid contact areas of the wellbore and maintains a minimum 7" nominal flow path. It does however, come with a significant cost and also requires P&A of the reservoir section prior to side-tracking.

Option 4 – Drill New Wells

The final option is to drill new wells. It is assumed that this option will require new wellheads and Xmas trees. It is also likely that new platforms will be required as there are very few platform slots available. It is assumed that these wells will be of similar design to the existing well stock but with corrosion resistant alloy tubulars and CO_2 resistant cement. A cost estimate for this is given below. No risk assessment has been done for this option at this stage as the well will be designed to be ALARP.

This option is the highest cost by far. It also brings forward all well P&A cost and potentially platform decommissioning cost. It is however the lowest risk option as wells can be designed for CO_2 storage from the outset.