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Demonstrating a Refinery-adapted cluster-integrated strategy
to enable full-chain CCUS implementation - REALISE

Deliverable D3.7 - High-level schematics (process flow diagrams) from Emitter to Storage

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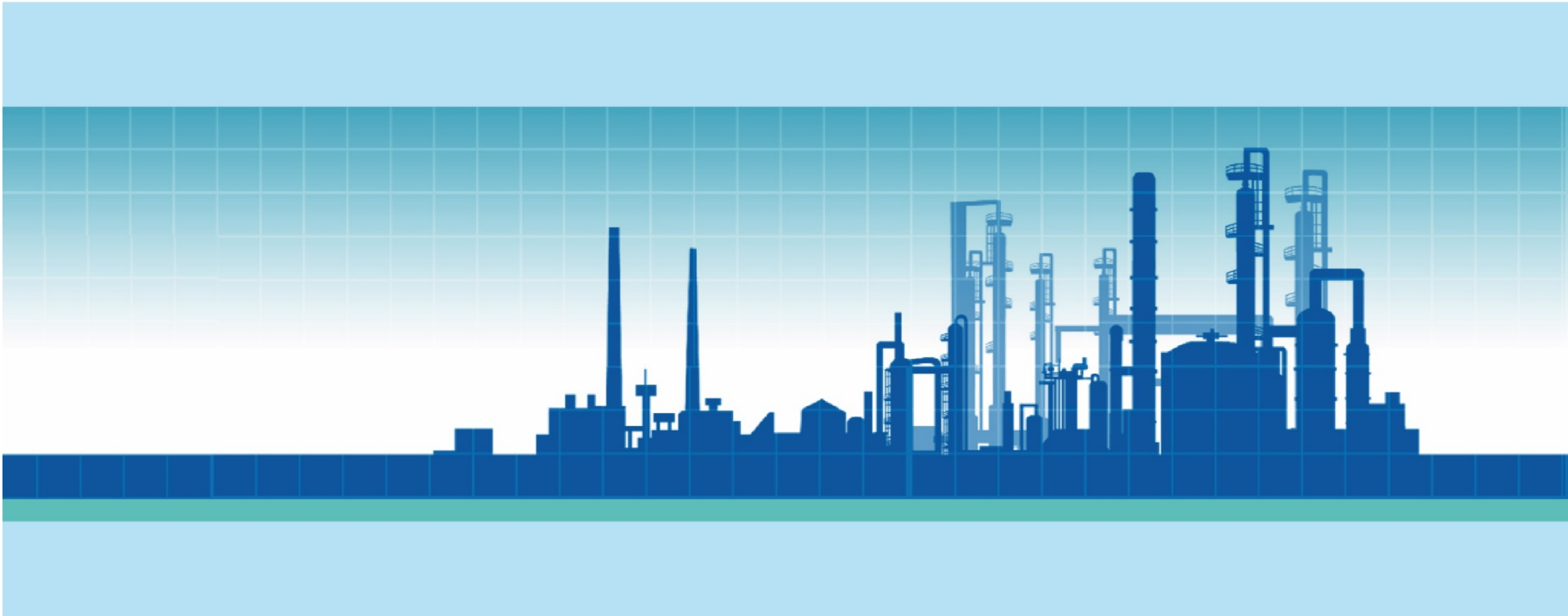

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Document History

Revision History

This document has been through the following revisions:

Version No.	Revision Date	Brief Summary of Changes	Name
0.5	02/02/2022	First (Rough Cut) working draft completed	Paul Murphy (on behalf of Ervia)
0.8	16/03/2022	Minor revision of rough cut draft including incorporation of PFD;s	Paul Murphy (on behalf of Ervia)
1.0	19/04/2022	Fine cut working draft agreed following whole team meeting reviewing comments	Paul Murphy (on behalf of Ervia)
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Authorisation

This document requires the following approvals:

AUTHORISATION	Name	Signature	Date
WP Leader	Paul Murphy	Paul Murphy	06/05/2022
Project Coordinator	Inna Kim	Inna Kim	06/05/2022

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Disclaimer

Glossary of Terms

Acronym, Term or Abbreviation	Explanation
bar	Bar is a metric unit of pressure. It is equal to 100 kPa.
bara	When pressure is measured relative to a perfect vacuum, it is called absolute pressure
BoD	Basis of Design provides all the principles, business expectations, criteria, considerations, rationale, special requirements, and assumptions used for decisions and calculations required during the design stage
CCGT	Combined Cycle Gas Turbine. A combined-cycle power plant uses both a gas and a steam turbine together to produce up to 50% more electricity from the same fuel than a traditional open-cycle gas turbine
CCUS	Carbon capture, utilization and storage, also referred to as carbon capture, utilization and sequestration, is a process that captures carbon dioxide emissions from sources like industry or power plants and either reuses or stores it so it will not enter the atmosphere.
CO_2	Carbon dioxide - a colourless gas having a faint sharp odour and a sour taste. It is a greenhouse gas, but it is a minor component of Earth's atmosphere, formed in combustion of carbon-containing materials, in fermentation, in respiration of animals, and employed by plants in the photosynthesis of carbohydrates.
Inch Terminal	The entry and exit point for gas between the KEL owned and operated KHGF and GNI owned natural gas network
LP	Low Pressure
MEG	MonoEthylyneGlycol
REALISE	Demonstrating a Refinery-Adapted Cluster-Integrated Strategy to Enable Full-Chain CCUS Implementation. Project funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 884266
SI	International System of Units
TEG	TriEthylene Glycol

Executive summary

The REALISE project team has examined a scenario of carbon capture from the largest industrial emitters in the Cork, Ireland area, consisting of two natural gas fired power plants and an oil refinery, where they are treated as a carbon capture cluster. It was found that the cluster which currently comprises approximately 80% of the emissions within a 60 km radius of Cork Harbour could capture CO_2 and permanently store it either in indigenous locations or export it to permanent storage overseas. The full study includes both technical and economic assessment for the cluster.

The estimated volume of CO_2 that could be captured from the cluster of three emitters in the case study ranges from 1.61 million tonnes to 2.77 Million tonnes per annum (Mtpa) under the low and high scenario respectively. The base case anticipates 2.23 Mtpa of CO_2 can be captured annually over a period of 25 years. The base case assumes the two power plants are operated at 55% load factor while Irving Oil Whitegate refinery is operated at 96% load factor and all plant are fitted with post combustion carbon capture rate of 90%. Further studies by REALISE are examining higher capture rate, possibly up to 99%.

This report presents high-level schematics from emitter to storage.

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1 Project Outline

1.1 Carbon Capture Utilisation and Storage

CCUS is being assessed for utilisation in Ireland as part of the overall goal to move Ireland towards a cleaner energy future by reducing CO_2 emissions from the electricity, heating, industry, agriculture and transport sectors.

This study is focused on the feasibility of developing a CCUS project located in the lower Cork harbour area; serving two large Combined Cycle Gas Turbine (CCGT) gas power generation plants and an oil refinery.

Cork is the second largest city of Ireland with a population in excess of 300,000. It is planned that this Cork cluster could be expanded over time to bring in other industries located in the greater Cork area. The city is contained within the county of Cork which has a population of just over 540,000, an area of 7,500 km^2 and contains Cork Harbour, the second largest natural harbour in the world after Sydney, Australia.

Other industrial clusters in Dublin (the capital city), Limerick (the third city) and Drogheda (port town with a large Liquefied Petroleum Gas (LPG) shipping facility and cement plant) are also either under consideration or could be considered in the future.

The focus of the Cork CCUS project is to utilise the depleted Kinsale Head Gas Field (KHGF) as a long-term storage facility, coupled with marine infrastructure that would facilitate the transportation of CO_2 to other long-term below ground storage facilities in Europe.

1.2 REALISE

REALISE – Demonstrating a Refinery-Adapted Cluster-Integrated Strategy to Enable Full-Chain CCUS Implementation

As part of the CCUS development process, REALISE will develop carbon capture, utilisation and storage strategies for oil refineries centred industrial clusters and demonstrate in a pilot scale an absorption technology based on novel solvent for cost-efficient and environmentally sustainable CO_2 capture from multiple flue gas sources.

REALISE further addresses the full CCUS chain including CO_2 transport, storage and utilisation options for the specific business cases to be developed in the project for Ireland, South Korea and China, as well as assessment of the financial, political and regulatory barriers and opportunities in these countries.

1.3 Basis Of Design (BoD)

The basis of design is determined by the following design parameters:

1. The main **emitters** for the study table are listed below; along with respective CO_2 emissions to be included as the design basis.

The following are the selected cluster locations:-

- Whitegate Oil Refinery – Owned and operated by Irving Oil,
- Aghada CCGT Power Station - Owned and operated by Electricity Supply Board (ESB) and
- Whitegate CCGT Power Station Owned and operated by Bord Gáis Energy (BGE)

2. Current **options for storage** are export or indigenous storage i.e.;-

I. Export: by ship to another country for injection into their geological formations, or

II. Indigenous storage: injection into Ireland's geological formations.

While other options will become available in the future, for REALISE the Northern Lights Project will be considered in this study as the potential receiving faculty for the produced CO_2 for the export option (Option i).

The Kinsale Head depleted gas field will be considered for the indigenous storage option (Option ii).

3. The **Carbon Dioxide (CO_2) specification** for export to the Northern Lights Project is outlined in Table 1. Please note the specification for indigenous storage has not been developed but the Acorn Project is cited as a good example in Table 2.

Based on REALISE Task 2.0 the specification for export is given in Table **1**; Table **2** gives the CO_2 quality requirements for transport to indigenous storage. The captured CO_2 will contain impurities and non-condensable gases. The non-condensable gases are components that, when pure, will be in gaseous form at 15 barg and -26°C. The content of non-condensable gases will be limited by the actual solubility in the liquid CO_2 in the interim storage tanks at the capture plants.

The captured CO_2 will require further treatment since the CO_2 must be free of significant impurities such as hydrogen sulphide and water, otherwise, the gas can corrode the pipeline.

The major impurities influence the characteristics of the CO_2 stream; in general, the impurities lower the density of the CO_2 stream and increase the overall 'critical pressure' leading to uncertainties over what conditions are required within the transport system.

Table 1: Export Option - Northern Lights CO_2 Composition Requirements

Component	Concentration, ppm (mol)
Water, (H_2O)	≤ 30
Oxygen, (O_2)	≤ 10
Sulphur oxides, (SO_x)	≤ 10
Nitric oxide/Nitrogen dioxide, (NO_x)	≤ 10
Hydrogen Sulfide, (H_2S)	≤ 9
Carbon monoxide, (CO)	≤ 100
Amine	≤ 10
Ammonia, (NH_3)	≤ 10
Hydrogen, (H_2)	≤ 50
Formaldehyde	≤ 20
Acetaldehyde	≤ 20
Mercury, (Hg)	≤ 0.03
Cadmium, (Cd) and Thallium, (Tl)	≤ 0.03 (sum)

Table 2: Indigenous Storage Option - Amec Foster Wheeler report[1]: Requirements

Component	Recommended Specification,	Advisory Notes
CO_2	95 mol%	
Hydrogen Sulphide	<200 ppmv	Health & Safety
Carbon Monoxide	<2000 ppmv	Health & Safety
NO_x	<100 ppmv	Health & Safety
SO_x	<100 ppmv	Health & Safety
Oxygen	<10 ppmv	Technical: Pipeline and storage
Nitrogen	1 mol %	Technical: EOR led
Hydrogen	1 mol %	Technical: EOR led
Argon	1 mol %	Technical: EOR led
Methane	1 mol %	Technical: EOR led
Non-condensable	4 mol %	Technical: Pipeline led
Water	50 ppmv	Technical: Hydrate & corrosion
Hydrocarbons	2 mol %	
Particulates	1 mg/Nm^3	Technical: Pipeline led
Particle size (micron)	≤10 µm	Technical: Pipeline led
Mercury	Regulation	
Ammonia	<50 ppmv	Technical
Other	Caution: must not negatively impact hazards of a release, pipeline/storage/well integrity	

1.3.1 Scope Premise

The main premise for the basis of design, is that CO_2 is received from the capture plant output battery limit (boundary fence), where the CO_2 can be conditioned and compressed for transport by pipeline to either:

1. Intermediate storage for ship transport for export or
2. Onwards transportation to indigenous storage at a depleted gas field.

[1] AMEC, 2015. TVU CCUS, Work pack 5-Onshore Infrastructure. Pipeline Network CO_2 Quality Specification.

Note: The carbon capture plant and related technologies are not part of the scope for Task 3.3, the capture plant is dealt with in another Project Realise Task 2 This study (Task 3.3) is focused on the CO_2 cluster transportation of CO_2 and storage only.

The basis of this section of the study is:

- Conditioning of CO_2 to meet compression and transport requirements,
- Compression of CO_2 to meet transport requirements for export and indigenous storage ,
- Transportation of CO_2 via onshore pipelines,
- Export Storage of CO_2 to meet shipping requirements (ship size, liquefaction, temporary storage, jetty, and loading arms, and
- Indigenous Storage of CO_2 to meet depleted field requirements (pipelines, conditioning, compression, onshore and offshore infrastructure)

1.3.2 Emitters

The scope for the Task 3.3 report is a cluster transport study that centres on the transportation of captured CO_2 at the selected cluster locations to potential storage locations.

The main emitters for the study table are listed below along with respective CO_2 emissions; to be included as the design basis.

The following are the selected cluster locations:-

- Whitegate Oil Refinery (Irving Oil) [Grid Ref 51°49'15.0"N 8°14'27.9"W]
- Aghada CCGT Power Station (ESB) [Grid Ref 51°50'02.5"N 8°14'14.7"W]
- Whitegate CCGT Power Station (BGE) [Grid Ref 51°48'58.8"N 8°14'49.1"W]

The locations were selected on the basis of being the optimal cluster of the largest CO_2 emitters in the Cork Harbour area and the cluster can be considered for potential expansions in the future, if deemed appropriate, based on the market evolution.

The cluster location also leverages selection based on:

- Existing assets/infrastructure for repurposing potential,
- Proximity to indigenous storage (Kinsale Head depleted gas field), and
- Proximity to a deep water harbour

Table 3: Emitter details and CO_2 emissions per year

Site / Location	Sector	Owner/Operator	Capacity (MWe)	CO_2 Emissions (Mt/y) As per C02 Cork cluster proposed annual production base case scenario
Whitegate Refinery	Oil Refining	Irving Oil	N/A	.32
Aghada CCGT	Power Generation	ESB	430	1.08
Whitegate CCGT	Power Generation	BGE	450	1.08

Table 4: Emitter details and CO_2 flow rate in KG/hr

Site / Location	Min CO_2 KG/Hr	Max CO_2 KG/Hr	Average CO_2 KG/Hr
Whitegate Refinery	26,849	38,356	36,822
Aghada CCGT	65,687	199,053	109,479
Whitegate CCGT	65,687	199,053	109,479

Table 5: Composition table between amine unit and compression unit

Compound	Concentration	
CO_2	Balance	
N2	500	ppm-V/V
O2	50	ppm-V/V
Aldehydes	5	ppm-V/V
NOx	<10	ppm-V/V
NH3	<5	ppm-V/V
SO2	0	ppm-V/V
Water	Saturated at 30 C and 2 bara	

1.3.3 Design cases

The three design cases to be considered are shown in Table 6.

Table 6: Design Cases

Design Case	Description
1	**Export of CO_2** via a new jetty at Aghada site
2	**Export of CO_2** from the existing jetty at the Whitegate refinery
3	**Indigenous Storage of CO_2** via the Inch Terminal to the depleted Kinsale Head Reservoir

The REALISE project will incorporate the following components for the various export design cases:

1. Output from the respective Capture Plant battery limit
2. Conditioning / Compression Plant adjacent to the Capture Plant (gaseous phase output)
3. Pipeline transportation (gaseous phase)
4. Liquefaction Plant (liquid phase output)
5. Pipeline transportation (liquid phase)
6. Intermediate Storage (liquid phase)
7. Pipeline transportation to vessel (liquid phase)

The REALISE project will incorporate the following components for the indigenous storage design case:

1. Conditioning / Compression Plant adjacent to the Capture Plant (gaseous phase output)
2. Pipeline transportation (gaseous phase)

1.4 Description of the deliverable and purpose

The purpose of this Task group within REALISE is to undertake an assessment of the potential for CCUS at an oil refinery which is part of a large CCUS cluster. The cluster transport study centres on the transportation of the captured CO_2 at the identified cluster locations to selected storage locations.

This report outlines the findings for deliverable D3.7 assigned to this Task Group, which is as follows:

- Deliverable D3.7 Provide high-level schematics (process flow diagrams) from Emitter to Storage

This report is closely linked with deliverables D3.5 and D3.6, which present the analyses and results that form the basis for the design of the elements of the transport and storage system:

- Deliverable D3.5: Assessment of injection profile and infrastructure requirements to control & monitor of transportation pipelines and intermediate storage vessels;
- Deliverable D3.6: Assessment of options to provide flexibility in the design and operation of the transport and storage network.

2 High-level schematics (process flow diagrams) from Emitter to Storage

As mentioned in the previous section, Deliverables D3.5 and D3.6 present the analysis that led to the design that is outlined below in process flow diagrams.

1.. Layout of the system

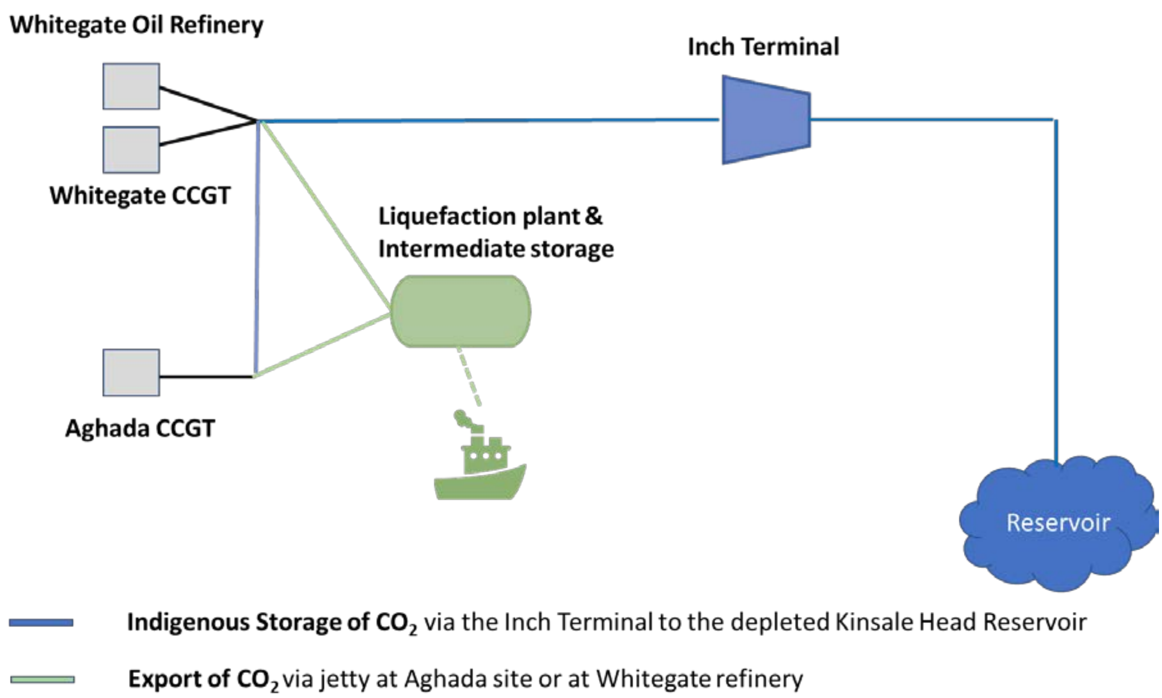

Figure 1 Schematic layout of the system.

The layout of the system can be found in Figure 1. Here the three capture locations are depicted together with the options for transport and storage.

Only two options will be assessed. The storage in the indigenous field and the storage using the Northern Light location via ships. Though three cases are defined because the location of the liquefaction and intermediate stage facility, used for the CO_2 export option, could either be at the Aghada site or at Whitegate refinery there are only two cases for storage. However, for the analysis carried out in this report that difference has no significant influence on the results and therefore they are combined into one case.

The two Process Flow Diagrams (PFDs) are also depicted in Figure 2 and Figure 3. The two options will now be dealt with separately.

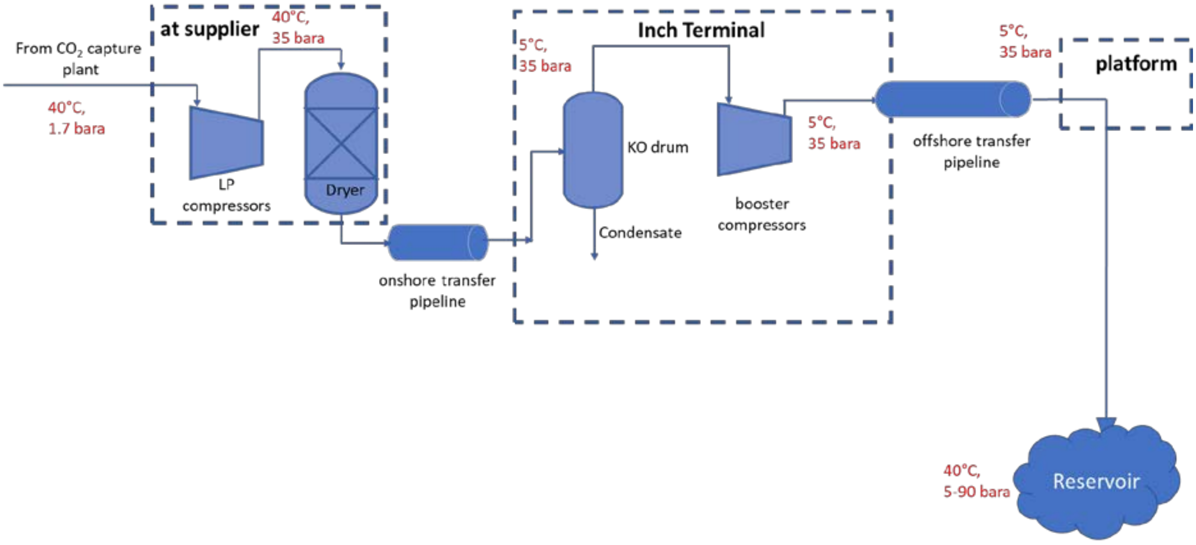

Figure 2 PFD of storage to indigenous field

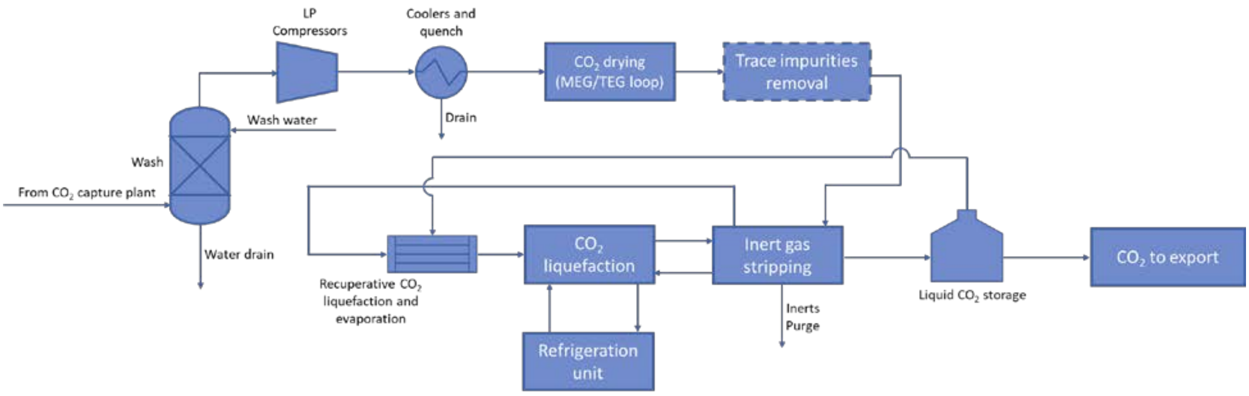

Figure 3 PFD of export option

In Figure 2 the option to the indigenous field is depicted. At the capture site at the supplier a low-pressure compressor is installed to raise the pressure to ~35 bar. Then after the onshore pipeline the fluid arrives at the Inch Gas Terminal where the pressure is raised again to go in the offshore pipeline which takes the CO_2 to a platform where it enters the well to the subsurface storage location.

In Figure 3 the flow diagram for the export option is depicted. Here more processes must be completed such as drying of the CO_2 and the liquefaction, and an intermediate storage facility is required to store the CO_2 before it can be transported in the ship which brings the CO_2 to its final destination.

3 Bibliography

AMEC, (2015). TVU CCUS, Work pack 5-Onshore Infrastructure. Pipeline Network CO_2 Quality Specification.

Gas Networks Ireland Functional Specification Requirements:

AM-FSR-010 Instrumentation equipment

AM-FSR-028 Control system equipment

AM-FSR-027 Electrical equipment