ERVIA CCS PRE-FEED STUDY

FEED Basis of Design - Cork

MDE1234-BEC-01-CX-RP-Z-0002
S3 P01
27 June 2022

Document status

Status	Revision	Purpose of document	Authored by	Reviewed by	Approved by	Review date
S3	P01	Issued for Pre- FEED	PD	CB	CB	24/06/2022

Approval for issue

CB	27 June 2022

Prepared by:

RPS / Bechtel

Prepared for:

Ervia

Dublin | Cork | Galway | Sligo
rpsgroup.com

RPS Group Limited, registered in Ireland No. 91911
RPS Consulting Engineers Limited, registered in Ireland No. 161581
RPS Planning & Environment Limited, registered in Ireland No. 160191
RPS Engineering Services Limited, registered in Ireland No. 99795
The Registered office of each of the above companies is West Pier Business Campus, Dun Laoghaire, Co. Dublin, A96 N6T7

Contents

Tables

Appendices

Holds

HOLDS	Description	Responsibility
N/A		

Glossary

Term	Definition
AACE	Association for the Advancement of Cost Engineering
CCGT	Combined Cycle Gas Turbine
CPF	Central Processing Facility
CCS	Carbon Capture and Storage
FEED	Front End Engineering Design
MMtpa	Million Metric Tonnes Per Annum

References

1. Cork CCS Project Option Site Specific Case Study, 267553-REP-001, Issue 04, 16 Dec 2020
2. Ashrae Handbook- Fundamentals (SI) (2017)- Roches Point, Ireland (WMO:039520). Available from- ASHRAE climatic design conditions 2009/2013/2017 (ashrae-meteo.info) [Accessed on 09/09/2021]
3. Ashrae Handbook (2009), Appendix- Design Conditions for Selected Locations. Available from- https://www.captiveaire.com/catalogcontent/fans/sup_mpu/doc/winter_summer_design_temps_us.pdf [Accessed on-13/09/2021]
4. EPA IPC Reg. No. 576 Proposed Determination for Electricity Supply Board Aghada Generating Station Whitegate, County Cork (2002). Available from- Microsoft Word - 576TCReport.doc (epa.ie) [Accessed on 20/09/2021]
5. Met Éireann Return Period Rainfall Depths for sliding Durations based on Depth Duration Frequency (DDF) Model - Fitzgerald D. L. (2007), Estimates of Point Rainfall Frequencies, Technical Note No. 61, Met Eireann. Available from- Services - Met Éireann - The Irish Meteorological Service [Accessed on 9/9/2021]
6. Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions, I.S. EN 1991-1-4:2005+NA:2013 (2005). Available from- 98705226958.pdf (standards.ie) [Accessed on 16/09/2021]
7. Eurocode 1 - Actions on structures. General actions - Snow loads (+AC:2009) (+A1:2015). I.S. EN 1991-1 -3:2003&A1:2015 (2010). Available from- 753181013011.pdf (standards.ie) [Accessed on 16/09/2021]
8. Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings, I.S. EN 1998-1:2005 (2004). Available from- 98700969003.pdf (standards.ie) [Accessed on 16/09/2021]
9. UK Hydrographic Office-Admiralty Tide Tables, United Kingdom and Ireland, NP201B, Volume 1B (2021). [Accessed on 24/09/2021]
10. Electricity Supply Board Aghada Combined Cycle Gas Turbine Power Plant Environment Impact Statement July 2004 Report P378250R6050001 [Accessed on 28/09/2021]
11. MDE1234-RPS-01-CX-RP-Z-0010 Operations and Maintenance Philosophy - Cork
12. MDE1234-RPS-00-CX-RD-Z-RD0001 Document Register - Cork
13. MDE1234-RPS-05-CX-RP-Z-RP-0005 Preliminary HAZOP Close Out Report – Cork
14. MDE1234-RPS-05-CX-RP-Z-RP-0006 HAZID Close Out Report, Cork

1 INTRODUCTION AND SCOPE

1.1 Project Background

Ervia is assessing how Carbon Capture and Storage (CCS), located close to large-scale CO_2 emitters can play a role in reducing Ireland's CO_2 emissions. A technical feasibility study on the potential for large-scale CCS in Ireland was completed by Ervia in 2020.

The general location of Aghada Power Station in County Cork was selected as a potential site for a Central Processing Facility (CPF) for liquefaction, storage, and export of CO_2 overseas via a new marine jetty. The CPF will cater for CO_2 captured at 3 emitter locations (Whitegate Power Station, Irving Oil Whitegate Refinery and Aghada CCGT). A new CO_2 gas pipeline gathering network will transport CO_2 from the emitters to the CPF.

Ervia has appointed RPS / Bechtel to carry out a Pre-FEED study that involves a detailed assessment of the key CPF, pipeline and storage infrastructure necessary to condition, compress, transport and store liquid CO_2 at Cork harbour for subsequent loading onto ships for export. (Note: The scope of this project does not include the carbon capture facilities at each emitter).

Additionally, the new marine jetty in Cork will also be used for import of liquid CO_2. This scenario considers the regasification of liquid CO_2 at Cork for transport via pipeline to the Inch terminal which is the link to indigenous offshore permanent storage at the depleted Kinsale Head Gas Field.

1.2 Scope

This document sets out the basis of design for executing the FEED study for CO_2 transport from emitter sites to storage and the marine jetty for ship transport from Cork. The study will also address the importation of liquid CO_2 from other sources for pipeline transfer to indigenous storage.

The process of CO_2 capture at emitter sites is excluded from the FEED study. It is considered that the CO_2 from the capture plants is conditioned, and meets the specification specified in Table 4-3. The CPF process will consist of only refrigeration and liquefaction.

The regasification of CO_2 in Cork is included in the FEED study. It is to be assumed that the regasification plant will take advantage of the seawater from the existing Aghada CCGT plant outlet for the vapourisation process.

Project co-ordinates shall be confirmed during the FEED study.

2 APPLICABLE REGULATIONS AND STANDARDS

In the event of conflict or deviation from requirements stipulated in this design basis and other applicable documents, the following order of precedence shall govern:

- European Regulations
- Irish Regulations
- European Standards
- International Standards
- Irish Standards
- Ervia Standards

Additional preliminary lists of relevant regulations and standards are contained within the philosophy documents Issued for Pre-FEED. The following table lists the project philosophies developed during Pre-FEED which shall be reviewed at the commencement of FEED.

Table 2-1 Project Philosophy Documents

Philosophy Document	Document Reference
Process and Utilities Design Philosophy	MDE1234-RPS-01-CX-RP-Z-0003
Process Control and Safeguarding Philosophy	MDE1234-RPS-01-CX-RP-Z-0004
Pipeline Design Philosophy	MDE1234-RPS-01-CX-RP-Z-0005
Material Selection Philosophy	MDE1234-RPS-01-CX-RP-Z-0006
Flow Assurance & Hydraulic Analyses	MDE1234-RPS-02-CX-RP-Z-0001
Marine Design Philosophy	MDE1234-RPS-01-CX-RP-Z-0008
Health, Safety, Security and Environment Philosophy	MDE1234-RPS-01-CX-RP-Z-0009
Operations and Maintenance Philosophy	MDE1234-RPS-01-CX-RP-Z-0010
Process Safety Design Basis	MDE1234-RPS-01-CX-RP-Z-0011
Power Generation and Electrical Systems Philosophy	MDE1234-RPS-01-CX-RP-Z-0012
Communications and Controls Philosophy	MDE1234-RPS-01-CX-RP-Z-0013
Stakeholder Management Philosophy	MDE1234-RPS-01-CX-RP-Z-0014
Legislative Approvals Philosophy	MDE1234-RPS-01-CX-RP-Z-0015
Project Execution Plan	MDE1234-RPS-01-CX-RP-Z-0018

3 UNITS OF MEASUREMENT

SI measuring units as shown in Appendix A of this document will be followed.

4 BASIS OF DESIGN

4.1 Design Capacity

The design capacity of each liquefaction train shall be 0.44 MMtpa CO_2. There will be 4 liquefaction trains of 0.44 MMtpa each (3 operating and 1 standby).

The design capacity of the regasification train shall be 0.5 MMtpa CO_2. There will be one regasification train of 0.5 MMtpa .

It is considered that the liquefaction and regasification trains will not be operating simultaneously (i.e. plant will either be in liquefaction or regasification mode).

4.2 Onstream Factor

Each of the four liquefaction trains shall be designed for 350 operating days (8,400 hours) per year. The design life of the new CPF shall be 25 years, i.e. the design shall be such that the train will be able to operate at 100% of design feed throughput for 25 years, with inspection turnarounds occurring every 4 years.

The design life of new pipeline will nominally be 40 years.

4.3 Turndown Requirements

The design shall be such that each train will be able to operate at 0.125MMtpa CO_2 which is 50% of maximum flowrate from the lowest emitter i.e. Whitegate Refinery.

4.4 CO_2 Source Flowrates

Whitegate Refinery, Aghada CCGT and Whitegate CCGT are the three CO_2 emitters considered for the pre-FEED study scope for CO_2 transport, storage and shipping of CO_2 from Cork. Refer to Table 4.1 for CO_2 flowrates from emitters:

Table 4-1 CO_2 Flowrates from Source, MMtpa

Source	CO_2 Flowrates from Source MMtpa		
	Max/Min Year 1	**Max/Min Year 2**	**Max/Min Year 3**
Whitegate Refinery	0.25/0.125	0.25/0.125	0.25/0.125
Aghada CCGT	-	0.5/0.25	0.5/0.25
Whitegate CCGT	-	-	0.5/0.25
Total (Max/Min)			1.25/0.125

Notes:
1. *Minimum total CO_2 flowrate considered to be 0.125 MMtpa (50% of maximum flowrate from lowest emitter i.e. Whitegate Refinery).*

4.5 Project Phases

There are four phases of the project, refer to Table 4.2 for details of different phases of the project.

Table 4-2 Project Phases

Project Phase	Description
1	CO_2 from Cork and liquefaction and export via new jetty
2	Import of liquified CO_2 and export via new jetty
3	Cork gaseous CO_2 is sent to Inch Terminal for sequestration
4	Imported liquid CO_2 is re-gasified in Cork and sent to Inch Terminal

4.6 CO_2 Specification from Source

The quality of CO_2 produced by emitters is very important as it relates to integrity of the transport and storage system. It is considered that CO_2 from capture plant is conditioned, and no further treatment of CO_2 has been considered. Dehydration is required at the capture plant to ensure dry CO_2 enters the pipeline. Oxygen removal to achieve the oxygen specifications is by catalytic reaction with injected hydrogen, which generates water and shall be located upstream of the dehydration i.e. also included in the capture unit. As the optimum conditions for dehydration and oxygen removal is at 30-40bara, the expected delivery pressure from the capture unit is expected to be at 35bara. The specification of CO_2 from emitters is governed by the specification provided by Equinor to Ervia for the purposes of shipping and sequestration. Refer to Table 4.3 for CO_2 specification from emitters.

Table 4-3 CO_2 Specification from Source/Emitters

Component	Recommended Specification
CO_2	>99.97 mol%
H_2S	<9 ppmv
Carbon Monoxide	<100 ppmv
NOx	<10 ppmv
SO_X	<10 ppmv
Oxygen	<10 ppmv
Nitrogen	-
Hydrogen	<50 ppmv
Argon	-
Methane	-
Non-condensable	-
Water	<30 ppmv
Hydrocarbon	-
Particulates	1 mg/Nm^3
Particle size	≤10µm
Mercury	<0.03 ppmv

Component	Recommended Specification
NH_3	<10 ppmv
Others	Amine <10 ppmv Formaldehyde <20ppmv Acetaldehyde <20pmv Cd+Tl <0.03 ppmv

Note: CO_2 specification is related to gaseous phase CO_2.

4.7 CO_2 Specification for Pipeline

CO_2 pipeline to be designed for most stringent of Acorn and Equinor specifications. As agreed with Ervia, the specification of exported CO_2 for the Equinor's Northern Lights project and Acorn is as specified in Table 4.4.

Table 4-4 CO_2 Pipeline Design Specification

Component	Equinor Specification	Acorn Specification
CO_2	>99.97 mol%	≥ 95 mol%
H_2S	<9 ppmv	< 200 ppmv
Carbon Monoxide	<100 ppmv	<2000 ppmv
NOx	<10 ppmv	<100 ppmv
SO_X	<10 ppmv	<100 ppmv
Oxygen	<10 ppmv	<10 ppmv
Nitrogen	-	≤1 mol%
Hydrogen	<50 ppmv	≤1 mol%
Argon	-	≤1 mol%
Methane	-	≤1 mol%
Non-condensable	-	≤ 4 mol%
Water	<30 ppmv	≤ 50 ppmv
Hydrocarbon	-	≤ 2 mol%
Particulates	1 mg/Nm^3	<1 mg/Nm^3
Particle size	≤10µm	≤10µm
Mercury	<0.03 ppmv	
NH_3	<10 ppmv	< 50 ppmv
Others	Amine <10 ppmv Formaldehyde <20ppmv Acetaldehyde <20pmv Cadmium+Thallium (Cd+Tl) <0.03 ppmv	

Note: Equinor and Acorn specifications are related to gaseous phase CO_2.

4.8 CO_2 Conditions at Emitter Battery Limit (CPF)

CO_2 emitters shall ensure that operating pressure and temperature of CO_2 at emitter battery limit will be as provided in Table 4.5.

Table 4-5 CO_2 Conditions at Emitter Battery Limit

Parameter	Whitegate Refinery	Aghada CCGT	Whitegate CCGT
Pressure, bara	35	35	35
Temperature Min/Max, °C [1]	11/37	11/37	11/37

[1] CO_2 cooling by emitters can be by sea water, cooling water or air. Depending upon the cooling medium, CO_2 temperature at emitter battery limit can be:

- *Sea water: Min = winter sea temp +5°C approach, Max = summer sea temperature +10°C approach*
- *Cooling tower water: Max = max design wet bulb temperature + 5°C+ 10°C*
- *Air cooling: Max = max design dry bulb temperature + 15°C*

4.9 CO_2 Delivery Specification

CO_2 delivery specification for project will be the most stringent of Equinor and Acorn specifications. Refer to Table 4.6 for export CO_2 specification.

Table 4-6 CO_2 Delivery Specification

Component	Recommended Specification
CO_2	>99.97 mol%
H_2S	<9 ppmv
Carbon Monoxide	<100 ppmv
NOx	<10 ppmv
SO_X	<10 ppmv
Oxygen	<10 ppmv
Nitrogen	-
Hydrogen	<50 ppmv
Argon	-
Methane	-
Non-condensable	-
Water	<30 ppmv
Hydrocarbon	-
Particulates	1 mg/Nm^3
Particle size	≤10µm
Mercury	<0.03 ppmv
NH_3	<10 ppmv
Others	Amine <10 ppmv

Component	Recommended Specification
	Formaldehyde <20ppmv Acetaldehyde <20pmv Cd+Tl <0.03 ppmv

Note: CO_2 specification is related to gaseous phase CO_2.

4.10 CO_2 Delivery Conditions

CO_2 transport by ship is achieved in semi pressurised vessels at medium pressure conditions. Existing CO_2 carriers operate under medium pressure conditions which maintain the CO_2 between 14 bara to 20 bara at equilibrium temperature. Refer to Table 4.7 for CO_2 ship transport conditions.

Table 4-7 CO_2 Ship Transport Conditions

Parameter	Ship Transport Conditions Range (Medium Pressure Conditions)
Pressure, bara (Min/Max)	14 / 20
Temperature, °C (Min/Max)	-30 / -19.5

4.11 Pipeline Conditions from Emitters to CPF

Gaseous CO_2 will be transported from emitters using pipeline to CPF. The gaseous CO_2 pipeline conditions from emitters to CPF are as specified in Table 4.8.

Table 4-8 Pipeline Conditions from Emitters to CPF

Parameter	Pipeline Section 1 White Gate Refinery	Pipeline Section 2 White Gate CCGT	Pipeline Section 3 Aghada CCGT
Minimum Gas Capacity, MMtpa	0.125	0.25	0.25
Maximum Gas Capacity, MMtpa	0.25	0.5	0.5
Pipeline Inlet Temperature (Min/Max), °C	11/37	11/37	11/37
Pipeline Arrival Temperature[1] (Min/Max), °C	10/27	10/27	10/27
Pipeline Inlet Pressure, bara	35	35	35
Pipeline Arrival Pressure[1], bara	32.5	32.5	32.5
Pipeline Design Temperature[1], °C	70	70	70
Pipeline Design Pressure[1], bara	40	40	40

[1] Flow assurance to provide preliminary values for the study and final values will be confirmed for FEED.

4.12 Metering and Monitoring of CO_2

Custody metering and quality monitoring of CO_2 will take place at emitter sites.

Emitters shall share the CO_2 quality and metering data with Ervia control centre in Cork. Emitters shall also share calibration records of CO_2 metering and quality monitoring instruments and analysers with Ervia. The emitter shall inform the Operator at the CPF immediately if there is any deviation in quality of CO_2. Emitters shall immediately close the isolation valves at their facility if there is any deviation in quality of CO_2.

If the CPF Operator determines that the quality of CO_2 entering the gathering network is out of specification (either by own analysis results or analysis results provided by the emitter), the CPF Operator should inform Operator at emitter's site so that Operator at emitter's site can shut the pipeline operations. Provision is also provided for CPF Operator to initiate remote shutting of pipeline valves using motor operated valves. This action will contain the out of specification CO_2 to the pipeline. The above measures will protect the CPF from out of specification CO_2. The out of specification CO_2 in the pipeline can be depressurised using a depressurisation valve. Venting of out of specification CO_2 will be at the emitter sites. Refer Operations and Maintenance Philosophy (Ref. 11) for more details.

Metering and quality monitoring of stored CO_2 will be provided for CO_2 that will be exported from Cork CPF via ship.

4.13 Meteorological Data

4.13.1 Temperature

Table 4-9 Temperatures for use in Design

Parameter	Value
Design Maximum Dry Bulb Temperature (DBT), ºC (n=20) [1]	28 ºC[2]
Design Maximum Wet Bulb Temperature (WBT), ºC (n=20) [1]	21 ºC[2]
Design Maximum DBT for Air Coolers, ºC	22 ºC[3]
Sea Water Summer (Maximum) Temperature, ºC	19 ºC[4]
Sea Water Winter (Minimum) Temperature, ºC	6 ºC[4]
Design Maximum Temperature for Outdoor Electrical Equipment, ºC	Equipment specific
Design Maximum Temperature for Indoor Electrical Equipment, ºC	Equipment specific
Design Maximum Temperature for Electrical Lighting Fittings, ºC	Equipment specific
Design Maximum Temperature for Surfaces exposed to Solar Radiation, ºC	Equipment specific
Winterising (Minimum) Temperature for pour point and freeze protection, ºC	Equipment specific
Low Ambient Temperature, ºC (n=20) [1]	-3.8 ºC[2]
Low Ambient Design Temperature, ºC	-12.5 ºC[5]

[1] *n= Year Return Period Values of Extreme Temperature*

[2] *ASHRAE CLIMATIC DESIGN CONDITIONS 2017*

[3] *ASHRAE 2009*

[4] *ESB-EIS, July 2004, Report P378250-R605-0001- https://www.eib.org/attachments/pipeline/20070106_eia_en.pdf*

[5] *Design Assumption*

Table 4-10 Sea Water Supply and Return Temperature for Regasification for use in Design

Parameter	Value[1]	
	Maximum	Minimum
Sea Water Temperature for Regasification (Inlet), ºC	32	11.4
Sea Water Temperature for Regasification (Outlet)[2], ºC	19	5

1.Sea water supply and return temperature from EPA IPC Reg. No. 576 Proposed Determination: https://epawebapp.epa.ie/licences/lic_eDMS/090151b2800bff3c.pdf

2. Sea Water Outlet Temperature for regasification to be confirmed during FEED.

4.13.2 Atmospheric Pressure

Table 4-11 Atmospheric Pressure[1]

Parameter	Value
Minimum, bara	1
Normal / Average, bara	1.013
Maximum, bara	1.024

[1]World Weather Online- Whitegate Cork- https://www.worldweatheronline.com/whitegate-weather-history/cork/ie.aspx

4.13.3 Humidity

Table 4-12 Humidity[1]

Parameter	Value
Minimum, %	82%
Maximum, %	89%

[1]World Weather Online- Whitegate Cork- https://www.worldweatheronline.com/whitegate-weather-history/cork/ie.aspx

4.13.4 Rainfall

Table 4-13 Rainfall Data for use in Design

Parameter	Value
Average Annual Rainfall[1], mm	945 mm
Design Rainfall in 15 min[2], mm per annum	6.7 mm
Design Rainfall in 24 h[2], mm per annum	38.4 mm
Design Rainfall in 48 h[2], mm per annum	48.7 mm

[1] ASHRAE CLIMATIC DESIGN CONDITIONS 2017
[2] Met Éireann Return Period Rainfall Depths for sliding Durations

Table 4-14 Rainfall Intensity for use in Design

	Rainfall Intensity (mm/hr) *				
Duration	2yr ARI	5yr ARI	10yr ARI	30yr ARI	100yr ARI
10 min	6.5	9.3	11.5	15.5	21.2
15 min	7.7	11	13.5	18.2	25
30 min	10	14	17.1	22.8	30.9
1 h	12.9	17.9	21.7	28.6	38.2
24 h	42.5	55.2	64.3	80.1	100.9

** Met Éireann- Return Period Rainfall Depths for sliding Durations*

4.14 Wind Data

I.S. EN 1991-1-4:2005+NA:2013 "Eurocode 1: Actions on structures – Part 1-4: General actions – Wind actions (Including Irish National Annex)" provides details on appropriate wind loading (see Table 4-15).

Table 4-15 Wind Speeds for use in Design*

Parameter	Value
Fundamental basic wind speed velocity (V_{bmap})	25.8
Distance upwind to shoreline (L_{shore})	0
Altitude above sea level (C_{alt})	0
Direction Factor (C_{dir})	1
Season Factor (C_{season})	1
Shape parameter for probability factor (K)	0.2
Exponent for probability factor (n)	0.5
Annual probability of exceedance (p)	1 in 50 Years
Orthography type	N/A
Terrain category	Sea

Notes:
** Eurocode 1 – Actions on Structures – Part 1-4 General Actions – Wind Actions*

4.15 Snow Data

IS EN 1991-1-3:2003 “Eurocode 1 - Actions on structures. General actions - Snow loads (+AC:2009) (+A1:2015) provides details on snow loading that should be used (see Table 4-16).

Table 4-16 Snow Data

Parameter	Value
Altitude	0
Ground Snow Load kN/m^2	0.6
Topography	Normal
Exposure Coefficient (Ce)	1
Thermal Coefficient (Ct)	1

4.16 Ice Data

IS EN 1991-1-3:2003 “Eurocode 1 - Actions on structures. General actions - Snow loads (+AC:2009) (+A1:2015) states:

(8) This Part [of Eurocode 1] does not give guidance on specialist aspects of snow loading and Ice data, for example*:*

1. *impact snow loads resulting from snow sliding off or falling from a higher roof.*
2. *the additional wind loads which could result from changes in shape or size*
3. *of the construction works due to the presence of snow or the accretion of ice.*
4. *loads in areas where snow is present all year round.*
5. *ice loading.*
6. *lateral loading due to snow (e.g., lateral loads exerted by drifts);*
7. *snow loads on bridges.*

As IS EN 1991-1-3:2003 does not give guidance on ice loading and is deemed not a consideration in the Irish Standards, the consideration of ice loading is not a design requirement for the project.

4.17 Seismic Data

I.S. EN 1998-1:2004 “Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings” states the following:

> *“Following established engineering practice, all of the Republic of Ireland is deemed to be in an area of very low seismicity and as such national annexes are not considered necessary for adopted EN 1998 parts”.*

On the basis of the above, the consideration of seismic factors is not a design requirement for the project.

4.18 Metocean Data

Table 4-17 Tide Levels

Parameter	Levels* (m)	
	Cobh – Cork (Chart Datum)	Cobh –Cork (Malin Head Datum*)
Highest astronomical tide, m	+4.4	+1.84
Mean high water spring, m	+4.1	+1.54
Mean high water neap, m	+3.2	+0.64
Mean sea level, m	+2.2	-0.36
Mean low water neap, m	+1.3	-1.26
Mean low water spring, m	+0.4	-2.18
Lowest astronomical tide, m	-0.10	-2.66

Notes:

** Admiralty Tide Tables, United Kingdom and Ireland, NP201B, Volume 1B, 2021, UK Hydrographic Office - These levels refer to m above Chart Datum which is 2.56 m below OD Malin Head at Cobh respectively*

4.19 CO_2 Transport and Storage Infrastructure

The CO_2 is liquified and transported via a CO_2 carrier (marine vessel) from cryogenic intermediate storage tanks. Cryogenic CO_2 piping will run from the intermediate storage tanks along a new jetty to the jetty head where it will be discharged via cryogenic loading arm into visiting CO_2 carrier.

It is expected that initial operations with relatively low export throughput would start with smaller ship sizes of 7,500m^3 and a cargo transfer rate of 800 t/hr of liquid CO_2 under medium pressure conditions. Larger ship sizes of 15,000m^3 may be required as export throughput increases. The following table provides the analysis for ship sizes of 7,500m^3 and 15,000m^3.

Table 4-18 Ship Data

Parameter	Value	Value
Ship Size, m^3	7,500	15,000
Ship loading rate, t/hr	800	16,00
Number of loading arms (minimum)	2	4
Export throughput (MMtCO_2/year)	1.25	1.25
Total Distance (nautical mile)	900	900
Total ships required per year	151.5	75.8
Estimated round trip travel time, days	6.9	6.9
Inter arrival period, days	2.3	4.6
Storage Buffer, production days	3	3
Storage capacity, m^3	18,550	26,050

CO_2 transport and storage facilities at Cork will be designed to cater to ship sizes of 7,500m^3 with partial investment as discussed below to cater to ship sizes of 15,000m^3.

1. Storage capacity and loading lines at Cork are sized based on a ship size of 7,500m^3. Storage capacity is based on 3 days production + parcel size of 7,500m^3. Plot space will be kept for additional storage capacity required for ship size of 15,000m^3 + 3 days of production.
2. Exisiting BOG compressor package for ship size of 7,500m^3 with design margin is considered adequate for a ship size of 15,000m^3. This shall be verified during FEED.
3. Plot space provided for one additional loading pump required for ship size of 15,000m^3.
4. Plot space provided for 2 additional loading arms required for ship size of 15,000m^3.

5 RELEVANT PRE-FEED DOCUMENTS

The following philosophies, studies, and analyses have been developed as part of the pre-FEED study. These documents shall be reviewed by the FEED contractor at the outset of FEED.

- Health, Safety, Security and Environment (HSSE) Philosophy
- Process and Utilities Design Philosophy
- Process Control and Safeguarding Philosophy
- Process Safety Design Basis
- Material Selection Philosophy
- Operations and Maintenance Philosophy
- Communications & Control Philosophy
- Pipeline Design Philosophy
- Flow Assurance & Hydraulics Analyses
- Pipeline Crack Propagation Study
- CO_2 Network Separation Study
- Gas Dispersion Study Report
- Marine Design Philosophy
- Marine Operations Study
- Jetty Preliminary Layout Philosophy
- Power Generation and Electrical Systems Philosophy
- RAM (Reliability, Availability, Maintainability) Study
- Stakeholder Management Philosophy
- Legislative Approvals Philosophy
- Preliminary Project Execution Plan

Appendix A
Units of Measurement

UoM for PFD, Heat Material Balance and Stream Summary

Parameter	UOM	Remarks
Flowrates of vapours, gases, steam, liquids, catalyst and solids	tonnes / hr or kg/hr or MMtpa;	
System Pressure	bara, barg	
Vacuum	mm Hg abs	
Delta P	mm Hg / bar	
Temperature	deg C	
Level	% Vol.	Non-linear level control shall be used wherever applicable.

UoM for Datasheets, Specifications, Design Documents and Drawings

Parameter	Unit of Measurement				
SPACE AND TIME					
Length	m	mm			
Area	m^2	mm^2			
Volume	m^3	l (litre)	ml		
Time	s	hr	day		
Velocity	m/s	mm/s			
Acceleration	m/s^2				
Volume Flow	m^3/s	l/s	ml/s	m^3/h	m^3/d
Plane angle	rad	degree	minute	second	
Solid angle	sr				
Angular velocity	rad/s				
PERIODICITY					
Frequency	MHz	kHz	Hz		
Rotational frequency	rev/s	rpm			
MECHANICS					
Mass	t (tonne)	kg			
Mass Flow	t/hr		kg/hr	MMtpa	
Molar Flow	kgmol/h		kgmol/s		
Volumetric Flow	m^3/hr				
Normal Volumetric Gas Flow	Nm^3/hr	(0°C and 1.013 bara)			

Standard Volumetric Liquid Flow	Sm^3/hr	(15^oC)			
Density	kg/m^3				
Liquid Absolute Density	kg/m^3	(15^oC)			
Momentum	kgm/s				
Moment of inertia	kgm^2				
Force	N				
Moment of force	Nm				

Pressure (Absolute)	bara	mmHgA			
Energy, Work	MJ	kJ	kJoules		
Power	MW	kW	W		
Dynamic Viscosity	cP (centipoise)		Pa s		
Kinematic Viscosity	cSt (centistokes) m^2/s				
Surface Tension	dyne/cm				
Conductivity	µS / cm				
Sound Pressure	dB				

HEAT

Absolute temperature	K
Customary temperature	ºC
Heat Quantity	kJoules
Heat flow rate	kJoules/hr
Density of heat flow rate	kJoules/m^2hr
Thermal conductivity	Watt/m-K
Coefficient of heat transfer	kJoules/hr m^2 □C
Specific heat capacity	kJoules/kg-^{o}C
Specific entropy	kJoules/kg
Calorific value (mass basis)	kJoules/kg
Specific energy, specific enthalpy, specific latent heat	kJoules/kg
Calorific value (volume basis)	kJoules/Sm^3

ELECTRICITY AND MAGNETISM

Electric current	kA	A	mA		
Electric charge, quantity of electricity	kC	C	µC		
Electric potential and electromotive force	kV	V	mV	µV	
Electric field strength	V/m				
Capacitance	F	µF	pF		
Current density	A/mm^2		A/m^2		
Magnetic field strength	A/m				
Magnetic flux	Wb	mWb			
Magnetic flux density	T				
Self inductance, mutual inductance	H	mH	µH		
Permeability	H/m				
Resistance, impedance, reactance	MΩ	kΩ	Ω	mΩ	µΩ
Conductance	kS	S	mS	µS	
Resistivity	Ωm	µΩm			
Active power	MW	kW	W		

Reactive power	MVAr	kVAr	VAr		
Apparent Power	MVA	kVA	VA		
Electrical energy	MWh	Wh	MJ	kJ	J
ILLUMINATION					
Luminous intensity	Cd				
Luminous flux	Lm				
Illumination	Lx				
Luminance	cd/m^2				

Notes:

- *Millimeter (mm) shall be used for piping system sizing.*
- *Standard conditions are 15^{o}C and 1.013 bara.*
- *Normal conditions are 0^{o}C and 1.013 bara.*
- *Conditions for specific gravity are T^{o}C / 15^{o}C.*