International Hydrogen Ramp-up Programme – H2Uppp

Greenhouse Gas Emission Calculation for an 820 TPD Green Methanol Project

Malkangiri, Odisha, India

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

H2Uppp

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List of Abbreviations

BESS	Battery Energy Storage System
CCS	Carbon Capture and Storage
CCU	Carbon Capture Unit
CDR	Commission Delegated Regulation
CO_2	Carbon Dioxide
DG	Diesel Generator
EU	European Union
FEED	Front-End Engineering Design
GHG	Greenhouse Gas
GWP	Global Warming Potential
H_2	Hydrogen
H_2SO_4	Sulphuric Acid
HCl	Hydrochloric Acid
HP	High Pressure
KOH	Potassium Hydroxide
KTPA	Thousand Tonnes Per Annum
kWh	Kilowatt-hour
LNG	Liquefied Natural Gas
MeOH	Methanol
MGO	Marine Gas Oil
MJ	Megajoule
MW	Megawatt
N_2O	Nitrous Oxide
NaOH	Sodium Hydroxide
PtX	Power-to-X
RE	Renewable Energy
RED II	Renewable Energy Directive (EU) 2018/2001 (recast directive)
RFNBO	Renewable Fuel of Non-Biological Origin
TPA	Tonnes Per Annum
TPD	Tonnes Per Day

Executive Summary

This document presents a comprehensive greenhouse gas (GHG) emissions assessment for a 275 kilo-tons per annum (KTPA) [or 820 Ton per Day (TPD)] green methanol production facility utilising renewable electricity, electrolytic hydrogen, and captured biogenic carbon dioxide (CO_2) from a paper mill as feedstocks. The renewable assets are not co-located and use the grid to transmit power. This assessment follows a full lifecycle approach and covers well to final use emissions. It evaluates the plant's carbon intensity, emission drivers, and compliance with applicable regulatory frameworks, particularly the EU Renewable Fuels of Non-Biological Origin (RFNBO) delegated acts (EU) 2023/1184 & (EU) 2023/1185.

The analysis demonstrates that e-methanol produced under the assumed conditions can achieve significant GHG reductions compared to fossil-based methanol, provided strict renewable electricity sourcing and transparent CO_2 accounting methodologies are implemented. The dominant contributor to lifecycle emissions are shipping emissions from Kakinada Port in India to Hamburg Port in Germany.

Key Results:
Production Capacity: 275 KTPA Green Methanol
GHG Assessment Boundary: Well-to-end-use (Well-to-grave)

- Fossil baseline/ fossil fuel standard set : 94.0 gCO_2 e/ MJ
- 70% emission reduction Benchmark (EU RFNBO Thresholds): 28.2 g CO_2 e/ MJ
- Carbon intensity: 13.5066 g CO_2 e/ MJ, i.e., approximately 86% emission savings
- Carbon intensity: 0.2688 Kg CO_2 e/Kg methanol which corresponds to approx. 86% emission savings with respect to fossil fuel benchmark

Key emission contributor: Shipping emissions of 0.1533 kg CO_2 e/kg MeOH due to transportation from Kakinada Port in India to Hamburg port, Germany.

Regulatory Outcome:
Meets >70% GHG reduction versus fossil baseline limit set for RFNBO compliance under Directive (EU) 2018/ 2001.

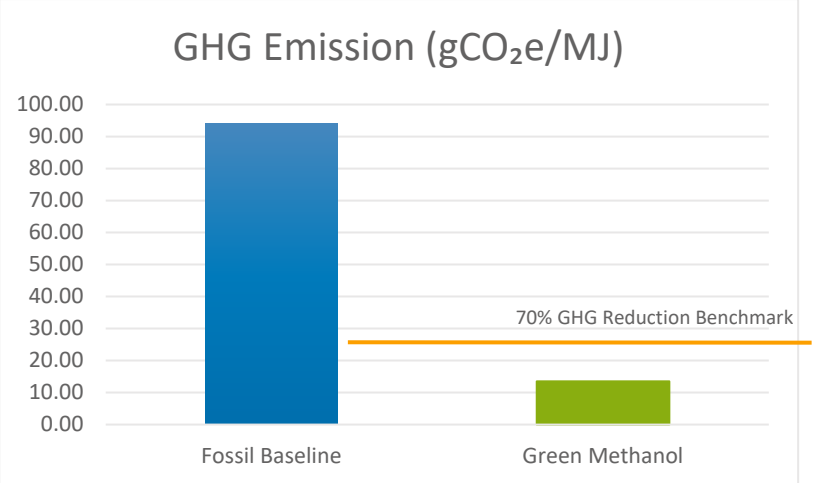


Figure 1 GHG emission results

1 Introduction

ReNew E-Fuels Private Limited (hereinafter referred to as ReNew) established in 2011, is one of India's leading renewable energy companies in terms of total energy generation capacity. Since commencing operations with a 25.2 MW wind project in Jasdan, Gujarat, the company has grown exponentially and has a current renewable asset base of over 19.2 GW, including projects under development and in the pipeline.

ReNew is planning to set up a green methanol plant. It is proposed that green methanol (referred to as "PRODUCT") produced shall be exported or utilised domestically to cater global energy demand. The proposed facility shall be using green hydrogen produced from water electrolysis using water and renewable energy (RE) as input / feed for the electrolyser. RE would be fed from a ReNew power plant (hybrid - solar & wind) through open access to meet its power input requirement. The proposed facility will utilise all the generated hydrogen in the project to produce green Methanol.

2 Project Background

The vision for India's green hydrogen economy was set on 15 August 2021 (75th Independence Day) with the launch of the National Hydrogen Mission by the Prime Minister of India. In January 2023, the Indian National Green Hydrogen Mission has been approved by the Government of India with an outlay of EUR 2.25 billion until 2030. The Mission aims at making India a global hub for green H_2 production, utilisation and export.

In the future global energy transition, green methanol will play a key role. Methanol is needed in many industry processes, such as formaldehyde production, production of gasoline, methanol-to-olefins (MTO), Methyl Tert-Butyl Ether (MTBE), solvent applications, etc. In addition to green methanol projects for the local market, projects for the export market, where higher offtake prices are expected, can also support the general market ramp-up of green methanol projects in India as a first step.

To further explore how green methanol projects can be set up in India and how they can be aligned with European regulations such as RED II, this PPP project has conducted a comprehensive pre-feasibility study of a green methanol project suitable for domestic as well as for export. The green methanol will be produced using hydrogen through the water electrolysis process and CO_2 sourced from a biogenic source.

2.1 Objective of H2Uppp PPP Measure

The objective of the H2Uppp PPP measure is to enable the development of a bankable green methanol export project from India to the EU by building capacities and enabling an optimised design and configuration of the project in line with EU RED regulations.

2.2 Document Scope

The purpose of this document is to provide a robust and transparent GHG emission assessment for a commercial scale green methanol production facility. The key objectives are:

- Quantification of lifecycle GHG emissions associated with the green methanol production;
- Determination of the carbon intensity per kilogram of green methanol;
- Evaluation of compliance with regulatory frameworks.

2.3 Scope and Functional Unit

- Assessment Boundary: Well to end use (well-to-grave)
- Plant Capacity: 275 KTPA green methanol
- Electrolyser Technology: Alkaline

- CO_2 source: Biogenic
- RE power: Solar + wind (assets are not co-located and use the grid for transmission)
- Destination Port: Hamburg, Germany
- Commercial Operation: 45 months from FEED

3 Process Description

3.1 Plant Capacity

The methanol unit shall be capable of producing 820 TPD of green methanol. The hydrogen unit and the CO_2 capture unit shall be designed in terms of capacity to meet the CO_2 and H_2 requirements for producing 820 TPD of green methanol. The plant shall be designed for 30% turndown.

3.2 Design Life

The plant facility shall be designed for a design life of 25 years.

3.3 Source of CO_2

The source of captured CO_2 shall be selected carefully as some eligible sources lead to a negative GHG intensity (e ex-use emission) after the production of a carbon containing RFNBO and thus significantly help in carbon intensity reduction of RFNBO. The eligible sources are:

- the CO_2 has been captured from an activity listed under Annex I of Directive 2003/87/EC20 (the EU ETS) and has been considered upstream in an effective carbon pricing system and is incorporated into the chemical composition of the fuel before 2036. This date shall be extended to 2041 in other cases than CO2 stemming from the combustion of fuels for electricity generation, or
- the CO_2 has been captured from the air, or
- the captured CO_2 stems from the production or the combustion of biofuels, bioliquids or biomass fuels complying with the sustainability and GHG emissions saving criteria and the CO_2 capture did not receive credits for emission savings from CO_2 capture and replacement, set out in Annex V and VI of RED II, or
- the captured CO_2 stems from the combustion of RFNBOs or recycled carbon fuels complying with the GHG emissions saving criteria; or
- the captured CO_2 stems from a geological source of CO_2, and the CO_2 was previously released naturally.

A pulp and paper mill is selected as sustainable source of CO_2 for methanol plants as it works the full year. For a target capacity of 820 TPD of methanol production, the required CO_2 is 48.76 TPH which will be met from a CO_2 emitting source preferably located near to the methanol plant.

3.4 Site Location

The project will be located in Malkangiri district, Odisha, in India, with an available area of 140 acres. Hydrogen and methanol production facilities are preliminarily located adjacent to each other at project site. The carbon capture unit will be co-located at the methanol production facilities.

3.5 Export Port

For export, the port of dispatch has been identified as Kakinada Port and new methanol storage facilities will be constructed at an area near to the port.

3.6 Power Supply

The production facilities and carbon capture unit will be powered by renewable electricity via the Indian grid from the nearest substation. The renewable power is a mix of solar, wind and BESS.
The port will utilise its own electricity for logistic operations. It is important to highlight that the amount of electricity consumed for logistic purposes is significantly lower than the amount required for the molecule production plants.

3.7 Source of Raw Water

The raw water supply will stem from perineal Sabari River which is a tributary of Godavari River. Water allocation will be regulated from the competent authority as the project progresses. The water will be drawn by dedicated intake infrastructure and transported by a dedicated water pipeline to the project location. Sufficient storage will be kept at the plant location to continue uninterrupted operations during lean season.

4 Methanol Production Plant

The proposed production facility is a key step toward a green economy, with the objective of producing green methanol using renewable energy, green hydrogen and captured biogenic CO_2. The plant is designed to operate entirely on renewable power and to utilise 100% green hydrogen generated within the project boundary. A simplified block flow diagram of the process plant is given below.

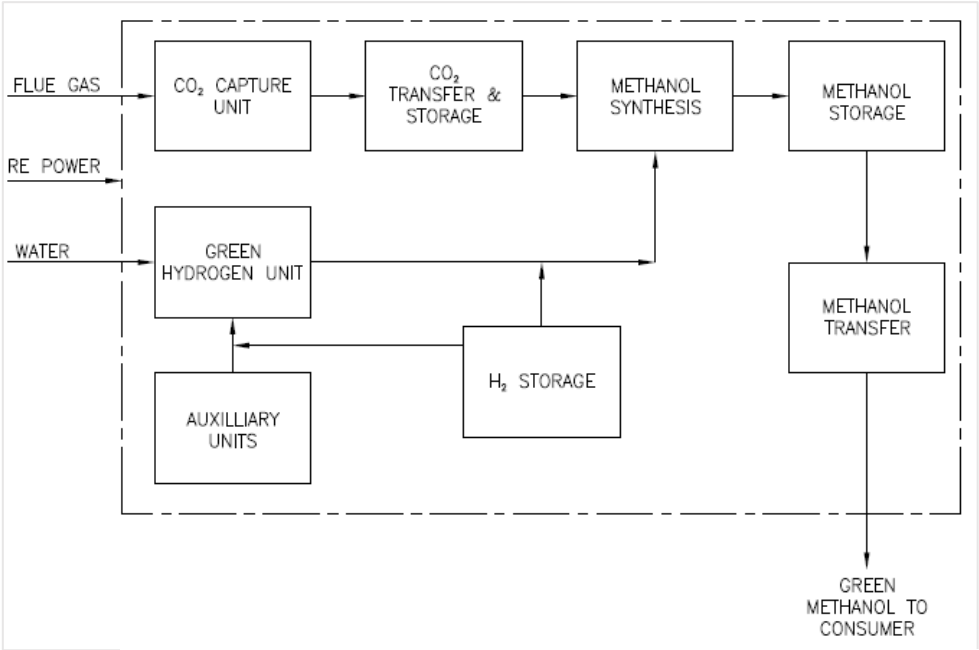


Figure 2 Simplified block flow diagram

Shown below are the hydrogen and CO_2 quantities required for methanol production.
Table 1 FEED to Methanol quantification

FEED to Methanol	Flow (Kg/h)
Hydrogen consumption	6780
CO_2 consumption	48763

5 Greenhouse Gas Emission Calculation Methodology and Assumptions

This GHG calculation has been carried out in accordance with the requirements of RED II and European Commission Delegated Regulations (EU) 2023/1184 and (EU) 2023/1185. The regulations establish harmonised rules for monitoring, reporting, and verification of embedded GHG emissions. They therefore define the system boundaries, methodological hierarchy, emission factors, and treatment of electricity, inputs, and by-products for installations producing RFNBOs. The calculation approach adopted in this report is aligned with the governing code to ensure transparency and consistency, thereby enabling comparability with EU benchmarks.

5.1 Standards and Guidelines

- Renewable Energy Directive
- CDR (EU) 2023/ 1984
- CDR (EU) 2023/ 1985
- Supporting Guidance from CertifHy frameworks

5.2 Key Considerations

- The raw water is expected to be sourced from the nearby perineal river 4 km away from the plant location. It will be transferred via pump, which will utilise grid power. This will result in a carbon emission of 0.00229 Kg CO_2 e/ Kg MeOH.
- The methanol pipeline for transferring methanol from the process plant to the port storage has a length of 200 km. A methanol booster station is provided at a 120 km from the methanol plant battery limit that will utilize the grid power for operation. This will result in an emission of 0.0013 Kg CO_2 e/ Kg MeOH.
- The port storage and transfer facility will utilise grid power. The grid emission factor is 0.710 Kg CO_2 e/ KWh. The total emission from the port storage and transfer is 0.0079 Kg CO_2 e/ Kg MeOH.
- The produced oxygen in the electrolyser will be vented to the atmosphere.
- The plant utilises two (2) units of emergency diesel generators with a capacity of 2.2 MW, to run a maximum of 24 hours in a year. This will result in emissions of 0.0003 Kg CO_2 e/Kg MeOH.
- All the chemicals, consumables and catalysts are expected to be sourced from a maximum distance of 150 km, except the deoxidizer catalyst, which is expected to be sourced from within 1000 km.
- The Carbon Capture Unit (CCU) will run on RE power.
- The Global Warming Potential (GWP) relative to CO_2 over the 100-year time horizon as set out in Annex V, part C, point 4 to Directive (EU) 2018/2001 and also shown below:
  - CO_2: 1
  - N_2O: 298
  - CH_4: 25
- The export and destination port details are as follows:
  - Port in India: Kakinada
  - Port in Europe: Hamburg, Germany
- The shipping vessel utilises Marine Gas Oil (MGO) as a shipping fuel.
- The shipping vessel will have a waiting time of one day each at the dispatch and destination port.
- Loading and unloading operations will require 30 hours both at dispatch and destination port.
- The total emissions due to methanol shipping are 0.1533 Kg CO_2 e/ Kg MeOH.

5.3 GHG Calculation Methodology

The Commissioned Delegated Regulation defines the formula for assessing the GHG emission of RFNBO, which is mentioned below

$$\mathbf{E = e_i + e_p + e_{td} + e_u - e_{ccs}}$$

Wherein,

E = ...total emissions from the use of the fuel (g CO_2eq/MJ-MeOH)
e_i = ...emissions from supply of inputs (g CO_2eq/MJ-MeOH)
$\mathbf{e_i = e_{i\ elastic} + e_{i\ rigid} - e_{ex\text{-}use}}$
$e_{i\ elastic}$ = ...emissions from elastic inputs (g CO_2eq/MJ-MeOH)
$e_{i\ rigid}$ = ...emissions from rigid inputs (g CO_2eq/MJ-MeOH)
$e_{ex\text{-}use}$ = ...emissions from inputs existing use or fate (g CO_2eq/MJ-MeOH)
e_p = ...emissions from processing (g CO_2eq/MJ-MeOH)
e_{td} = ...emissions from transport and distribution (g CO_2eq/MJ-MeOH)
e_u = ...emissions from combusting the fuel in its end-use (g CO_2eq/MJ-MeOH)
e_{ccs} = ...emission savings from carbon capture and geological storage (g CO_2eq/MJ-MeOH)[1]

5.4 Chemicals, Consumables and Catalysts

Table 2 Annual consumption of chemicals, consumables and catalysts

Sr. no.	Description	Consumption, kg/ year
1	KOH (Electrolyser Package)	220000.00
2	V2O5 (Electrolyser Package)	3400.00
3	Zeolite molecular sieve adsorbents (Electrolyser Package)	36000.50
4	Deoxidizer-Palladium catalyst (Electrolyser Package)	13666.67
5	Methanol Catalyst	45000.00
6	Anitiscalant (Cooling Tower Package)	109000.00
7	Biocide (Cooling Tower Package)	212000.00
8	Corrosion inhibitor (Cooling Tower Package)	96000.00
9	H2SO4 (Cooling Tower Package)	694000.00
10	Chlorine (Cooling Tower Package)	711000.00
11	Hypochlorite (Sewage Treatment Package)	39000.00
12	Ferric Chloride (Water Treatment Package)	357000.00
13	Sodium metabisulfite (Water Treatment Package)	12000.00
14	Caustic 48% (Water Treatment Package)	49800.00

[1] Refer to https://ptx-hub.org/wp-content/uploads/2023/04/International-PtX-Hub_EU-Requirements-for-green-hydrogen-and-PtX.pdf for the calculation methodology.

15	HCl 33% (Water Treatment Package)	687000.00
16	Dewatering Polymer (Water Treatment Package)	47000.00
17	Amine Solvent (100% wt basis) – CCU	120000.00
18	NaOH make-up (100% wt basis)	500000.00
19	Coordinate phosphate / PH treatment	3000.00

The chemicals, consumables and catalysts produce emissions of 0.07215 Kg CO_2e/Kg MeOH due to production and transportation of these items to the process plant.

5.5 Flaring Emissions

Table 3 Overview of process flaring streams

S. No.	Type	Frequency	Quantity	Remarks
1	Process Gaseous Waste Streams	Continuous	500-550 Nm3/hr H_2: 55-65 mol% CO + CO_2: 15-25 mol% Others: 10-30 mol%	No direct release of any gases to the atmosphere
2	HP Flare Package	Emergency	350-400 ton/hr H_2: 75 mol% CO_2: 25 mol%	Peak Emergency

The flaring of gases will result in an emission of 0.0310 Kg CO_2e/Kg MeOH.

5.6 Emission Sources Breakdown

Table 4 Lifecycle GHG emissions per kg MeOH

Parameter	Typical Value	Remarks
Input Emissions, ei	(-) 1.2966 Kg CO_2e/ Kg MeOH	(-) due to E ex-use
Production Emissions, ep	0.0314 Kg CO_2e/ Kg MeOH	
Distribution Emissions, etd	0.1629 Kg CO_2e/ Kg MeOH	
End use Emissions, eu	1.3711 Kg CO_2e/ Kg MeOH	

Shipping emissions of 0.1533 kg CO_2 e/Kg MeOH are included in the distribution emissions of 0.1629 kg CO_2 e/Kg MeOH. Following 'End-use Emissions', they constitute the second-largest share of total emissions.

6 Compliance Check

Total Emission (E):.....0.2688 Kg CO_2e/ Kg MeOH
Total Emission (E): .....13.5066 g CO_2e/ MJ

Fossil Fuel Standard Set: ....94.0 g CO_2e/ MJ
RFNBO Compliance: .....> 70% reduction vs fossil baseline

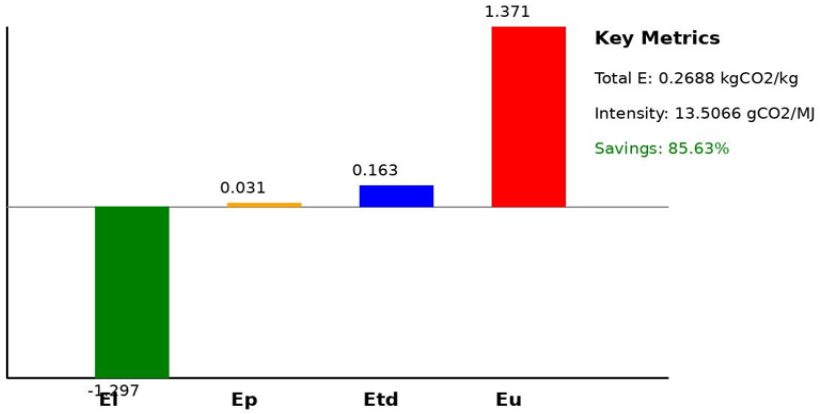


Figure 3 GHG emission breakdown

70% reduction value:.....0.7 X 94.0 g CO2e/ MJ
28.2 g CO_2e/ MJ
Total Emissions .....< 70% Fossil Fuel standard set

Result: The GHG emissions are well within the limit set for RFNBO in Directive (EU) 2018/2001

7 Key Risks for GHG Results

Below are some of the risks that can impact GHG results

- Grid emission factor variation.
- Change in sourcing location of chemical and consumables.
- A change in usage of diesel generator.
- A significant change in water and methanol pipe routing.
- A change in shipping route.

Most of the risks identified above have limited impact on the methanol carbon intensity, except a change in the shipping route, which can have a significant negative impact on the GHG emission values.

8 Recommendations

The following are critical caution points for Indian projects that could affect the overall configuration of the green fuel project:

- India, so far, is not considered as a single bidding zone. Indian projects shall closely monitor the resolution for setting up the RE facilities if utilising the grid for power transmission.
- Even though the use of industrial CO_2 coming from units listed in Annex I of the EU Directive 2003/87/EC20 is permitted till year 2041 in Commission Delegated Regulation (EU) 2023/1184, it cannot take credit of captured CO_2 in e ex-use as Indian CCTS scheme is not yet recognised by European commission.
- Commission Delegated Regulation (EU) 2023/1184 stipulates that electricity generation used for RFNBO production must not have received investment aid in order to fulfil the additionality requirement. Hence, all the incentives received shall be carefully analysed and assessed by the project developer in view of "no support" aspect of the additionality requirement.
- The following are recommendations to improve the carbon intensity:
  - LNG vessels instead of vessels utilising MGO.
  - Use of green/ low carbon/ gas generators against diesel generators.

9 Conclusion

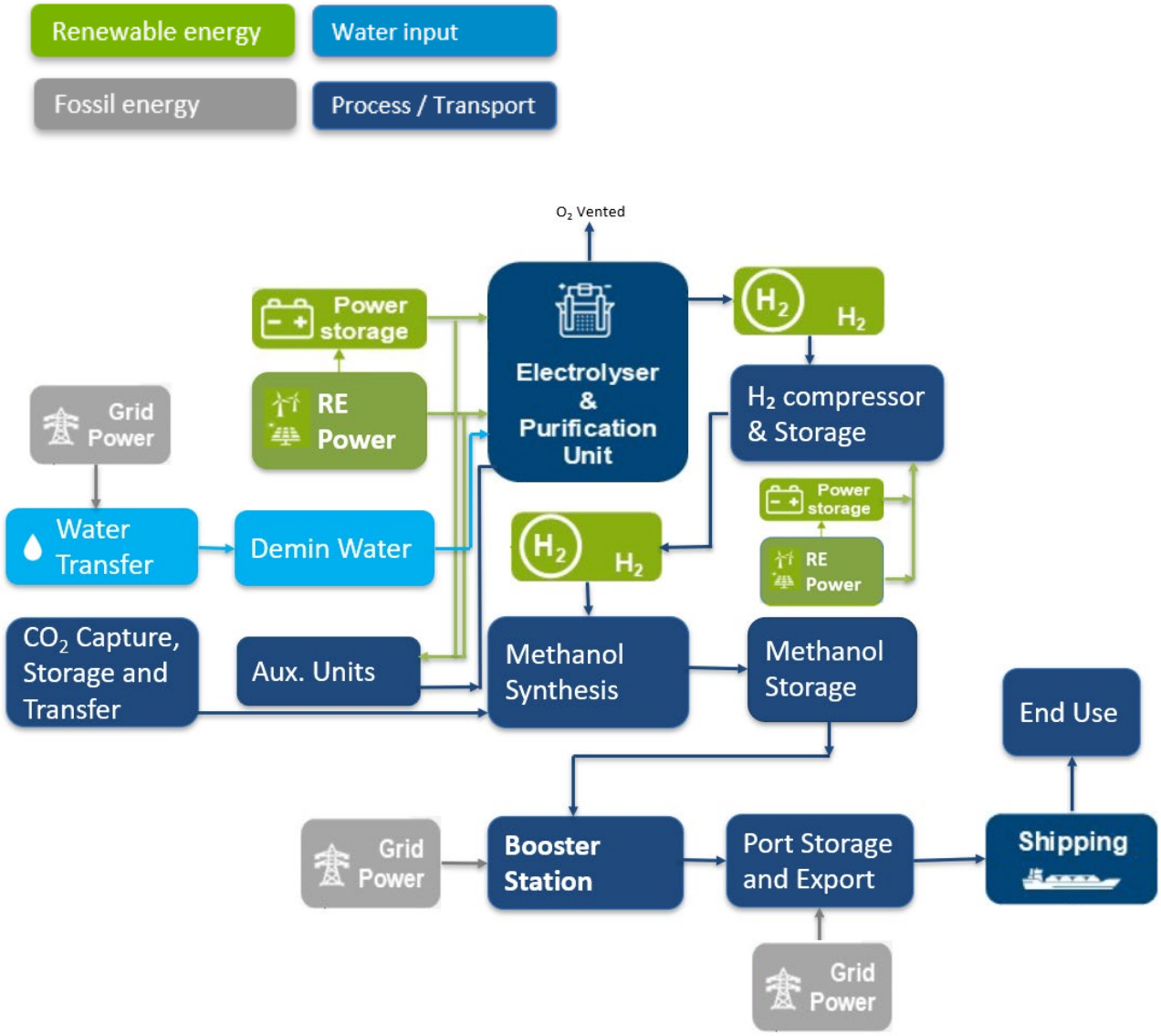
The 275 KTPA e-methanol project demonstrates compliance with the requirements of Directive (EU) 2018/2001 and meets the greenhouse gas (GHG) emission thresholds established therein. Strict adherence to the exclusive use of renewable energy for both the methanol production process and the associated carbon capture facility ensures that lifecycle emissions remain below the limits set out in Directive (EU) 2018/2001.

10 Appendices

APPENDIX A - GHG Calculation

Plant Capacity Basis		
Methanol Production	275	kTPA
Plant utilisation	335	Days
Methanol Capacity	820.00	TPD
Total Water Consumption	13875.00	m3/day
Total GHG Emission (E) calculations	**$= E_i+E_p+E_{td}+E_u.E_{ccs}$**	
i) Ei (input emissions)		
Inputs to the process are water, RE and CO2		
a) Emissions associated with input, RE power	0.0000	kgCO2/kg MeOH
b) Emissions associated with input, water supply	0.0023	kgCO2/kg MeOH
c) Emissions associated with other consumables	0.0317	kgCO2/kg MeOH
d) Emission associated with transportation of consumables	0.0405	kgCO2/kg MeOH
e) Captured CO2 (eex-use)	1.3710	kg CO2/kg MeOH
Total Ei= ei elastic + ei rigid - eex-use:	**-1.2966**	**kg CO2/kg MeOH**
ii) Ep (emissions from processing)		
Emissions from processing shall include direct atmospheric emissions from the processing itself, from waste treatment and from leakages		
a) Electricity for Production	0	kgCO2/kg MeOH
b) Process emissions	0	kgCO2/kg MeOH
c) Flare Package emissions	0.0310	kgCO2/kg MeOH
d) DG set emissions	0.0003	kgCO2/kg MeOH
Total Ep	**0.0314**	**kgCO2/kg MeOH**
iii) Etd (emissions from transport & distribution)		
MeOH pumping from booster station to Port storage	0.0013	kgCO2/kg MeOH
MeOH pumping from Port to Jetty (Pipeline transport)	0.0003	kgCO2/kg MeOH
Loading arm @ Kakinada Port	0.00001	kgCO2/kg MeOH
Power consumption @ port storage	0.00790	kgCO2/kg MeOH
Shipping to destination port emissions	0.1533	kgCO2/kg MeOH
Total Etd	**0.1629**	**kgCO2/kg MeOH**
Results		
Pipeline transfer		
Total E	0.2688	kgCO2/kg MeOH
	13.5066	gCO2/MJ MeOH
	85.63	**% emission savings**

APPENDIX B - Energy Mix for Green Methanol Production





The International Hydrogen Ramp-up Programme (H2Uppp) is supporting entrepreneurial engagement in the ramping-up of hydrogen in the Global South and is a funding programme of the:

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