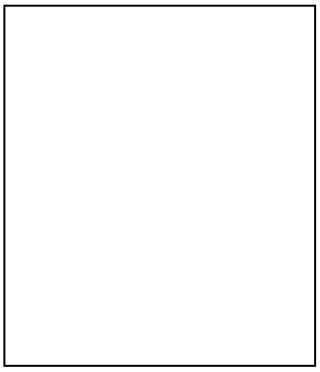
GREEN HYDROGEN BLENDING PILOT PROJECT

NTPC KAWAS

SEPTEMBER 2024

MESSAGE FROM CMD, NTPC LIMITED



Green Hydrogen plays a pivotal role in this energy revolution. Amongst all applications of green hydrogen 'blending green hydrogen with natural gas' is a low hanging fruit to achieve the national objective of energy security and decarbonisation.

NTPC feels proud in commissioning India's first green hydrogen blending project which has completed over 1.5 years of operation. This project marks a significant step towards our commitment to a cleaner, greener future, setting new benchmarks for the industry

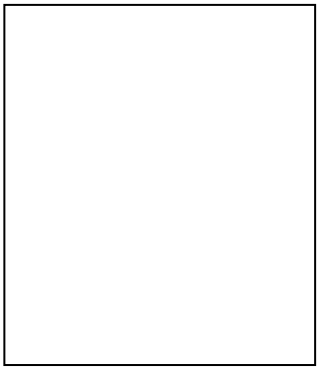
This initiative aligns with India's ambitious goals of achieving **energy independence** and transitioning to a **low-carbon economy**.

This report provides adequate information on replicating NTPC's success story on hydrogen blending project.

Gurdeep Singh

CMD, NTPC Limited

MESSAGE FROM DIRECTOR (PROJECTS), NTPC LIMITED



Green Hydrogen Mobility Pilot Project is a testament to our commitment and relentless pursuit of reducing carbon emissions. This project has been setup in one of our NTPC project at Kawas, Surat with intention to supply the hydrogen blended natural gas for 200 households in the township for upto 20% v/v. Green Hydrogen is generated in-situ by using renewable power from the nearby NTPC floating solar project and blended with natural gas.

We are immensely proud to collaborate with Gujarat Gas Limited (GGL) on the groundbreaking Green Hydrogen Blending Project. This partnership exemplifies our shared commitment to pioneering sustainable energy solutions and reducing carbon emissions.

We are deeply grateful for the unwavering support and guidance provided by the Petroleum and Natural Gas Regulatory Board (PNGRB) in the successful implementation of our Green Hydrogen Blending Project. Their guidance and approval have been pivotal in enabling us to embark on this innovative journey towards a sustainable energy future.

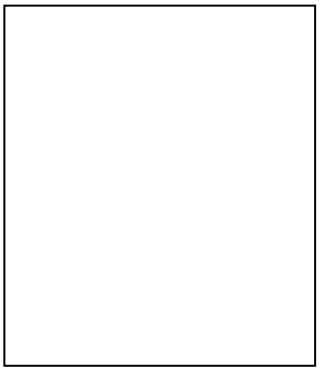
This document is prepared with the experience gained from implementing the project and continuous assessment of the blending system.

As we move forward, we remain committed to exploring new opportunities and pushing the boundaries of what is possible in the realm of sustainable energy.

K. Shanmugha Sundaram

Director (Projects), NTPC Limited

MESSAGE FROM EXECUTIVE DIRECTOR (RE), NTPC LIMITED



I am delighted to share the report on NTPC Green Hydrogen Blending Project success story. At present, hydrogen blending ratio upto 8% v/v is carried out in this project without any issues faced in the blending system and we are confident to increase this ratio, further reducing the carbon footprint.

This project, a collaborative effort with Gujarat Gas Limited (GGL), marks a significant milestone in our journey towards a greener future. GGL's trust on NTPC capabilities was instrumental in launching India's first green hydrogen blending project.

We would like to express our sincere gratitude to the Petroleum and Natural Gas Regulatory Board (PNGRB) for their invaluable support in the successful implementation of our green hydrogen blending project. The PNGRB's guidance and regulatory framework have been instrumental in ensuring the smooth progress of this initiative.

This report details project implementation, assessment process and results. We are confident it shall help others to set up this type of facilities elsewhere in the country without any difficulty.

In this energy transition, green hydrogen is poised to be a game-changer, offering a sustainable and scalable solution to reduce carbon emissions and support a cleaner future.

Rajiv Gupta

Executive Director (RE-NTPC) and CEO (NGEL)

ACKNOWLEDGEMENTS

This document is prepared with the encouragement and guidance from NTPC Management. We are thankful for the unique opportunity to work in one of the India's unique Green Hydrogen Blending Project at Kawas.

This project is India's first green hydrogen blending project operating at 8% v/v and supplying blended natural gas to the 200 households. The hydrogen concentration will be increased to 20% v/v in staggered manner with an approval from the regulator.

We deeply appreciate timely support from GGL and PNGRB extended from time to time for bringing the project to the current stage from ground zero.

We are also thankful to all the stakeholders for providing inputs in preparing this report.

NTPC Green Hydrogen Team

OBJECTIVE OF THIS DOCUMENT

1. This document provides information of NTPC Green Hydrogen Blending Pilot Project at Kawas, Gujarat. It covers details of the project, inputs and scope of work from NTPC and GGL, third party assessment outcomes and performance of the blending system etc.,
2. This document provides information to following identified stakeholders.
   - ❖ Owner:
     - Inputs required for establishing the green hydrogen blending project.
     - Gas composition and material assessment outcomes upto 8% v/v hydrogen blending.
     - Project information, layout and PI&D
     - Customer concerns and perceptions.
     - Performance details of the blending system.
     - Provides guidance for developing similar projects.
   - ❖ GA operator:
     - Statutory requirements and approval from the regulator
     - Details of the assessment to be carried out by the GA operator perspective.
     - Support and co-ordination between the owner and GA operator.
     - Outcomes of Gas composition and material assessment of PNG gas network components for upto 8% v/v hydrogen blending.
3. This document also provides standard technical specification for developing a hydrogen blending project.

Contents

Abbreviations

API RP	American Petroleum Institute Recommended Practice
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CC/CV	Constant Current / Constant Voltage
CGD	City Gas Distribution
CNG	Compressed Natural Gas
CO2	Carbon dioxide
DC	Direct Current
DCP	Dry Chemical Powder
DM Water	Demineralised Water
EMERA	Escape Muster and Emergency Response Assessment
EN	European Norms
GA	Geographical Area
GCR	Gas Cylinder Rules
GCV	Gross Calorific Value
GGL	Gujarat Gas Limited
GI	Galvanized Iron
G-L	Gas-Liquid mixture
H2	Hydrogen
HAC	Hazardous Area Classification
HAZOP	Hazardous Operability
IP	Ingress Protection
IRPA	Individual Risks Per Annum
IS	Indian Standard
ISI	Indian Standards Institution
ISO	International Organization for Standardization
LDT	Leak Detection Testing
LEL and UEL	Lower Explosive Limit and Upper Explosive Limit
LPG	Liquefied Petroleum Gas
LPT	Lock Pressure Test
MDPE	Medium Density Polyethylene
MMSCMD	Million Metric Standard Cubic Meter per Day
NCV	Net Calorific Value
NFPA	National Fire Protection Association
NG	Natural Gas
NM3/Hr.	Normal cubic meter per hour
NTU	Nephelometric Turbidity Unit
O&M	Operation and Maintenance
OISD	Oil Industry Safety Directorate
PBG	Performance Bank Guarantee
PE	Polyethylene

PEM	Proton Exchange Membrane
PESO	Petroleum and Explosive Safety Organization
PID	Proportional-Integral-Derivative
PLC	Programmable Logic Controller
PNG	Piped Natural Gas
PNGRB	Petroleum and Natural Gas Regulatory Board
PPM	Parts per million
QRA	Quantitative Risk Assessment
RE	Renewable Energy
SCMD	Standard cubic meter per day
SCMH	Standard cubic meter per hour
SMPV	Static and Mobile Pressure Vessel
T4S	Technical Standards and Specifications including Safety Standards
TPA	Tonne per annum
UPS	Un-interrupted Power Source
v/v	volume by volume
WL	Water Litres

1. Executive Summary

With the objective to reduce usage of natural gas and minimize climate change effects. Green hydrogen blending is being investigated as a potential solution across the globe. Green hydrogen is an energy that could play an important role in reducing emissions associated with difficult-to decarbonize sectors particularly from households cooking applications.

NTPC has commissioned India's first Green Hydrogen Blending Project at its power station in the state of Gujarat on 02 Jan 2023 with blending ratio of 5% v/v. This project includes an electrolyser unit and blending skid for mixing of green hydrogen with piped natural gas (PNG). Green hydrogen is produced using electricity from adjacent floating solar project of NTPC. The blending skid ensures blending of hydrogen gas from 5-20% by vol./vol. with PNG supplied from Gujarat Gas Limited (GGL).

Safety studies like HAZOP, QRA, EMERA, HAC were carried out in design phase to ensure project to safer and reliable in operation.

Petroleum and Natural Gas Regulatory Board (PNGRB) has given approval for 5% blending in the first phase of the project which would be progressively increased to 20% v/v.

Due to domestic usage, there is huge variations and spikes in the Natural Gas usage during the day. To ensure safe and reliable blending of hydrogen into the PNG network, the following innovative approaches and best practices from gas industries were incorporated into the system.

1. Active and Monitor Pressure Regulators.
2. High accurate flow control valve with PID Controller.
3. Static inline mixer.
4. H2 Analysers and Gas leak detectors.

The third-party testing firm was assigned to carry out the gas composition assessment at different location of the network, deterioration of metal and non-metal components used, if any. NTPC has provided in-depth training to all stakeholders to educate them in safety aspects before commencing of the blending operation and continues to provide the same at periodic intervals. Also, periodic customer survey has conducted through third party to ascertain easiness of use and degree of assurance for their wellbeing from gas suppliers.

PNGRB is being appraised continuously on the performance of the hydrogen blending system and they have enhanced the blending level to 8% v/v.

Various measurements taken diligently demonstrates the reduction of natural gas consumption of over 3% with 8% v/v of blending ratio, in comparison to un-blended natural gas usage. This figure will reach upto 8% with 20% v/v of hydrogen blending. The reduction in CO_2 emission in cooking application with 20% v/v blending is 6 TPA in comparison to present saving of 2 TPA of 8% blending.

2. Objectives

1. Impact assessment on hydrogen blending
    a. Gas homogeneity at highest and farthest point.
    b. Adverse effect on materials (metallic and non-metallic).
2. Validation
    a. Layout design of various system.
    b. Response time of components and instruments.
    c. Tuning of control valve operation.
    d. Analysis of blending ratio at various flow levels.
    e. Risk assessment & mitigation measures.
3. Knowledge on specific safety requirements and their compliances.
4. Understanding O&M issues.
5. Competency building in engineering, execution, and O&M.
6. Understanding user's concerns and perception.
7. Cost implications.

3. Overview

1. NTPC has developed a Green Hydrogen Blending Pilot Project at its Kawas Gas and Solar station, in Surat district, Gujarat. The project is located at 20 km distance from Surat Airport and the nearest railway station is Surat at a distance of 18 km.
2. The project involves supplying blended PNG to 200 households in NTPC Kawas Township. This system is designed for upto 20 percent vol/vol hydrogen blending to 100 SCMD of PNG.
3. A gas supply agreement was signed with M/s Gujarat Gas Limited (GGL) for laying of new PNG network and supply of Piped Natural Gas to NTPC Kawas Township. Earlier residents of NTPC Kawas are using Liquified Petroleum Gas (LPG) for the domestic cooking appliances.
4. Major components of the project are Hydrogen generation system, storage system and blending skid.

Figure-1: Location of pilot project at NTPC Kawas Township

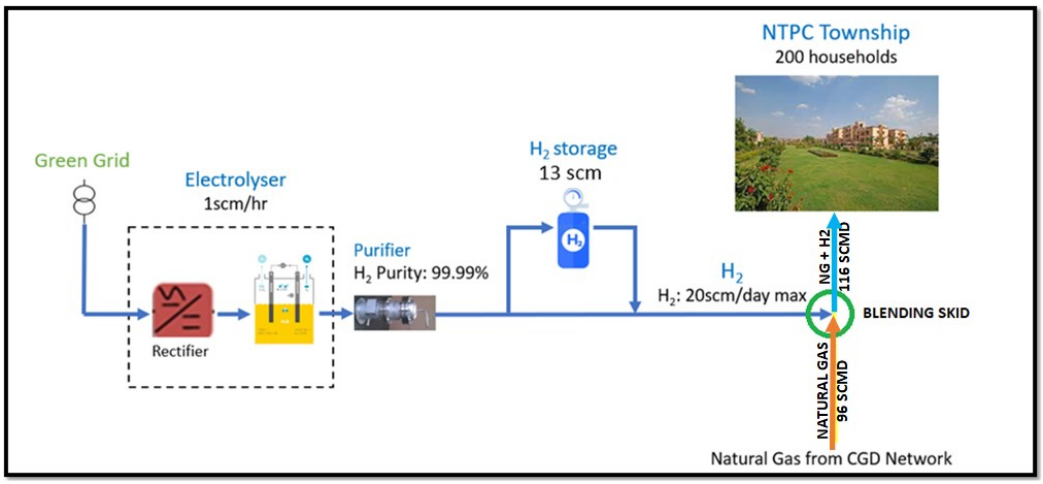


Figure-2: Scheme of the pilot project

4. Highlights

1. NTPC and Gujarat Gas Limited (GGL) inked an agreement on 05 April 2022 for the supply of Piped Natural Gas to the households of NTPC Kawas Township.

Figure-3: Signing of Gas Supply Agreement between the NTPC and GGL

2. Honourable Prime of Minister of India has laid the foundation Stone for this project on 30 Jul 2023 through virtual mode.

Figure-4: Foundation stone laid by Hon'ble PM of India

3. PNGRB has provided an approval for 5% hydrogen concentration with piped natural gas in Nov 2023.
4. NTPC has commissioned **India's first Green Hydrogen Blending Project** on 02 Jan 2023.

Figure-5: Opening of blended natural gas by HoP, NTPC Kawas

5. A third- party agency, Gujarat Energy Research Management Institute (GERMI) was engaged to carry out gas composition and material assessment in this project.
6. Obtained approval from PNGRB to increase the hydrogen concentration with natural gas from 5% v/v to 8% v/v on 03 Nov 2023.
7. Performance of the H2 blending system, third-party assessment report for 8% blending and QRA of network for 15% blending submitted to PNGRB.
8. The reduction in CO2 emission in cooking application with 8% v/v blending is 2 TPA (3%) and reduction of natural gas consumption is 3.5 scmd (3.5%).

5. Scope of NTPC and GGL

NTPC

1. Develop the Green Hydrogen Blending Project.
2. Obtain applicable approval from statutory regulator and local authorities.
3. RE power and water.
4. Land to establish of natural gas network inside the township.
5. O&M of complete hydrogen generation and blending system.
6. Safety studies for hydrogen generation and blending system.
7. Assessment of effect of blending on gas properties and degradation on components.

GGL

1. Obtain an approval from the regulator (PNGRB).
2. Establish the natural gas infrastructure.
3. Supply of piped natural gas.
4. O&M of natural gas network.
5. Safety studies for natural gas pipeline network.
6. Emission studies from cooking gas appliances as required by the regulator.

6. Project Details

6.1 Power and Water Inputs

1. Round the clock renewable power.
2. Water at a pressure of 1 bar for both hydrogen generation and cooling purposes.
3. Quantity and quality of the water as:

Flow: 1.0 kg/hr	Turbidity (NTU) – 1.8
pH – 6.75	Total Hardness (ppm as $CaCO_3$) – 140
Conductivity (µs/cm) – 630	

6.2 Natural Gas Specifications

1. Natural Gas Parameters
   a. Consumption: 100 scmd
   b. Temperature - Max 65 ^{0}C, Min 0^{0}C;
   c. Flow: 0 to 15 scmh.
   d. Pressure: 4 bar.
2. Natural Gas (NG) Composition

Typical Composition	Parameters % v/v	Typical Composition	Parameters % v/v
Methane	95.4	N_2	0.2
Ethane	3.657	CO_2	0.000025
Propane	0.534	Total	99.999425
n-Butane	0.105	GCV kcal/scm	9351
I-Butane	0.091	NCV kcal/scm	8340
n-Pentane	0.0028	Avg. Molecular Weight	16.78
i-Pentane	0.0077	Wobbe Index (MJ/scm)	48.95
C6+	0.0019		

Table 1: Natural Gas Composition

6.3 Sub System

A. Electrolyser

1. PEM 6.6 kW, 0.1 kg/hr conforming to ISO 22734:2019.
2. Purity 99.99% (impurity not more than 100 ppm).
3. 30 bar pressure.
4. Auto operation of dryers and de-oxy units.

B. Hydrogen Storage

1. Pressure Vessel (Type-1, 4*160 WL)
2. Storage capacity of 13 scm of hydrogen stored at 30 bar pressure (equivalent to 16 hours of consumption).
3. Pressure Vessel conforming to meet GCR and SMPV Rules 2016.

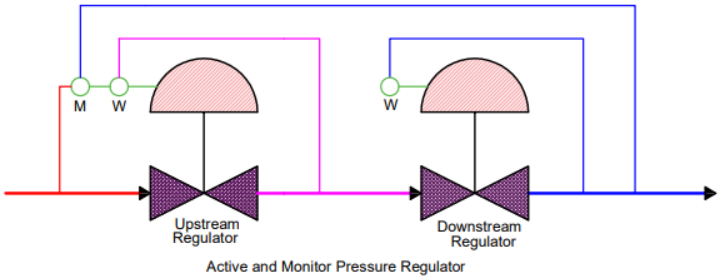
C. Hydrogen Blending Skid

1. Hydrogen at 4.5 bar is blended with natural gas at a pressure of 4 bar.
2. Feedback on hydrogen content (% by vol) in blended gas is to be calculated from volume flow of hydrogen and inlet natural gas. In case the system exceeds the set % of blending, automatic safe shutdown of the blending equipment takes place.
3. Operational definition of different blending levels:

% Blending Level	Acceptable operating range
5	3-5
10	8-10
15	13-15
20	17-19 (mixing level shall never exceed 20 %)

Table 2: Blending operation definition

4. Emergency Shut Down valve(s) are installed upstream of the pressure regulator to isolate the hydrogen and natural gas, in-case of emergency and leak detection.
5. Control logics for the isolation of hydrogen supply system in case of deviation from set purity of hydrogen.
6. Pressure control is achieved through the provision of Active and Monitor Pressure Regulator (i.e., monitor will be upstream of active regulator).



Active and Monitor Pressure Regulator

7. Mechanical shutoff valves are provided in the system to operate in-case of high pressure in the downstream.
8. In case of failure of mains power supply, safe shutdown of the blending system.
9. Entire gas from the main PE (polyethylene) pipeline (90 mm) is diverted into the blending setup through isolation valves.
10. After blending of hydrogen into natural gas at the required blending level, blended mixture is returned to the PE pipeline highlighted in yellow (figure 6).
11. Cumulative Flow meter is installed in incoming natural gas, incoming hydrogen to blending unit and the blended gas.
12. Entire blending setup is configured with bypass valve to ensure continuous supply of natural gas to consumers while undertaking maintenance on blending skid.

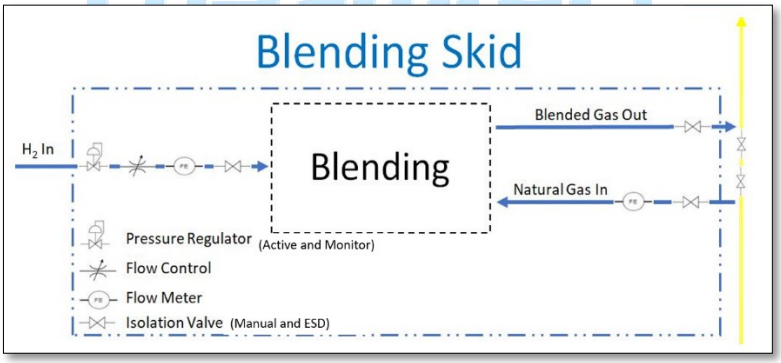


Figure-6: Schematic showing different functions.

D. Electrical

1. Electrical equipment is conforming to IS 5571:2009, “Guide for selection of Electrical Equipment for Hazardous Area”.
2. Two separate and distinct connections to earthing grid are provided for all electrical equipment operating on above 230V AC. Separate earthing grid is provided for instrument and electrical power.
3. Safe Zone and Hazardous Area is provided with appropriate lighting (flame proof).

Instrumentation and Control Systems

1. Gas (Hydrogen and Natural Gas) detectors are installed at strategic locations to detect any gas leakage.

2. Instrumentation and control system conforms to API- RP-551, 552, 554, 555 or EN 334, EN 14382.
3. System is configured to monitor (no control) remotely from any place using web interface.
4. Control system is provided with minimum 30 mins UPS backup.
5. Necessary Audio Alarm are envisaged to alert the surrounding public regarding leakage of hydrogen.
6. Data Historian are provided to store, retrieve, and analyse at least 1 year data.

Mechanical

1. N2 Purging provided to flush the H2, in-case of emergency operation.
2. Containerized solution for electrolyser, blending skid and control system is provided.
3. All butt-welding joints are radiographed for defect free erection.
4. All seamless piping is conforming to ASME B31.12, ASME B31.3 and PNGRB T4S guidelines, OISD 118, NFPA.
5. All the Safety Valves are ASME UV code stamped are sourced which require one time certification.
6. Non-return valves and isolation valves is placed appropriately to ensure natural gas doesn't leak into hydrogen supply section.
7. Appropriately placed isolation valves to ensure isolation of critical equipment in the event of malfunction or required maintenance.
8. All vents are routed to a safe area and in a manner that gas vented out is blown away from the nearest building. Height of vent is of minimum five (5) meters above ground level. Flame arrestor is installed in all venting points.
9. Welded joints and fittings are used and flanged joints are minimized and used only where absolutely necessary.
10. Appropriate pressure tests and flushing procedures is carried out at site after integration of all equipment before commissioning.
11. Emergency pushbuttons and Safety banner, emergency operation instructions are provided at all locations for the safe operation of the plant.
12. Fire extinguishers (4x10 kg of DCP and 2x9 kg of CO_2) are provided at suitable locations as suggested by gas operator.

Civil

1. Crash Guards are installed at the suitable locations in the project.
2. Gravel base is provided to avoid weed growth.
3. Facility is provided with proper security fencing and access gate(s).

7. Process Description

Power from nearby 1MW floating solar is rectified to DC power and DM Water is fed into electrolyser for the generation of hydrogen. Generated hydrogen is stored into the cylinders and also fed directly into the blending skid. Based on the natural gas flow and preset blending level, the hydrogen gas is blended into the piped natural gas.

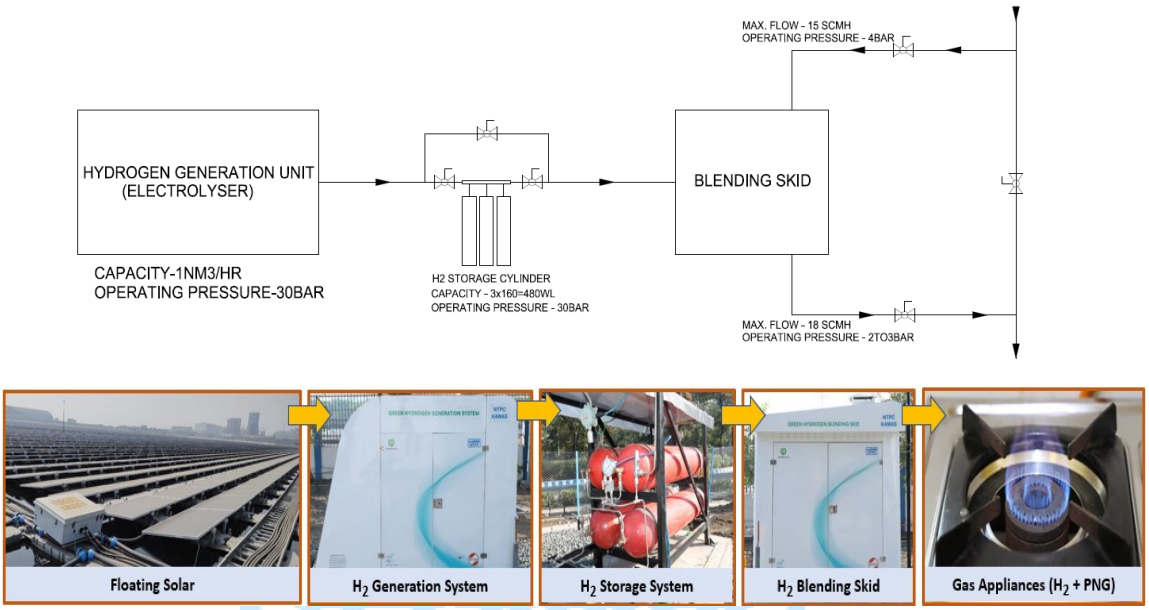


Figure-7: Block Diagram of the Hydrogen Blending System

7.1 H2 Generation Unit - PEM Electrolyser

1. DC power provided to the Electrolyser Stack through the Rectifier (CC/CV mode).
2. DM water of 0.5 µs/cm is produced from the incoming raw water and stored it in the DM water tank.
3. DM water and DC power is fed into electrolyser stack to produce hydrogen and oxygen. The produce hydrogen is fully saturated and contains some PPM oxygen.
4. Hydrogen is passed through the separator where the free liquid is be removed.
5. Hydrogen is then passed through the palladium catalyst for removal of oxygen and then passed through the air-cooled radiator to maintain the temperature.
6. Next, hydrogen is passed through regenerative dryer unit to remove the moisture content.
7. Hydrogen dew point and purity is measured continuously. In-case purity or moisture is beyond the limit, then hydrogen is be vented into atmosphere safely.

8. H2 Gas detector is placed at appropriate location to detect any leakage and generate alarm/shutdown the system. Alarm at 20% LEL of H2 and shutdown of complete system at 40% LEL of H2.

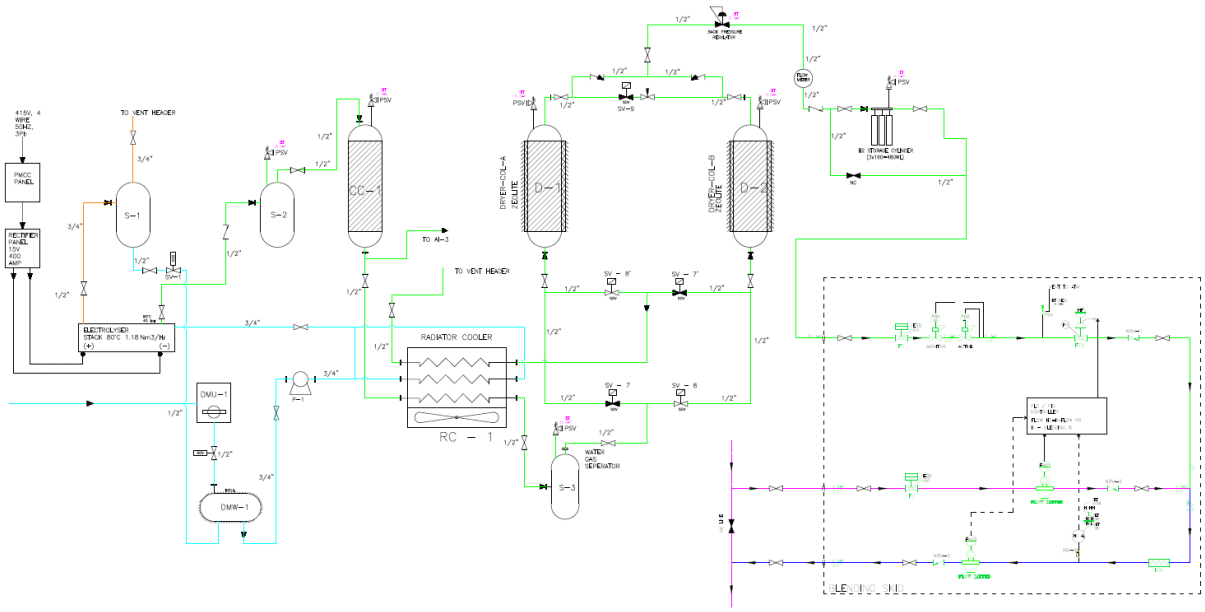


Figure-8: Process Flow Diagram of the Hydrogen Blending System

7.2 H2 Blending Skid

1. Blending skid receives natural gas from the piped natural gas network and hydrogen from the storage cylinder. Then hydrogen is blended with natural gas of pre-set blending level and blended gas line is connected back to PNG network.
2. In the NG and H2 line flow meter, pressure transmitter & temperature transmitter is placed, and inputs are provided to the PLC system.
3. Based on the inputs from NG Flow meter and preset blending ratio, output of the PID controller decides opening position of the control valve.
4. Active & Monitor pressure regulator is placed in the H2 line for pressure control.
5. For enhanced blending the blended gas is passed through the static mixture.
6. After the blending a hydrogen analyser will check the correctness of the blending ratio. In case of any variation in H2 % from the set higher and lower limits, alarm is be generated and further if the variations exceed the set higher threshold value system will shut down.
7. H2 and hydrocarbon gas detector is placed at appropriate location to detect any leakage and generate alarm/shutdown the system. Alarm at 20% LEL of H2/hydrocarbon and shutdown of the system at 40% LEL of H2/hydrocarbon
8. In case of any abnormalities in the process parameters like pressure, temperature, blending ratio etc, alarm is generated, and system will be shut down if the value increases beyond the set threshold value.

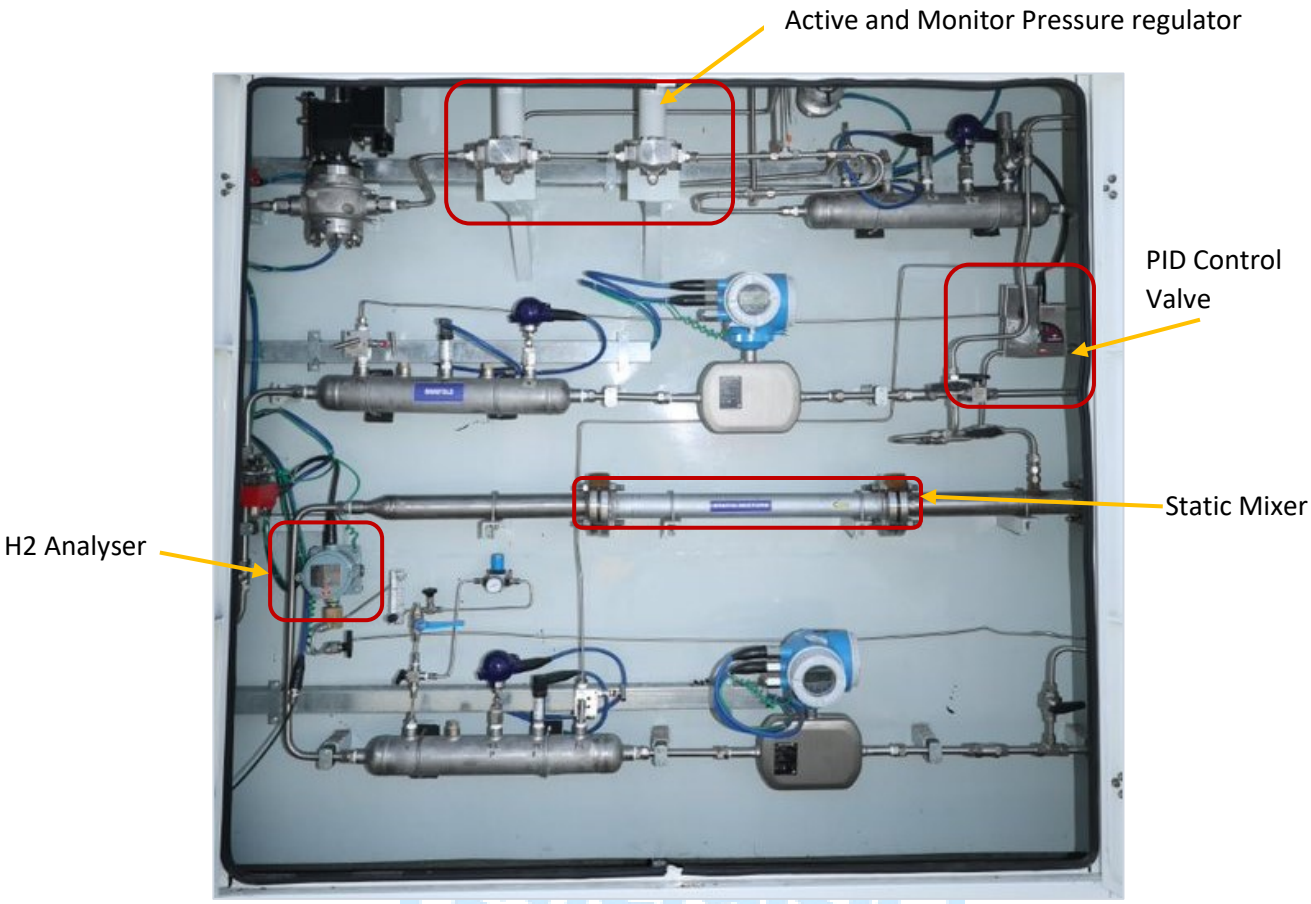


Figure-9 View of Hydrogen Blending Skid (2m x 2m)

8. Safety Provisions:

8.1 Safety System

1. Active and Monitor Pressure regulator.
2. Analyser for continuous detection of H2 purity.
3. Control system provided with minimum 30 mins. power backup.
4. Accuracy of measuring instruments and control elements is 1% of better.
5. Emergency Shutdown for overpressure, leakages and power failure.
6. Online analyser (H2, NG, and blended gas) for feedback control & protection.

8.2 Leakage Mitigation

1. Audio alarm incorporated for alerting public (in-case of H2 leakage).
2. Gas detectors for H2 and NG at strategic locations to detect any gas leakages.
3. Flame arrester in all venting points.

8.3 Standard Compliance

1. Pressure Vessel: SMPV Rules, 2016 and GCR, 2016.
2. Piping:
    a. Layout – OISD 118.
    b. H2-ASME B31.12, NFPA2 and NG-ASME B31.3, PNGRB T4S Guidelines.
3. Electrical Equip. for Hazardous Area: IS 5571:2009, Earthing: IS 3043:2018.
4. Instruments & Control System: API RP–551, 552, 554, 555 and EN 334, EN 14382.
5. Safety Valves: ASME UV stamped.
6. PESO (Exempted due to low volume of storage as per Gas Cylinder Rules, 2016).

8.4 Safety Studies

1. Hydrogen Generation and Blending System Facility
    a. Hazard Operability (HAZOP) - M/s Nachiket Enterprise
    b. Quantitative Risk Assessment (QRA) - M/s DNV
    c. Hazardous Area Classification (HAC) - M/s DNV
    d. Escape Muster Evacuation and Rescue Analysis (EMERA) - M/s DNV
2. Natural Gas Pipeline Network
    a. QRA - M/s Bureau Veritas - (upto 10% H2 Blending) in Oct 2023
    b. QRA - M/s Bureau Veritas - (upto 15% H2 Blending) in May 2024

9. Performance of Blending System:

9.1 Hydrogen Blending Performance

1. 5% v/v Hydrogen pre-set blending level

Year	Month	Avg. blending level (% v/v)
2023	Jan	3.76[1]
	Feb	4.19
	Mar	4.31
	Apr	4.34
	May	4.34
	Jun	4.30
	Jul	4.30
	Aug	4.19
	Sep	4.23
	Oct	4.28
	Nov	4.25

2. 8% v/v Hydrogen pre-set blending level

Year	Month	Avg. blending level (% v/v)
2023	Dec	7.56
2024	Jan	7.48
	Feb	7.43
	Mar	7.34
	Apr	6.96

3. Monthly Flow details

Monthly Details	Monthly Avg. till Dec, 2023	Monthly Avg. after Dec, 2023
NG Flow (scm)	1000	1100
H2 blended NG flow (scm)	40	87
Avg. blending (% v/v)	4.4	7.6

[1] The customers on this blended network were very few in the starting month of commissioning leading to low consumption of Natural Gas. As per blending system protection measures if Natural Gas flow is less than 1.5 scmh in the network, hydrogen blending is stopped and only natural gas flow is established. This led to flow of Hydrogen only when it crossed the threshold of 1.5 SCMH, hence low blending percentage.

9.2 Leak Detection Testing of PNG network

1. Leak Detection is carried out for Low pressure (110 mbar) PNG network at on every month basis by using combination of Lock pressure Test (LPT) and Leak Detection Testing (LDT) techniques.
2. Till date only one minor leakage was identified in one fitting on 04/02/2023 and same was rectified.

9.3 Gas Composition and Burner testing network

1. Establishment of stagnant network and riser pipeline.

Figure-10: Stagnant PNG pipeline at nearby by building

2. A tapping was taken from low pressure PE line for around 70 meters to the nearest building (with no customer)
3. Testing riser of GI piping was installed on this 2-storey building with regulator and two termination, top & bottom. Sample are collected from both points & tested in lab to verify gas analyser reading & also to establish any change in homogeneity for stagnant gas.

Figure-11: Stagnant riser pipelines and tapping points

4. Blended gas was allowed to line pack the tapping line and dummy riser, then samples taken.
    a. 5% of H2 in the blended gas, same was verified from the sample taken from testing riser: Results 4.82% and 4.96% at bottom & top respectively.
    b. 8% of H2 in the blended gas, same is verified from the sample taken from testing riser: Results 7.87% & 7.82% at bottom & top respectively.

5. Burner is connected to both points of riser termination
    a. 5% of H2 in the blended gas: Normal flame behaviour observed
    b. 8% of H2 in the blended gas: Normal flame behaviour observed
6. Blended gas was packed into tapping line and dummy riser and was isolated for 48 hours to check change inhomogeneity
    a. 5% of H2 in the blended gas, same was verified from the sample taken from testing riser: Results 4.75% & 4.96% at bottom & top respectively.
    b. 8% of H2 in the blended gas, stagnant sample taken from testing riser: Results 7.79% & 7.72% at bottom & top respectively.

The above assessment has been carried out at each level of blending ration (5% and 8% v/v) separately before charging the blended gas into the PNG network.

9.4 Operational efficiency of Instruments and valves

In a day, there will be huge flow variation in the PNG network for domestic application due to intermediate usage of cooking i.e., morning, afternoon and night.

Sometimes very minimum flow of natural gas take place in the gas network for which flow measurement and control valve operation shall be very accurate and fast acting.

Operation of blending system with reference to natural gas flow and maintaining pre-set blending level within limits for typical day is shown below.

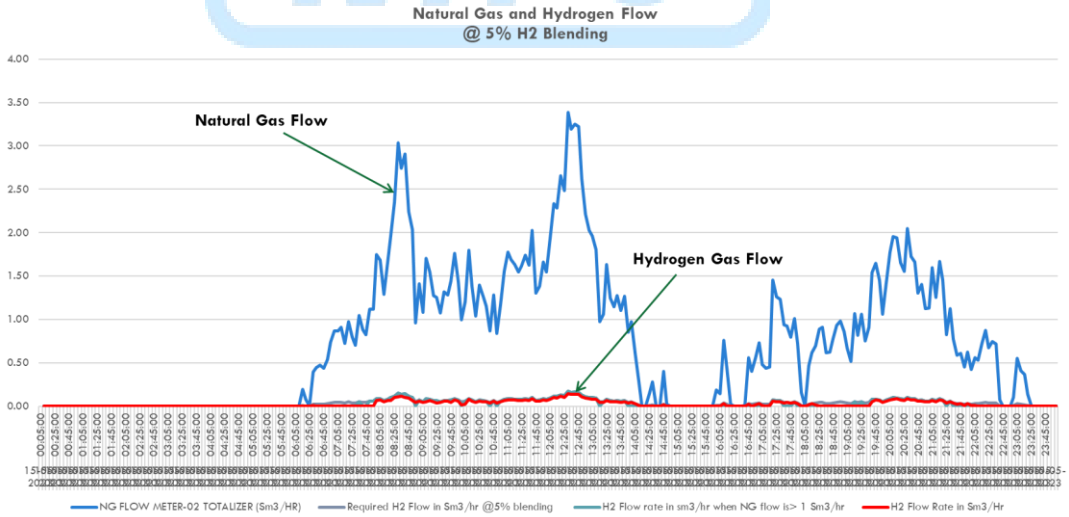


Figure-12: Representative flow of natural gas and hydrogen

10. Third Party engagement for assessment, training and outcomes

The objective of this assessments is to perform various testing on the PNG network, gas composition, conducting surveys for designing and developing a safe, reliable, and compatible hydrogen blending system for different blending pre-set ratio for PNG Network and educating various stakeholders on hydrogen blending system.

This assessment is carried out for different blending pre-set ratio at various interval (daily, weekly, fortnightly, monthly).

10.1 Gas Composition Assessment

1. Gas Analysis for its homogeneity with regards to Hydrogen and Natural Gas
    i. Monthly periodicity.
    ii. Three gas samples taken from
        1. blending skid.
        2. highest point (two floor).
        3. farthest house of the PNG network.
2. Quantity of injection of odorous agent (mercaptan) at 5%, 10%, 15% and 20% blending ratio to keep mercaptan concentration same.
    i. Once in a week for 4 weeks for each level of blending.
    ii. Assessment for the concentration of mercaptan carried out in each level blending percentage, what is the concentration level of mercaptan.

10.2 Material Assessment

Every 3 months (samples of PE and GI items for exposure of blended natural gas)

i. Microscopic assessment of materials used in PNG network, both PE and GI
ii. Thickness survey and corrosion mapping of materials or pipeline
iii. Adverse effect on sealing components, rubber used in PNG network.
iv. Destructive testing on specimen of various pipelines, fittings etc., to understand the Mechanical and chemical properties.
v. Adverse effect on burners in gas stoves.

10.3 Stakeholder Education and Training

1. Educating prospective user on blending covering different section of NTPC employees, wards and dependents of employee, other occupants of township on hydrogen gas, blending system, first aid etc.,
2. Development of various modules required for educating all stakeholders.

10.4 Customer Perception Survey

Conducting customer perception studies for minimum same 25 households every three months

1. Heating performance wrt cooking time.
2. Gas flow sound during cooking
3. Flame ignition ease
4. Flame visibility
5. Flame stability/flickering
6. Normal gas smell
7. Emergency contact details

10.5 Assessment outcomes

A. Gas Composition

1. 5% v/v Hydrogen blending with PNG (in avg.)
    i. Blending skid -4.82%; Highest Point –4.65%; Farthest Point –4.76%

2. 8% v/v Hydrogen blending with PNG
    i. Blending skid -7.77%; Highest Point –7.6%; Farthest Point –7.71%
    ii. Additional Samples
        1. Domestic connections during peak hours of flow – 7.96% v/v.
        2. Commercial connection during peak hours of flow – 7.71% v/v.

Figure-13: Gas Sample collection from the blending skid

B. Odourant Dilution[2]

[2] Odourant gas level variation can be due to change in the injection level at source.

1. 5% v/v Hydrogen blending with PNG at Blending skid – 2.2, 2.3, 2.4 PPM
2. 8% v/v Hydrogen blending with PNG at Blending skid – 3.0, 4.2, 3.2 PPM

Figure-14: Odourant gas analysis

C. Materials Assessment

1. Assessment is carried out for every 3 months.
2. Samples Collected: PE pipe, GI pipe, burner, rubber items etc.,
3. Exposure: 18 months of exposure to blended gas
    i. 5% v/v. - 11 months
    ii. 8% v/v. - 6+ months

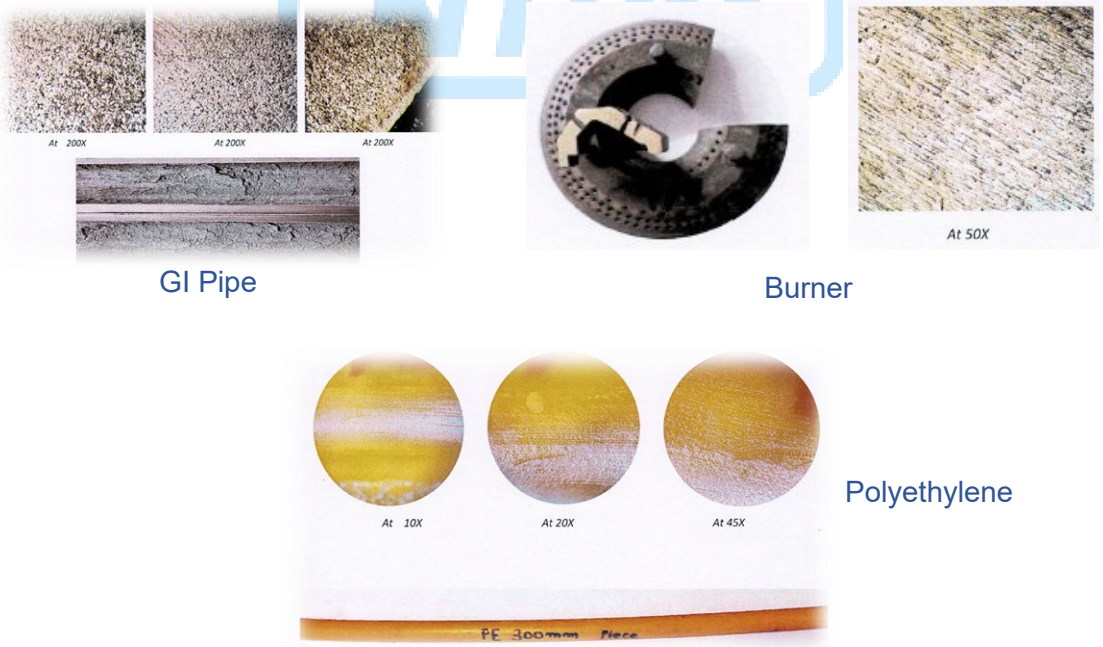


Figure-15: Microscopic examination of different materials

4. Results : No variations or adverse effects

Material	Test / Analysis	Inference

Galvanised pipe	Composition	No variation
	Tensile test	No variation
	Corrosion mapping	No adverse effects
	Macro structure	No discontinuity
Rubber seal	Compatibility test	No adverse effects
Burner	Macro structure	No discontinuity
Polyethylene pipe	Corrosion mapping	No adverse effects
	Macrostructure	No discontinuity

D. Customer Perception Survey

1. Survey is conducted for every 3 months.
2. Samples: 25 numbers of residential customers are surveyed.

The summarized results of survey along with corrective actions taken are:

1. Heating performance w.r.t cooking – almost all were found satisfied
2. Any gas flow sound during cooking – almost all reported no sound
3. Flame ignition ease during starting – maximum found it normal
4. Flame visibility in gas appliance – all found it normal (blue)
5. Flame stability during cooking – almost all reported normal
6. Gas smell / concentration adequacy – maximum reported normal, checked at burner in case of issue and found in order
7. Actions in case of gas leakage – all of them responded by either turning off the gas supply, open door/window, call emergency no. etc.
8. Awareness of emergency contact details – majority were found aware, checklist along with emergency contact details were shared

Figure-16: Customer perception survey at residential connections

E. Awareness Training Sessions

Conducted for residents of NTPC township covering following key aspects:

1. Natural Gas – Properties and its advantages
2. Hydrogen Gas properties
3. Project about H2 blending in Natural Gas
4. Advantages of the blending project
5. Hazards related to Natural Gas & Hydrogen
6. Brief on Testing carried out for this project
7. Flame behavior of NG & H2 at different blending %
8. Do's & Don't for PNG connections
9. Sharing of emergency contact details
10. Customer Service-related information

Figure-17: Awareness session and training program

11. Project Management

Sl. No.	Work Description	Start	Finish	Period	02-06-22	09-06-22	16-06-22	23-06-22	30-06-22	07-07-22	14-07-22	21-07-22	28-07-22	04-08-22	11-08-22	18-08-22	25-08-22	01-09-22	08-09-22	15-09-22	22-09-22	29-09-22	06-10-22	13-10-22	20-10-22	27-10-22	03-11-22	10-11-22	17-11-22	24-11-22	01-12-22	08-12-22	15-12-22	22-12-22	29-12-22	05-01-23
					WK-1	WK-2	WK-3	WK-4	WK-5	WK-6	WK-7	WK-8	WK-9	WK-10	WK-11	WK-12	WK-13	WK-14	WK-15	WK-16	WK-17	WK-18	WK-19	WK-20	WK-21	WK-22	WK-23	WK-24	WK-25	WK-26	WK-27	WK-28	WK-29	WK-30	WK-31	WK-32
1	Layout and PI&D	10-06-2022	08-08-2022	59																															
2	HAZOP for blending and PNG network	28-06-2022	08-08-2022	41																															
3	QRA, HAC, EMERA studies	12-08-2022	26-08-2022	14																															
4	Geotech work on identified Site	29-08-2022	02-09-2022	4																															
5	Approval from regulator (PNGRB)	09-09-2022	19-09-2022	10																															
6	Installation of PNG header and gas network	22-08-2022	15-10-2022	54																															
7	Civil Work	20-09-2022	10-12-2022	81																															
8	Fabrication at OEM works	01-10-2022	20-11-2022	50																															
9	Transportation of equiments and materials to NTPC Kawas	20-11-2022	25-11-2022	5																															
10	Erection work of H2 blending system	25-11-2022	15-12-2022	20																															
11	Interconnection to GGL CGD network for PNG connections	10-12-2022	12-12-2022	2																															
12	Commissioning, Testing of PNG connection to Households	20-10-2022	28-10-2022	8																															
13	Commissioning, Testing of H2 Blending System	15-11-2022	30-12-2022	45																															
14	Connecting H2 blending system with PNG network	12-12-2022	28-12-2022	16																															
15	Trial Operation of H2 Blending System	02-01-2023	02-01-2023	1																															
16	Start of PNG flow to households	02-01-2023	02-01-2023	1																															

Table 5: Project activities of hydrogen blending system and PNG connections

12. Economics

Monthly spending on cooking gas cost comparison of individual household for different fuel source like LPG, PNG and hydrogen blended PNG of this pilot project is provided below.

Blending %	Spending on LPG (1)	PNG flow	Spending on PNG (2)	H2 Flow	Spending on H2 (3)	Cost of Blended PNG (4) = (2) + (3)	Benefit of using blended PNG over LPG (1)-(4)
	₹/month	scm/month	₹/month	scm/month	₹/month	₹	₹
0%H2	954	15	795	0	0	795	159
5%H2	954	14.7	779	0.9	111	890	64
10%H2	954	14.4	763	1.5	185	949	6
15% H2	954	14.1	747	2.4	296	1044	-90
20%H2	954	13.8	731	3.6	445	1176	-222

Assumptions

a. LPG Calorific Value, kcal/kg – 10960.
b. LPG cylinder cost (Kawas) - ₹ 1100/-
c. PNG Calorific Value, kcal/kg – 9000.
d. PNG cylinder cost - ₹ 53/scm.
e. Energy consumption – 60 kWhr/kg of hydrogen.

Note:

In this pilot project, investment on the electrolyser is alone half of the total cost of the project. which is very high. Due to this, cost of green hydrogen is very high which increased the cost of blended natural gas.

Typically blending project feeding to a regular GA, the cost of hydrogen would be less than one third of the hydrogen cost of this pilot project.

13. Conclusion

This pilot project is operating successfully for more than 18 months with all precautions and regulatory guideline compliances. Till date, it has been demonstrated that hydrogen blending upto 8% v/v is possible without any changes in the gas network.

Conclusions from extensive testing during pilot project operations are the following.

1. present natural gas network is safe in all aspects whilst operating with a blended gas of upto 8% v/v of hydrogen.
2. No material degradation or damages related issues has been observed wrt pipeline network both for above the ground GI pipes and underground MDPE pipeline.
3. Adverse effect on cooking stove burner material is absent.
4. No gas in-homogeneity and odourant dilution related issues have been reported.
5. Households are at ease in using blended PNG for cooking applications as no change in cooking time, paleness in flame, flame stability etc.,
6. Enhancing the knowledge base of the customer is important and their support is immense in implementing this project.
7. For a present pilot project, the operational cost of blending hydrogen seems to be in a higher side. For a regular GA, the cost of hydrogen would be ₹400/kg which reduces the cost blended hydrogen. So that, it remains economical at all range of blending levels.

Based on data and experience from this pilot project, the following are recommended.

1. For a PNG connection, hydrogen blending upto 8% v/v can be implemented without any additional modifications.
2. Augmenting a blending skid to the existing PNG network requires minimum space and investment.
3. High degree of automation in operation can be achieved requiring minimal manual intervention.
4. Instead of retrofitting the existing LPG stove for piped natural gas usage, a specially designed cooking stove for PNG connection be used. These offer more thermal efficiency and helps to reduce natural gas consumption. This cooking stove are recently introduced in the market with ISI mark.
5. Energy intensive industries like refineries, glass and steel industries can incorporate the hydrogen blending system with least change in the existing system.

With the positive results obtained so far, NTPC is hopeful of completing the pilot project with 20% v/v blending.

At present, there is a restriction of 2% v/v hydrogen content in the natural gas in the CNG network because of storage cylinder material restrictions. Considering the present natural gas consumption of India in CGD[3] network of 35 MMSCMD, the reduction in natural gas

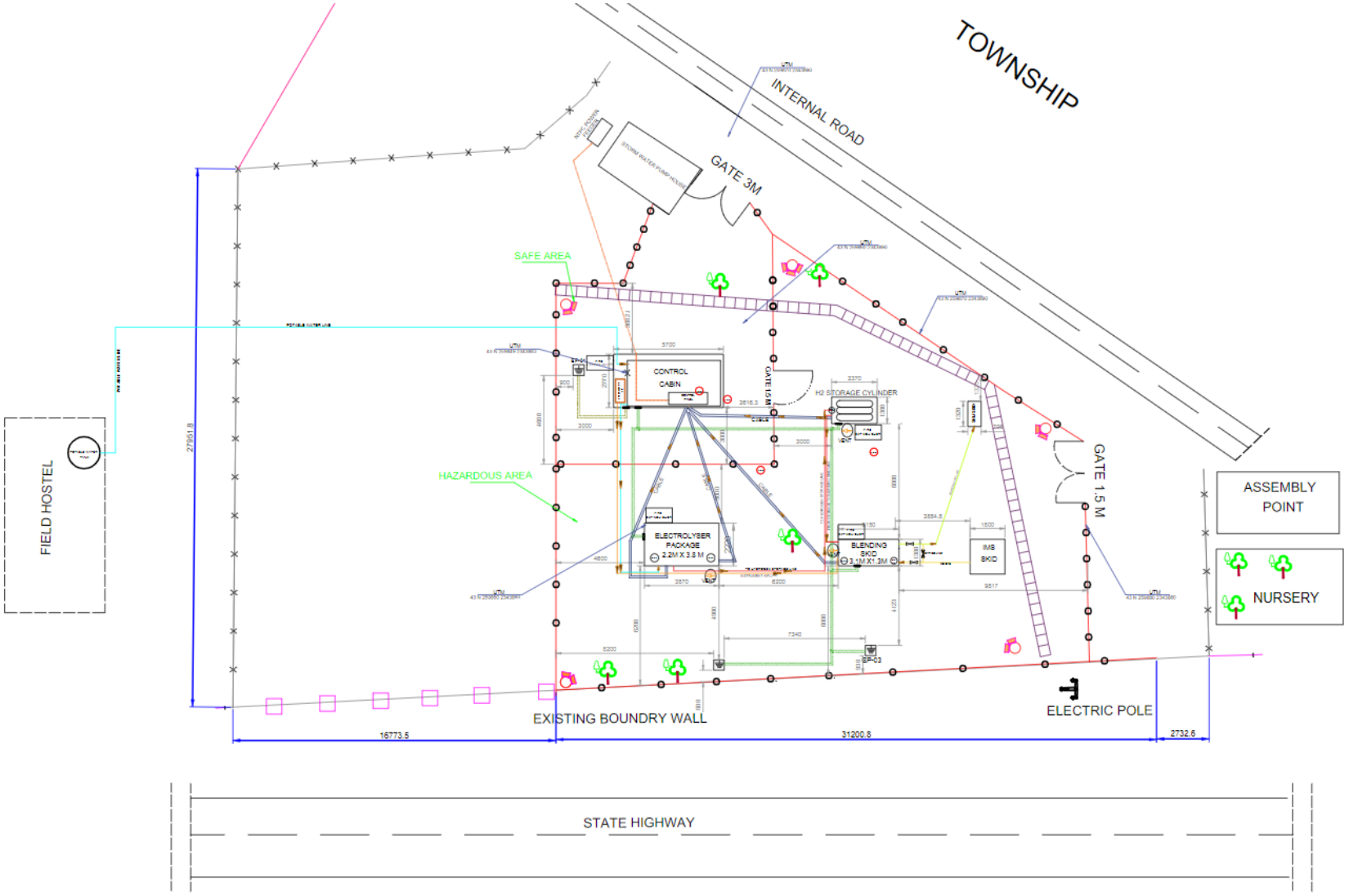
[3] CGD refers to City Gas Distribution system which is combination of PNG and CNG. PNG is for domestic and industrial heating uses while CNG is for transportation use. In India more than 42 % users are in the PNG category.

consumptions with 2% v/v hydrogen blending is 0.25 MMSCMD and the carbon mitigation potential is 0.2 MMTPA. Also, the cost increases marginally to the tune of merely 1.5% of existing ones.

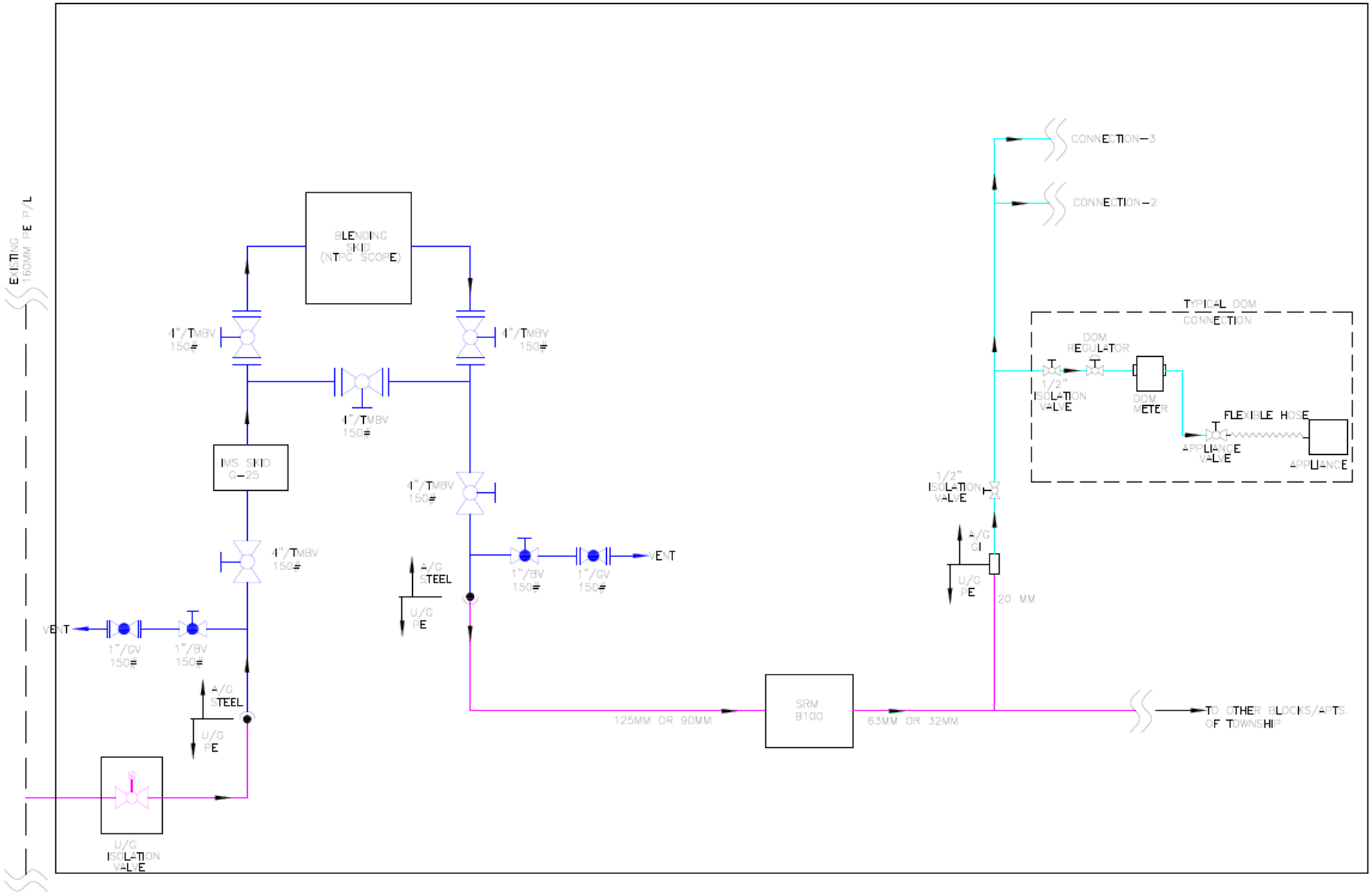
With the sound engineering configuration developed for this NTPC Kawas project, the same can be readily adopted by other gas operators with minimal changes to have the quicker adoption across the countries.

In India, when this is adapted in mass scale significant import substitution with minimal cost implication to the consumers can be achieved.

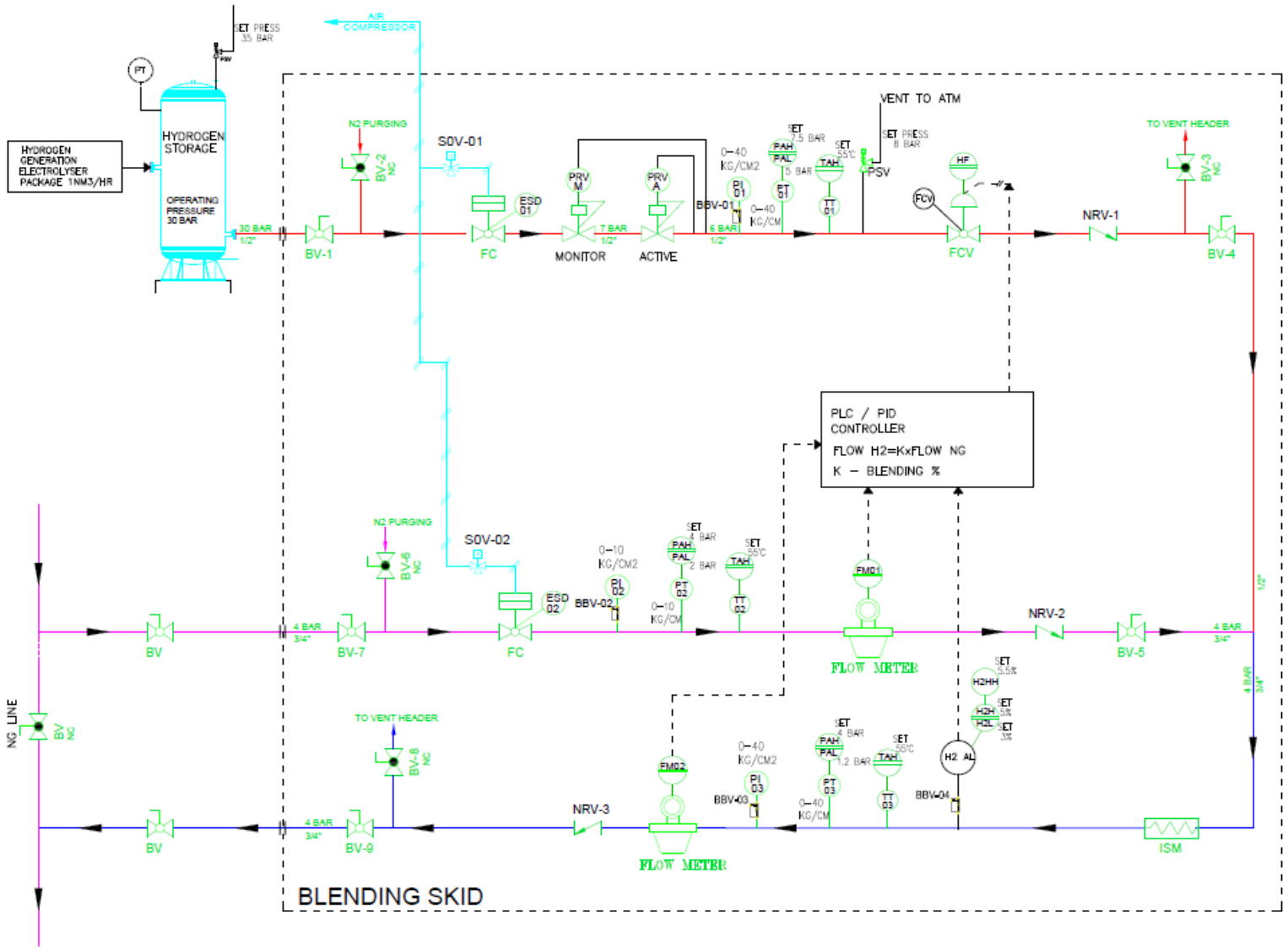
Annexure-I Overall Plant Layout



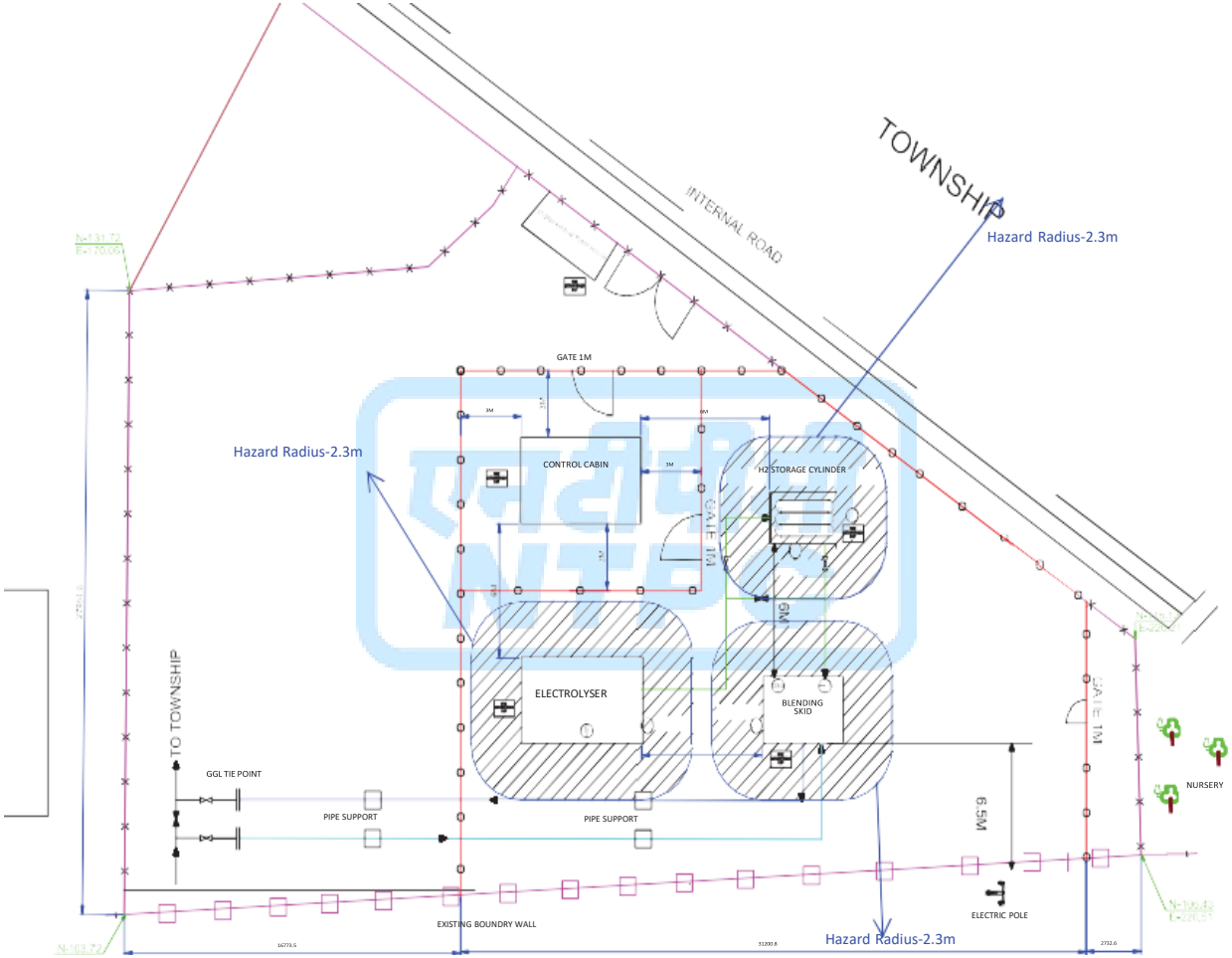
Annexure-II PI&D of Hydrogen Blending PNG Network



Annexure-III PI&D of Hydrogen Blending Skid



Annexure-IV Hazardous Area Classification (HAC) Study



Outcomes

1. Hazardous Area Classification for the complete setup based on the vent hydrogen dispersion analysis.
2. Hatched area identified as hazardous zone, it shall use the hazardous area compliant equipment and restricted personnel access.

Risk contours for hydrogen blending terminal

Outcomes

1. Individual risks per annum (IRPA) for workers in the facility is in acceptable region.
2. Location specific onsite and offsite risks due to jet fire and explosion is minimal.
3. Risk is at highest in the centre (dark red) and minimal at outer (yellow).

Annexure-VI International Experiences in Hydrogen Blending

Globally few countries like UK, Germany, US, Australia have tried blending at various level of blending ratios. In Australia, HyPSA-Hydrogen project currently in operation with 5% v/v of hydrogen blending. In UK, HyDeploy projects at Keele University and Winlaton has carried out hydrogen blending at 20% v/v and found no impact in the gas networks. In Germany, Erftstadt Hydrogen project has demonstrated hydrogen blending upto 20% v/v and found no problems with residential gas appliances.

In India, GAIL has initiated blending at Indore city (MP) and few like OIL, Adani and Torrent have announced their intentions to do so.

Annexure-VII

STANDARD SCOPE OF WORK
AND
TECHNICAL SPECIFICATIONS

Contents

ABBREVIATIONS

AC	Alternating Current
ACB	Air blast Circuit Breaker
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ATEX	ATmosphère Explosible
ATS	Automatic Transfer Switch
BASEEFA	British Approval Service for Electrical Equipment in Flammable Atmospheres
BESS	Battery Energy Storage System
BMS	Battery Management System
BPV	Boiler Pressure Vessel
BS	British Standard
CBCT	Core Balancing Current Transformer
CCoE	Chief Controller of Explosives, PESO
CCTV	Closed Circuit Television
CEA	Central Electricity Authority
CENELEC	European Committee for Electrotechnical Standardization
CGA	Compressed Gas Association
CIMFR	Central Institute of Mining and Fuel Research
CPWD	Central Public Works Department
CSIR	Council of Scientific and Industrial Research
DC	Direct Current
DCP	Dry Chemical Powder
DIN	Deutsches Institut für Normung
DM Water	Demineralised Water
DMP	Disaster Management Plan
DMR	Double Modular Redundancy
EC	European Regulation
ECBC	Energy Conservation Building Code
ELCB	Earth Leakage Circuit Breakers
ELR	Earth Leakage Relay
EMC	Electromagnetic compatibility
EMERA	Escape Muster and Emergency Response Analysis
EMS	Electrical Management System
EN	European Norms
EPC	Engineering, Procurement, and Construction
ERTL	Electronics Regional Test Laboratory
ESD	Emergency Shutdown Device
EWS	Engineering Workstation
FBT	Fast bus transfer
FCEV	Fuel Cell Electric Vehicle
FFL	Finished Floor Level

FM	Factory Mutual Laboratories
FRLS	Fire Retardant and Low Smoke
GC	Gas Chromatograph
GUI	Graphical User Interface
H2	Hydrogen
HAC	Hazardous area classification
HART	Highway Addressable Remote Transducer
HAZOP	Hazard and Operability
HIRA	Hazard Identification and Risk Assessment
HMI	Human machine interface
HT	High Tension
HTFS	Heat transfer fluids
HTRI	Heat Transfer Research, Inc
HVAC	Heating Ventilation and Air Conditioning
ICS	Integrated Control System
ICS	Integrated Control System
IEC	International Electrotechnical Commission
IECEx	International Electrotechnical Commission Explosive
IEEE	Institute of Electrical and Electronics Engineers
IMD	Indian Meteorological Department
IP	Ingress Protection
IS	Indian Standard
IS	Intrinsically Safe
ISA	International Society of Automation
ISO	International Organisation for Standards
LAN	Local Area Network
LCD	Liquid Crystal Display
LCIE	Laboratoire Central Industries Electriques
LED	Light Emitting Diode
LEL	Lower Explosive Limits
LOTO	Lock Out Tag Out
LT	Low Tension
MCB	Miniature Circuits Breakers
MCC	Motor Control Cubicle
MCCB	Moulded Case Circuit Breaker
MSDS	Material Safety Data Sheet
NBC	National Building Code
NDE	Non-Destructive Examination
NDT	Non-Destructive Testing
NFPA	National Fire Protection Association
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
OISD	Oil Industry Standards Directorate
OPC	Optical portable communication
OPC	Ordinary Portland Cement
OPEX	Operational Expenditure

OWS	Operator Workstation
PAM	Personnel Area Monitor
PBG	Performance Bank Guarantee
PCC	Point of common coupling
PEB	Pre-Engineered Building
PESO	Petroleum and Explosive Safety Organisation
PG	Performance Guarantee
PLC	Programmable Logic Controller
PNGRB	Petroleum and Natural Gas Regulatory Board
PSA	Pressure Swing Absorption
PSU	Power Supply Unit
PTR	Performance Track Record
PVT	Production Validation Test
PWHT	Post Weld Heat Treatment
QMR	Quadruple Modular Redundancy
QRA	Quantitative Risk Assessment
RE	Renewable Energy
RMU	Ring Main Unit
RO	Reverse Osmosis
RS	Raman Spectrometry
RTC	Round the clock
SCADA	Supervisory Control And Data Acquisition
SCVS	Servo Controlled Voltage Stabilizer
SIL	Safety Integrity Level
SIS	Safety Instrumented System
SMART	Specific, Measurable, Achievable, Relevant, Time-bound
SMPV	Static and Mobile Pressure Vessel
SPD	Surge Protection Device
SS	Stainless Steel
SSD	Solid State Drive
	Technical Standards and Specifications including Safety Standards
TCP/IP	Transmission Control Protocol/Internet Protocol
TEMA	Tubular Exchanger Manufacturers Association
TMR	Triple Modular Redundancy
TMS	Thermal Management System
UL	Underwriter Laboratory
UPS	Un-interrupted Power Supply
VFD	Variable Frequency Drive
WL	Water Liters
XLPE	Cross Linked Polyethylene
ZLD	Zero Liquid Discharge

A. PROJECT INFORMATION

1. Introduction

COMPANY_____ intends to setup green hydrogen blending project at LOCATION_____, India. It is intended to blend upto ____% v/v of hydrogen along with in-situ generation[1] or external sourcing of _____kg/day of green hydrogen. It shall have a dedicated facility for Hydrogen Generation, Compression, Storage, Blending system and other allied works.

2. Location

The locational details of the proposed project site are as indicated below:

Latitude	…. ^{0} ….' …. "N
Longitude	…. ^{0} ….' …."E
Height above mean sea level	….. m
Seismic Zone	…….
Distance from ……town	……. km
Distance from national highway No. …….	……. km
Distance from state highway No. …….	……. km
Distance of nearest airport …….	……. km
Distance of nearest seaport …….	……. km
Distance of nearest railway station …….	……. km

3. Climatological Data

Highest temperature reaches in last decade	……. (^{0}C)
Lowest temperature reaches in last decade	……. (^{0}C)
Relative Humidity: Maximum Minimum	……. % ……. %
Heaviest rainfall in 24 hours so far	……. cm
Maximum wind speed	……. km/h

Design ambient temperature[2] (unless specified otherwise)	___^{0}C to ___^{0}C
Wind Rose diagram of the location shall be provided by owner.	

[1] Owner can provide the requirement of electrolyser system, in-case of setting up of in-situ generation. Otherwise, details of the existing hydrogen generation/availability can be mentioned along with integration.

[2] Owner can decide the design temperature based on the highest and lowest temperature with safety margin by considering the future requirement.

4. Near vicinity building and infrastructure

Owner shall provide the details of important buildings, educational institutions, health care facilities, place of worship etc.,

Nearest Hospital..... ..... km

Nearest School/College .... km

Nearest Shopping Mall .... km

Nearest Religious Places..... ..... km

B. SCOPE OF WORK

1. Intent of Specification

1.1 This specification is intended to cover the activities and services in respect of the execution of complete Hydrogen Blending Project, from electrolyser to blending skid (along with storage) for _____, India.

1.2 It is not the intent to specify completely all aspects of design and construction. Nevertheless, the equipment and civil works must conform to high standards of engineering, design and workmanship and shall be capable of performing continuous operation, in a manner acceptable to the Owner, who will interpret the meaning of the specification, drawings. Also, the Owner shall have a right to reject or accept any work or material which in his assessment is not adequate to meet the requirements of this specification and/or applicable Indian/International standards mentioned elsewhere in the specification.

1.3 Bidder is required to carefully examine and understand the specifications and seek clarifications, if required, to ensure that they have understood the specifications. The Bidder's offer should not carry any sections like clarifications, interpretations and/or assumptions. However, if the Bidder feels that, in his opinion, certain features brought out in his offer are superior to what has been specified, the same maybe highlighted separately. The interpretation of Owner in respect of the scope, details and services to be performed by the Bidder shall be binding unless specifically clarified otherwise by the Owner in writing. Therefore, Bidder is advised to seek all such clarifications as required by him, prior to submitting of the techno-commercial bid proposal.

1.4 Where-ever the national and international standards are mentioned, the latest standard version with its amendments is applicable.

2. Design Requirements

a. Facilitate inspection, cleaning and maintenance with the care to safety in operation and personnel protection.
b. Minimize turnaround times.
c. Provide safety, reliability and flexibility of service.
d. Adequate provision for future expansion and modification.
e. Maximum interchangeability of equipment.
f. Desired level of operator interface to achieve co-ordinated efficient and failsafe operation, data logging and maintenance of the equipment.
g. Minimize fire risk.
h. Automatic protection of all mechanical and electrical equipment's.
i. Equipment and machinery within the design operating limits.
j. Adequate provision for future extension and modification.
k. Suitability for applicable environmental factors.
l. Equipment with adequate capacity.
m. Control and indication.
n. Energy efficient equipment (motors, lighting fixtures).
o. Required redundancy (based on specific process / operating needs) shall be built in for the continuity in operation at full capacity is achieved.

3. Brief Scope of Work

3.1 The bidder shall be responsible for the design, engineering, supply, construction, erection, testing, commissioning of the hydrogen blending project, including civil and architectural works with _____ **years**[3] of operation and maintenance (O&M) works of all systems on turnkey basis.

3.2 The equipment/system/documentation as below, are in the scope of bidder:

a. _____ **kW Hydrogen generation system** for generating min _____**kg/day** hydrogen.

b. **Hydrogen compression system** to compress the hydrogen to a pressure of ____bar of rated capacity of _____ **kg/hr**.

c. **Hydrogen storage facility** to store ____**kg at** _____**bar** in H2 cylinders cascades.

d. **Hydrogen Blending Skid** to blend requisite hydrogen upto ___**% v/v** with natural gas at ____**bar**.

e. **Battery Energy Storage System (BESS)** of ___**kW/**____**kWhr** to support electrolyser coolers, other critical equipment's and control system.

f. **Complete civil and electrical works** with integration of HT System, H2 generation, compression, storage and blending system and BESS including office cum switchgear building.

g. Unified **Integrated Control System (ICS)** incl. SCADA and EMS for the control and monitoring of the entire plant.

h. Conducting safety studies of Hazard and Operability (**HAZOP**), Safety Integrity Level (**SIL**), Hazard Identification and Risk Assessment (**HIRA**), Quantitative Risk Assessment (**QRA**), Hazardous area classification (**HAC**), Escape Muster and Emergency Response Analysis (**EMERA**), Disaster Management Plan (**DMP**).

4. Detailed Scope of Work

4.1 Hydrogen blending project shall be designed, constructed, operated and maintained in accordance with NFPA, PNGRB T4S and PESO guidelines and ISO 22734.

4.2 The hydrogen blending project comprises the following systems:

Sl. No	Description	Quantity
1	Hydrogen generation system[4] (Electrolyzer and its accessories)	1 Lot
2	Hydrogen compression system[5] with all accessories	1 Lot

[3] Owner has to fill how many years of O&M to be part of this contract.

[4] In-case of hydrogen is provided by Owner directly, the same can be removed and mention the integration part in the scope of work.

[5] Typically, electrolyser system can produce hydrogen at pressure upto 40 bar. There will be no need of compression system for blending with natural gas at DRS and downstream. Compressor will be required where there is space constraint for hydrogen storage at low pressure or hydrogen blending with natural gas at transmission line. Owner can decide themselves for the requirement of compression system.

3	Hydrogen storage system	1 Lot
4	Hydrogen blending skid	1 Lot
5	Complete Civil and Electrical Works	Lumpsum
6	O&M of complete system (Including operation, preventive and breakdown maintenance along with supply and replacement of spares, consumables, fulfilling statutory requirements etc., housekeeping, security)	___ Years

4.3 The completion of all facilities, including commissioning of the hydrogen blending project should be completed within _____ months[6] from the date of placement of award.

4.4 [7]Effluent Treatment Plant (ETP) along with neutralizing pit, regular disposal of RO membrane and sludge disposal system shall be in the scope of the bidder.

4.5 Zero Liquid Discharge (ZLD) system shall be provided for the complete plant.

4.6 Non evaporative type, closed cycle for all the heat exchangers shall be provided.

4.7 All licence fees, technology fees, customs clearance (including reconciliation with customs authorities as required), custom duty charges and port clearance, port charges, statutory requirements, and clearance, if any, shall be under scope of bidder.

4.8 Obtaining necessary clearance from all the local administration and statutory regulator.

4.9 The safety, security and housekeeping of the hydrogen blending project will remain with the bidder during the total execution, commissioning, trial run, PG test and O&M period of the contract.

4.10 Temporary porta-cabins with basic furniture and washroom facility are required to be setup separately at site for use by owner and bidder shall be provide by bidder till the completion of all facilities in hydrogen blending project. Temporary arrangement for works, testing lab, storage shed, accommodation for labour and staff, site office shall be arranged by the bidder.

4.11 Arranging construction power and construction water for setting up of the project, besides arranging potable water for labour and other personnel at the worksite/colony.

4.12 Office cum switchgear building shall comply with Super ECBC standard. All construction material including cement, wood, reinforcement and structural steel, mud (as per applicability), stone, coarse and fine aggregate and finishing items etc. shall be arranged by the bidder. Pre-Engineered Building (PEB) components can be considered, if required.

4.13 Usage of fly ash bricks for all construction activities need to be followed.

4.14 Supply[8] and installation of solar rooftops in the available space of Office cum switchgear building with on-grid and off-grid capability shall be provided.

4.15 Providing complete drainage arrangement including any dewatering, site approach and service roads shall be ensured.

4.16 Pavement shall be done for the complete facilities.

[6] Owner can mention the contract period for the complete package completion.

[7] ETP, ZLD and heat exchangers are required only for the in-situ hydrogen generation. Marked in blue colour.

[8] Owner can define the installation capacity with required performance ratio.

4.17 Site grading including slope protection, ground preparation/filling/levelling, compaction of the identified area for the hydrogen station.

4.18 Civil/Foundation works for Office cum Switchgear complex, Electrolyser system, Hydrogen Storages, Hydrogen Compression unit, Hydrogen blending skid, Switchgear, Electrical Panels, SCADA Panels, Batteries, Control room equipment(s), BESS, transformer etc.,

4.19 3D model of the hydrogen blending project built to scale (for placing inside the model room) shall be provided.

4.20 The interiors of the building must be furnished with premium furniture, sanitary and light fittings.

4.21 Appropriate number of CCTV cameras (high resolution, manual and digital focus with night colour vision) for at least 15 days storage of data to be provided to cover entire hydrogen blending project (area indicated in the site map). The feed from the CCTV camera system shall be made available locally at control room & security room and remotely from any part of the country.

4.22 Connecting roads for vehicular movement and enough space for staff and visitor vehicle parking to be provisioned.

4.23 Brick or concrete boundary wall (3 meter from FFL) with plastering and concertina wire fence for outer area of hydrogen blending project and wire mesh boundary wall for internal area of hydrogen blending project along with landscaping and façade.

4.24 Water supply pipe work for maintenance, horticulture etc.,

4.25 Sanitary and plumbing works including connection with existing service networks.

4.26 Crash Guards to be suitably installed based on layout of the project.

4.27 Display board/Billboard/LED/Neon signages.

4.28 Arrangement of drinking water cooler cum heater of 150L and 30L capacity of each 2 nos and establishment of pantry facilities.

4.29 All architectural works are required for aesthetic view of station.

4.30 Horticulture work based on the inputs by Owner is to be implemented.

4.31 Cutting, clearing, transporting and disposal of trees, plants, bushes, other vegetation, roots, stubs etc. as required for the construction of station and regular O&M is under bidder scope

4.32 Pavement and gravel base to avoid weed growth is required in area of electrolyser, compressors, storage vessel and transformers etc. Bidder shall ensure no stagnation of water in plant and suitable routing of runoff rainwater.

4.33 All works shall be carried out meeting the requirements of this specification. However, for any additional details, then provisions of CPWD specification, National Building Code (NBC) shall be followed.

4.34 All incidental items not shown or specified but reasonably implied or necessary for the completion and proper functioning of the hydrogen station, all in accordance with the specifications including revisions and amendments there to as may be required during the execution of work. It shall be in the scope of bidder.

C. TECHNICAL SPECIFICATIONS

1. Brief Input and Output of the System

Table-1: Inputs and outputs

Sl. No.	Description	Parameters
1	Duration of operation of Electrolyzer	__ hours (__ AM to __ PM) / Continuous Operation
2	Land available	_____acre for hydrogen blending project and office cum switchgear building. The owner shall provide the encumbrance free land, with required set back. [9]Topological and Soil Investigation details is be provided in Annexure-V.
3	[10]Raw Water	River/Sea/Treated sewage or wastewater for utilities and potable water for office. Water quality details is be provided in Annexure-II. Point of connection is not less than ____ meters
4	Electrical power input	__ kV, 3-Ph, 50Hz, AC power / DC Power Point of connection is not less than ____ meters from the RMU.
5	Discharge/Drain output	Zero Liquid Discharge System

Table.2 Natural Gas Specification

Sl. No.	Parameter	Specification
1	Pressure	_____ bar
2	Flow Rate (nominal)	_____ scm/hr.
3	Min. and max. flow rate	_____ scm/hr. and _____ scm/hr.
4	Temperature	____°C
5	Composition	Refer Annexure - XX

[9] Owner can provide the topological and soil investigation report of the existing site location. If not available, it can be included in the bidder scope.

[10] Sl. No. 3 and 5 of Table.1 can be provided for in-situ hydrogen generation

2. Brief requirements of the System[11]

Table.3 Hydrogen generation system

Sl. No.	Parameter	Specification
1	Electrolyser Technology	Any variant of bi-polar type[12] complying to **ISO 22734:2019 / IS 16509:2020**
2	No. of Electrolyser Units	Capacity: 1x100% or 2x50% or 3x35% (independent streams of operation starting from rectifier till compressor)
3	Hydrogen generation	Min. _____ kg in max. ___ hours of operation
4	% Purity	≥ 99.97% (ISO 14687: 2019 Grade D)
5	Start-up time (warm)	≤ 15 minutes[13]
6	Storage facility for water (DM and raw water each), with level indicator, level switches and level transmitters	Sufficient to hold one day requirement for hydrogen generation
7	De-Oxo and Dryer unit per electrolyser	De-Oxo (1 x 100%) Dryer (1 Working + 1 Regenerative)

Table.4 Hydrogen compression system[14]

Sl. No.	Parameter	Specification
1	Compressor Technology	Diaphragm/Ionic/Hydraulic
2	No. of Units[15]	Capacity: 1x100% or 2x50% or 3x35% (independent streams of operation)
3	Compressor Capacity	Min. _____ kg/hr.
4	Compressor Outlet Pressure	_____bar
5	Compressor Outlet Temperature[16]	_____°C
6	Standards	API 617/API 618 and EIGA DOC 244 with all safety devices

[11] Owner shall provide the details mentioned in Table.3 and Table.4 based on the requirements.
[12] O2 concentration should not exceed 0.5% V/V in Hydrogen at Electrolyser outlet till service life of the stack. H2 concentration in O2 should not exceed 2.0% V/V at Electrolyser outlet till service life of the stack.
[13] Bidder to keep provision for heating during shutdown period (non-sunshine hours) so that stipulated start-up time is adhered to.
14 Bidder shall supply the compressor system with the approval from CCoE, PESO
15 Appropriate standby compressor is of Owners choice.
[16] It is optional requirement; Owner can specify this parameter for the optimizing the storage capacity.

Table.4 Hydrogen storage system[17]

Sl. No.	Parameter	Specification
1	Type of H2 Storage Cylinder / tubes[18]	Type 1/2/3/4
2	No. of bank/rack	2 or 3 in cascade format
3	Storage Capacity (Usable)	Min. _____ kg
4	Storage Capacity (Total)	_____ kg
5	Storage Pressure[19]	_____bar
6	Standards	ISO 12245 / ISO 11119 / ISO-10961/ EN 17533 / EN 17339 / BS EN-13769 / BS EN-13807

Table.5 Hydrogen Blending Skid[20]

Sl. No.	Description	Parameter
1	Blending level	Upto _____ % v/v.
2	Regulators	Active and Monitor
3	Valve	Shutoff, Safety, isolation valves, check valves
4	Controller	PID Ratio controller with control valve
5	Meter	Flow Meter (Coriolis)
6	Analyzer	H2, NG and Blended gas analyzer, dew point meter
7	Mixing Device	Static Mixer

[17] Diameter of hydrogen storage cylinders used for filling and storage of CHG shall not exceed 80 cm with approval from CCoE, PESO.
[18] Hydrogen storage tubes are preferred for the bulk hydrogen storage more than 200 kg, typically exceeds 5m in length. Type-4 is a must requirement, if the ambient temperature is less than 25°C.
19 As on Aug 2024, PESO has given the following approvals for the storage cylinder at various pressure levels of different types (Type-1 for 500 bar, Type 3 for 450 bar and Type-4 for 381 bar)
[20] Bidder shall supply the blending system with the approval from CCoE, PESO (If required)

Table.6 BESS[21]

Sl. No.	Parameter	Specifications
1	Rated energy (useful capacity)	_____ kWhr
2	Rated power (Net)	_____ kW at MCC end.
3	Type of battery	Ni-Cd / Ni-MH / Li-ion / Sodium-ion
4	Connectivity	Standalone mode as well as in tandem operation (off-grid and on-grid) Fast Response less than 100ms
5	Round-trip Efficiency	Min. 90%
6	Power Quality	CEA, Grid Code regulations, IEC, IEEE
7	Features (Automatic)	EMS, BMS and TMS

3. Detail System Requirements

3.1 Electrical

3.1.1 The bidder shall be responsible for the complete system starting from drawl of AC power from RMU of Discom's to Switchgear MCC including stepdown transformer for hydrogen generation, compression storage, blending of hydrogen with natural gas and other auxiliaries.

3.1.2 Statutory Requirements

The following statutory regulations of relevant clauses shall be followed for design of electrical system.

a. Indian Electricity Act and Rules.
b. The Factories Act.
c. The Gas Cylinder and SMPV Rules.
d. Other statutory bodies e.g. CEA / State Electrical Inspectorate etc.,

3.1.3 Electrical Equipment's

3.1.3.1 All electrical equipment's shall be of higher efficiency (IE3 or better).

3.1.3.2 Equipment's installed in hazard zone shall be of flameproof and explosive proof. It shall also comply with NFPA, IEC, IS-5571 and IS-15142 etc., Ordinary industrial electrical shall not be used in zone 2 areas.

[21] BESS of suitable capacity is included to cater the need of critical drives (excl. UPS but incl. compressor, electrolyte coolers, fire water jockey pump etc.,) in-case of RE RTC power. If the Solar power is only sourced, BESS cater the above requirement and non-sunshine hours operation of the station.

3.1.3.3 Electrical equipment for hazardous area shall be certified by testing authorities like CMRI / CIMFR / CPRI / ERTL or equivalent recognized independent test house such as BASEEFA / LCIE / PTV / UL / FM / ATEX / CENELEC / PTB, UL / FM. All equipment's (indigenous and imported) shall also have valid statutory approval i.e. CCoE, PESO.

3.1.3.4 All electrical equipment's shall be provided with suitable canopy for weather protection.

3.1.3.5 All panels, distribution boards, junction boxes installed in outdoor environment shall be of IP 67/68 protection. All bus bars shall be weatherproof IP55 with suitable seal and canopy.

3.1.3.6 Maximum surface temperature shall not exceed the ignition temperature of the gases as indicated by the T Class (T1- T6) of the apparatus as defined in IEC 60079 / IS 8239. The minimum temperature class to be considered as T3.

3.1.3.7 Critical loads e.g. Fire Station supply shall have two supplies from different power sources.

3.1.3.8 Design the power system to adapt and maintain the power quality parameters (harmonics and power factor etc.,) as per IEC 519, IEC 61000, IEC 62586, IEEE, CEA, Grid Code regulations.

3.1.3.9 Insulation coordination between the electrical equipment and the protective devices shall be done in line with IS 3716.

3.1.3.10 Control supply of local panel of critical loads, air compressor shall be provided with UPS.

3.1.3.11 Electronic cards of system like UPS, battery charger, VFD, SCADA, Heater, control system shall be ISA-G3 compliant as per Std. S.71.04 with Conformal coating is to be provided.

3.1.4 Switchgear

3.1.4.1 All HT and LT breakers shall have numerical relay for the protection, remote operation, and monitoring with LOTO provisions.

3.1.4.2 HT breaker shall be provided for the motor rating above 120 kW. Motors rated above 55 kW & upto 120 kW shall be controlled through ACB & motor protection relay and shall be fed from PCC.

3.1.4.3 All MCC switchboards shall have two bus sections each with provision for auto and manual changeover scheme through Sync. Check relay. Auto change over scheme shall be provided through logic in Numerical relay of bus coupler.

3.1.4.4 Fast bus transfer (FBT) scheme is to be provided in switchboard having high residual voltage during voltage dip.

3.1.4.5 HT and LT breakers and LT module shall be of metal clad and draw-out type.

3.1.4.6 All HT and LT incomer shall have Tri-Vector Energy Meter and/or net metering with interfacing provision for metering purposes and as per CEA/CERC guidelines.

3.1.4.7 In switchgear room floor shall have an electrical insulation coating of ___kV and 415V in accordance with IEC/ISO standards.

3.1.4.8 Bus-section feeder/circuit breakers shall have rating whichever is higher of the maximum connected load or bus-bar current rating.

3.1.4.9 Incomers of these switchgears shall be designed to cater to the complete load including 20% margin for future load growth.

3.1.4.10 Electrical running loads shall be uniformly distributed on each bus, and it shall be ensured that running and standby loads are fed from two different bus sections.

3.1.4.11 HV Switchgear shall comply with IEC 62271-200, IEC60470 and equivalent Indian standard.

3.1.4.12 Short circuit calculations shall be based on IEC 60909 /IS 13234.

3.1.4.13 All PTs shall be provided with additional Open Delta Tertiary winding with damping resistor.

3.1.4.14 Earth fault protection shall be provided with CBCT for providing sensitive E/F protection.

3.1.4.15 All the bus sections are to be designed for continuous parallel operation

3.1.4.16 Each MCC should be fed by two identical incomers and a bus coupler. Only four pole breakers in Incomer and Bus-coupler to be used in PCC.

3.1.4.17 Minimum 20% spare feeders or one no. of each rating and type on each side of the bus section whichever is more shall be provided.

3.1.4.18 All motors feeders rated above & including 15.0 kW & upto 55 kW shall be controlled through switch fuse unit, contactor, overload relay with CBCT, ELR for earth fault protection & shall be fed from MCC.

3.1.4.19 All TPN switch fuse feeders rated 250 A and above shall be provided with ammeter. All emergency / critical drives, irrespective of ratings, shall be provided with ammeter.

3.1.4.20 All Bus incomer breakers up to the PCC level shall be provided with the Under Voltage Tripping protection with time graded for various voltage levels.

3.1.5 Bus Duct

3.1.5.1 HV bus duct shall be phase segregated type, and MV & LV bus duct shall be non-phase segregated type with support structure would be of galvanized iron.

3.1.5.2 Bus bar material shall be electrolytic aluminium / copper with flexible expansion joints.

3.1.5.3 Bus insulators shall be non-hygroscopic, non-inflammable and flame retarding type.

3.1.6 Motors

3.1.6.1 All motors shall have class F insulation with temperature rise limited to class B.

3.1.6.2 Motors fed from variable frequency drive in hazardous area application shall be type tested as unit with the VFD panel. Input power supply for VFDs up to 150 kW shall be 415V AC and 3.3 kV for VFDs above 150 kW.

3.1.6.3 Microprocessor based variable speed drive shall be communicable type and shall be able to communicate with PLC / SCADA / DCS.

3.1.7 Transformers

3.1.7.1 Transformer rating shall suit 20% spare capacity with 100% standby transformers (for power distribution and lighting).

3.1.7.2 Distribution transformer upto 2.0 MVA shall comply to IS 1180 part-1 minimum level 3.

3.1.7.3 Less than 1000 kVA: oil- filled hermetically sealed type or dry type (if indoor) and 1000 kVA & above: oil-filled conservator type.

3.1.7.4 Synthetic fluid (e.g. silicone or ester or bio) shall be used instead of mineral oil.

3.1.7.5 Firewall shall be provided between two transformers.

3.1.8 Cables

3.1.8.1 Minimum size of high voltage cables shall also be based on the short circuit with stand capacity for a minimum time of 0.25 Sec with backup protection in line.

3.1.8.2 Selection of cables shall comply with IS, NFPA, IEC standards and suitable for hazardous areas. Fire protection for cables shall be provided as per IS12459.

3.1.8.3 Only screened type signal cables are to be considered in VFD applications.

3.1.8.4 All HV cables shall be with stranded aluminium conductor, dry cured XLPE insulated, insulation screened, PVC inner sheathed, armoured & FRLS PVC outer sheathed.

3.1.8.5 All LV power cables shall be with stranded aluminium / copper conductor, XLPE insulated, PVC inner sheathed, armoured & FRLS PVC outer sheathed. Copper conductor shall be used for sizes up to and including 10 sq. mm, and for higher sizes aluminium conductor shall be used.

3.1.8.6 All control cables shall be XLPE, armoured type with copper conductors, FRLS PVC outer sheath twisted pair overall shielded type.

3.1.8.7 All power and control cables shall be in single continuous lengths without any splices or intermediate joints. In no case the joint shall be located in hazardous area.

3.1.8.8 All incoming cables to switchgear/UPS/DC system/DBs and other equipment shall be sized for with additional capacity of 10% and Cable for capacitor banks shall be sized for 135% of the rated capacitor current.

3.1.8.9 Copper cables shall be used in UPS ACDB & ACDB to downstream distribution systems

3.1.8.10 Cables installed in aboveground enclosed areas shall be fire retardant and have non-propagating, self-extinguishing characteristics in accordance with IEC 60332 and IS 10810 Part 61-64.

3.1.8.11 Separate cables shall be provided for AC and DC signal/control circuits

3.1.8.12 All cables shall carry the cable tag numbers for easy identification.

3.1.8.13 Signal cables i.e. Instrument, communication, fire alarm, LAN and data highway, etc. cables shall preferably not be laid in the same trench/ tray along with electrical cables. In case these are laid in the same trench/ tray, a clearance of

minimum 300 mm from electrical cables shall be provided. GI earth strip of earthing grid shall run along the cable trays.

3.1.8.14 GI conduits shall be used between trenches and field equipment like motors, control stations etc.

3.1.8.15 Lighting cables shall be run along the structures/cables, buried between cable rack and equipment using conduit.

3.1.8.16 All cables i.e. HV and LV in concrete cable trenches shall be laid on cable trays only.

3.1.8.17 Fireproof coating shall be applied to the cable passing through electrical storeroom/battery bank room.

3.1.8.18 HT cable metallic screen SC rating shall be min 1KA for 2 sec of individual core.

3.1.9 DC System

3.1.9.1 Independent DC power supply system shall be provided for the following (unless otherwise specified):

a. Electrical Switchgear controls.

b. DC critical lighting and DC critical drives.

3.1.9.2 Each DC power supply system shall include battery bank, charger-cum rectifier and DC distribution board. System should be provided with a redundant battery charger with paralleling operation scheme and auto changeover.

3.1.10 UPS System

3.1.10.1 Uninterrupted power supply system shall be provided for critical loads that cannot withstand a momentary interruption in voltage (e.g. critical instrumentation, control, Human machine interface (HMI) for numerical relays, fire alarm, LAN system etc.)

3.1.10.2 UPS shall be of redundant (non-parallel) configuration with 2 x 100% capacity and with dual battery banks. Voltage stabilizer shall be Servo-controlled or static (solid state) type.

3.1.10.3 UPS system shall be provided with ACDB with two I/C & one B/C scheme with 100% redundancy of feeders on each section.

3.1.10.4 Bypass (SCVS) input supply of both the UPS systems shall be from the common source so that 110VAC output of both UPS systems shall remain synchronized with each other and synchronized (no break) transfer (<4ms) can be achieved at downstream ATS in case of failure running/preferred source of the ATS.

3.1.10.5 All the incoming power supply sources to the UPS system (UPS-1 / UPS-2 / Bypass) shall not fall on the same power source.

3.1.10.6 UPS system shall be sized to have at least 20% additional capacity with 20% additional feeders.

3.1.11 Emergency Power Supply System

3.1.11.1 Emergency power supply system, wherever envisaged, shall feed the following:

(a) Electrical loads essential for the safe shutdown of the plant.

(b) Emergency lighting.

(c) Communication system.

(d) Fire detection and alarm systems.

(e) D.C supply systems.

(f) UPS systems.

(g) Firefighting equipment excluding main firewater pump.

(h) Loads critical for process, plant and personnel safety.

3.1.11.2 Emergency power supply could be from a different power source or emergency generator as per project design data sheet. Where emergency generator is envisaged, emergency power supply shall be made available within a time period of 30 second from the instant of failure of normal supply.

3.1.11.3 The emergency generator shall, generally, not be required to run continuously in parallel with the normal power supply system. However, short time paralleling facility shall be provided for transferring load to normal power supply or other operational needs as required.

3.1.11.4 Battery Energy Storage (BESS) to be provided to cater to the emergency power supply system requirement of hydrogen blending project round the clock.

3.1.11.5 BESS discharging energy capacity at the end of 10 Years shall be 90% of rated energy capacity with round-trip (AC to AC) efficiency shall be 90% or better. It shall have both on-grid and off-grid capability.

3.1.12 Earthing and Lightning System

3.1.12.1 Design shall conform to IS:3043 2018 and lightning protection to IS/IEC: 62305, OISD-0180, National Building Code (NBC) and Code of Practice for Electrical Wiring Installations IS 732:2019 will be followed.

3.1.12.2 All electrical equipment operating above 110volts shall have two separate and distinct connections to earth grids. Separate earthing grid shall be provided for instrument, control system and electrical power. Separate earthing shall be provided for transformer neutral.

3.1.12.3 UPS, DCS, PLC, and other electronic instruments, including electronic relays, shall be provided with copper plate clean earth and kept galvanically isolated from the system and safety earthing.

3.1.12.4 Smart online earthing measurement system.

3.1.12.5 Lightning protection shall be designed according to the Lightning Protection Level I (LPL-I), as per the requirements of IS IEC-62305 and OISD-STD-180. All the components shall be tested as per IEC 62561.

3.1.12.6 Tanks, piping and process vessels and equipment containing flammable liquids or gas shall be earthed by a connection to the earth network, or by bonding to an earthed metal structure.

3.1.12.7 Surge protection shall be designed based on IEC 61643 with type-1 SPD.

3.1.12.8 Static Electric Discharge system shall be installed at all hydrogen locations (electrolyser, compressor, blending skid, storage cylinder and control and equipment room). Static Electric Discharge system shall have a dedicated earthing system.

3.1.13 HVAC System

3.1.13.1 Adequate HVAC system to be provided for the complete set-up including office, equipment rooms including security room.

3.1.13.2 Adequate ventilation shall be provided for Battery and Switchgear room.

3.1.13.3 Temperature and relative humidity shall be maintained for the human comfort and electronic cards requirements.

3.1.14 Lighting System

3.1.14.1 Lighting levels throughout the plant shall comply with hazardous area working conditions of NFPA and IEC standards. It shall also comply with IS 3646:1992 or latest.

3.1.14.2 LED fixtures with anti-glare shall be provided for outdoor and indoor lighting. It shall comply with hazardous area requirements.

3.1.14.3 Separate emergency lighting shall be provided for complete hydrogen blending project.

3.1.14.4 Exit Light fixtures shall be provided in ingress pathways, exit doors of all locations with dedicated power source.

3.1.14.5 Adequate number of self-contained portable hand lamps and battery-operated emergency lighting units shall be provided for immediate use for buildings where no DC supply is available

3.1.14.6 Lighting system shall consist of lighting transformers, lighting distribution boards (LDBs), lighting and power panels, fixtures, junction boxes etc. Outdoor lighting shall be operated based on synchronous timer / photoelectric cell with manual over-riding.

3.1.14.7 Lighting distribution board shall have two incomers and one bus coupler. A minimum of 20% MCB outgoing feeders shall be left as spare in all lighting & power Panels.

3.1.14.8 The lighting and power panels shall be provided with MCB and ELCB as incomer and Miniature Circuits Breakers (MCBs) for outgoing feeders control and protection of lighting circuits.

3.1.14.9 All DB / JB / Fixtures for emergency lighting & critical lighting to be colour coded for distinct identification.

3.2 Mechanical

3.2.1 Mechanical Equipment

3.2.1.1 All Piping along with Structure and Equipment's shall be designed as per the Dynamic/Wind/Seismic analysis.

3.2.1.2 Welding and Brazing Qualification shall be as per ASME BPV Sec. IX.

3.2.1.3 All couplings, gears, and exposed rotating parts shall be provided with adequate protection guards.

3.2.1.4 Noise level of the running equipment shall not exceed 85 dBA at 1m distance from source, unless otherwise specified.

3.2.1.5 Corrosion allowance for carbon steel vessels shall be minimum 3mm, unless otherwise specified.

3.2.1.6 All components/equipment shall meet the requirements of respective hazardous area classification.

3.2.1.7 Hydrogen generation can be either containerized standalone outdoor system or installed in the closed civil infrastructure. Clear separation distance between the equipment and outer wall shall be provided with minimum 600 mm in all sides.

3.2.1.8 Compression system shall be mounted on the foundation in a closed enclosure with proper noise insulation and well ventilated.

3.2.1.9 Hydrogen storage system be provided with well-ventilated shed having a light roof with louvers with at least two sides open. Safe weather protection over gaseous hydrogen storage system shall conform to the provisions of CGA PS-46.

3.2.1.10 Hydrogen blending can be either containerized standalone outdoor system or installed in the closed civil infrastructure.

3.2.1.11 Container or closed civil infrastructure shall have both active and passive ventilation system to avoid accumulation of hydrogen and hydrocarbons.

3.2.1.12 All underground vessels shall, tanks, piping shall be provided with galvanic/cathodic protection.

3.2.1.13 Non-Destructive Examination shall be performed as per ASME BPV Sec. V

3.2.1.14 Layouts for Oil and Gas Installations, safety requirements shall be as per OISD-118.

3.2.1.15 All flange joints on piping system including flanges on the equipment, manholes, etc shall be tightened using Hydraulic bolt tensioner and fasteners bolting nuts shall be marked for its tightness confirmation.

3.2.1.16 Hot Insulation materials, application etc. shall be based on recommendations of Standard specification for Hot insulation of vessels, piping and equipment of OEM. When operating temperature is below 200 °C, pipe shall be wrapped with Aluminium foil / SS foil (in case of SS lines) prior to insulating the line. All pipes shall be coated with zinc silicate coatings below 120 °C and silicon Aluminium above 120°C. No painting shall be done on SS lines. only Aluminium cladding sheets shall be used.

3.2.1.17 All items shall be marked (stamped/etched) in accordance with the applicable code/standard/specification along with the item code/tag no.

3.2.1.18 Compressed hydrogen storage cascade shall be designed such that, cylinders are easily removed from the cascade for the periodic testing process.

3.2.2 Piping/Tubing

3.2.2.1 Piping/tubing in gaseous hydrogen service as per ASME B31.12:2019 standard with min. stainless steel material. It shall also conform to ISO 15649.

3.2.2.2 Piping/tubing in gaseous hydrocarbon (NG) service as per ASME B31.3 standard and PNGRB T4S guidelines.

3.2.2.3 All piping/tubing must be labelled as per ANSI/ASME A13.1 standard. Associated items such as valves/check valves/filters must be tagged legibly for quick identification.

3.2.2.4 Piping/Tubing should be cleaned as per ASTM G93/G93M-19 standard on Oxygen side before putting into commissioning/service.

3.2.2.5 Flexible hoses used for hydrogen delivery shall conform to the provisions of ISO 21012.

3.2.2.6 All piping systems shall be hydro tested at 1.5 times the design pressure subject to Indian Boiler Regulation-1950, Regulation 374 or ASME B31.12:2019. However, for such systems where it is practically not possible to do hydro tests, the tests as called for in ASME B31.1:2022 in lieu of hydro test shall also be acceptable.

3.2.2.7 All fitting shall comply with EC-79 or better standards.

3.2.2.8 Piping used for DM Plant and DM water shall be stainless steel with min grade of 304.

3.2.2.9 All vents shall be routed to a safe area and in a manner that gas vented out is blown away from the nearest building. Height of vent shall be minimum five (5) meters above ground level. Distance between vent and fence shall be minimum five (5) meters from at least 3 sides. It shall also conform to the specification CGA G 5.5.

3.2.2.10 For added safety, optional arrangement be considered of making venting hydrogen passing through water column before release in the atmosphere.

3.2.2.11 It shall have a separate venting system for electrolyser, compressor, storage, and blending skid. Flame arrestor with temperature transmitter to be installed in all venting points. NFPA-2 Hydrogen technologies compliance shall be followed.

3.2.2.12 Piping shall be suitably supported to avoid vibrations and shall be designed so that forces and moments imposed on the compressor do not exceed the OEM's recommendation.

3.2.2.13 All carbon steel pipes and fittings having wall thickness 19 mm and above shall be post weld heat treated. All alloy steel (Cr-Mo) pipes and fittings shall be post weld heat treated irrespective of type or thickness of weld. All austenitic stainless-steel grades shall be solution annealed after welding. 100% radiography of welded joints shall be done both before and after PWHT.

3.2.2.14 All hoses shall be clearly marked with service and working pressure at both ends. Hoses shall be resistant to ageing, abrasion and suitable for outdoor installations. Complete Hose assembly shall be tested at two times the design pressure.

3.2.3 Valves and Tanks

3.2.3.1 All valve castings shall be of radiographic quality. Valves shall comply with ASME SEC-VIII, DIV.1, ASME SEC-V, ASTM stds.

3.2.3.2 All solenoid valves, control valves, critical manual valves shall be feedback mechanism about its status.

3.2.3.3 The system shall be provided with necessary connection with proper isolation devices, valves, regulators, manifold piping, cylinders, trollies, canopies to enable purging/flushing of the system with nitrogen for commissioning and at each maintenance work.

3.2.3.4 Supply and maintaining adequate quantity of nitrogen gas for emergency and O&M activities is in the scope of bidder.

3.2.3.5 All storage tanks shall be designed based on API 620 and API 650. DM Water Tank shall be provided with Stainless Steel Material.

3.2.3.6 Nozzle flanges up to 600 NB shall be as per ASME B16.5 and above 600 NB shall be as per ASME B 16.47 (SERIES 'B').

3.2.3.7 Filter housing design shall be as per ASME Section VIII, Div.1.

3.2.4 Platforms, Pipe Rack

3.2.4.1 Proper canopies, ramp protection to be provided at appropriate locations.

3.2.4.2 Platforms, ladders & stairways shall be consistent with access & safety requirements.

3.2.4.3 Platforms shall be provided with stair access in the case of platforms provided for normal monitoring.

3.2.5 Rotating Equipment's

3.2.5.1 Hydrogen compressors are to be located under shed and provision for top venting from compressor sheds shall be provided.

3.2.5.2 Compressors shall be located to keep suction lines as short as possible.

3.2.5.3 Compressors shall comply with API 617 / 618/ 619. Mechanical Run Test shall be carried out at OEM works.

3.2.5.4 Hydrogen compressor health monitoring system (vibration, temperature etc.,) shall be provided through PLC system.

3.2.5.5 Belts used for equipment located in hazardous area shall be static non-conducting type and shall be certified suitable for the area classification.

3.2.5.6 Separate air compression facility for instrument air as per their system requirements and service air for the maintenance.

3.2.5.7 Air compression facility shall be provided with auto and manual drain system.

3.2.5.8 Pumps for Fire Water Application shall be direct coupled.

3.2.5.9 All reciprocating pumps shall comply with API 674/675. Pulsation suppression and dampener shall be provided.

3.2.5.10 Positive Displacement Pump (Rotary) shall comply with API-676 and suitable to run simultaneously at the pressure-limiting accumulation pressure and at trip speed without suffering damage.

3.2.5.11 Pump and compressor drives shall have clear access.

3.2.6 Heat Exchangers

3.2.6.1 Thermal design should be performed using the latest HTRI or HTFS methods and software and shall comply with API 661.

3.2.6.2 All heat exchangers shall be hydrostatically tested and certified in the OEM works in comply with the provisions of the ASME Boiler and Pressure Vessel Code Section VIII and TEMA.

3.2.6.3 Shell & tube heat exchangers, minimum thickness shall be as per TEMA.

3.2.6.4 Air Cooled heat exchangers, minimum thickness shall be as per API 661.

3.2.6.5 Instrument air dryer used shall be any one of the following types: - Heatless purge type (PSA type) / Split flow no purge loss type / Heat of compression type.

3.2.7 Safety Valves

3.2.7.1 CHG cylinder fitted with safety relief devices or pressure relief devices in their bodies or valves, shall have such safety devices manufactured and maintained in accordance with IS: 5903, CGA S-1.1, CGA S- 1.2, CGA S-1.3, UN R-134 code

3.2.7.2 All the Safety Valves shall be **ASME UV code stamped**.

3.3 Instrumentation

3.3.1 Instrumentation System

3.3.1.1 Instrumentation System shall be designed based on Safety Instrumented System (SIS) requirement.

3.3.1.2 All instrumentation in safety/interlock loop shall comply with IEC 61508 & 61511 and subject to SIL Assessment and its requirements.

3.3.1.3 Instrumentation and control system shall in general meet the requirement of API-RP-551, 552, 554, 555 or EN 334, EN 14382 to the extent applicable.

3.3.1.4 All transmitters/instruments shall be intrinsically safe, and shall be certified for use in the specified hazardous area classification by any recognized authority like CMRS, FM, CENELEC, PTB, BASSEFA etc.

3.3.1.5 All solenoid valves shall be IS type with operating Voltage 24V DC (IS) and certified for use in specified hazardous area and shall be SIL-3 certified as minimum.

3.3.1.6 All intrinsically safe and explosion proof instruments, analyser and accessories shall be approved by CCoE, PESO.

3.3.1.7 Instrumentation shall be electronic type. Only final control elements shall be pneumatic.

3.3.1.8 Performance Track Record (PTR) for all field instruments and for system/subsystem (incl. PLC/SCADA) shall be minimum of 4000 hours.

3.3.1.9 All equipment shall meet the ECR/EMC technical requirements of IEC 61000, IEC 61326 and IEEE C37.90.

3.3.1.10 Instrumentation system shall be provided with two independent source and Instrument cubicles shall be dual fed and utilise redundant PSU's wired in hot standby mode.

3.3.1.11 2-o-o-3 voting configuration shall be used for all input signals to ESD/SIS.

3.3.2 Environmental protection

3.3.2.1 All instruments and equipment shall be suitable for the climatic data of the project.

3.3.2.2 All instruments, junction boxes, push button station, control cabinet, panels and enclosures in field shall be IS, dust proof, weatherproof to IP65 or NEMA 4X and secure against the ingress of fumes, dampness, insects and vermin.

3.3.2.3 All panels, distribution boards, junction boxes, pushbutton stations, control cabinet, instruments installed in hazards zone shall be of flameproof and explosive proof. It shall comply with ATEX and IECEx directives.

3.3.2.4 All the field instruments, analysers and equipment's other than used for H2 service shall be suitable for Zone-I Gr. IIA & IIB, T3 as minimum and respective hazardous zone for hydrocarbons.

3.3.2.5 Enclosures for Analyser's shall be suitable for Zone-1, Gr. IIC, T3 (as per individual hazardous area classification if is not available) and respective hazardous zone for hydrocarbons.

3.3.2.6

3.3.2.7 Instrument enclosure shall be designed with a dual compartment housing that provides metallic isolation between the electronics and the terminal compartments.

3.3.2.8 All instruments wetted parts shall be SS316 as minimum and electronic housing material shall be of Epoxy coated die cast Aluminium. For Gas Detector and instruments installed in toxic/corrosive environment SS housing shall be used.

3.3.3 Instruments

3.3.3.1 Dedicated online mass flow meter (Coriolis type) and gas analyser shall be provided in each stream of hydrogen generation system and online mass flow meter (Coriolis type) shall be provided in each stream of Compressor and blending skid.

3.3.3.2 Gas meter fitted at blending skid shall be calibrated for the specified hydrogen concentration in HNG/HCNG.

3.3.3.3 Pressure transmitter(s) should constantly monitor the system pressure. If the system pressure increases out of range, the hydrogen production should be stopped and put in standby. A temperature transmitter should constantly monitor and control the electrolyte temperature (in-case of alkaline electrolyser). The electrolyte levels should be measured by a level transmitter and controlled by a level controller.

3.3.3.4 All Transmitters shall be intrinsically safe & SMART type with HART protocol with integral LCD indicator, test terminals and bypass diode.

3.3.3.5 Field Transmitters shall be used in place of switches; all inputs to PLC/SCADA shall be through field transmitter

3.3.3.6 Proper approach or platforms shall be provided for all locally mounted gauges Field mounted Instruments, where feasible shall be close coupled (post mounted, if it's not feasible).

3.3.3.7 Thermowells and orifice plates shall be min. 316 stainless steel. Standard type orifice plates shall be designed as per ISO 5167.

3.3.3.8 All remote mounted instruments, including instruments connected to lines or vessels by means of flush or remote mounted diaphragm seals, e.g. transmitters, switches etc., shall be 316 stainless steel minimum unless process conditions require a more suitable material.

3.3.3.9 Liquid level applications, remote Diaphragm seal type Smart level instruments shall be used with local indicators.

3.3.3.10 Double isolation type root valve shall be provided for the hydrogen and hydrocarbon application >40 bar and others application >60 bar.

3.3.3.11 Temperature transmitters shall be Remote mounted type, dual channel, dual sensor dual compartment, smart transmitter with HART bus protocol, integral output meter, burnout protection and auto change over. It shall be used for all temperature measurements (other type shall be considered, if it is not feasible).

3.3.3.12 DM plant and all corrosive service shall have non-contact type level instrument.

3.3.3.13 All critical parameters like pressure, temperature, flow, levels shall have both local and remote indications. All critical parameter for operation and emergency shutdown of the station and/or individual equipment shall have 100% redundancy on instruments.

3.3.4 Control Valves

3.3.4.1 Control valves size shall be as per IEC/ ISA 75.01 and each valve trim shall be constructed from 316 SS, unless stated otherwise.

3.3.4.2 All control valves shall have their predicted aerodynamic / hydrodynamic noise level and comply with IEC 534-8-3 and IEC 534-8-4.

3.3.4.3 All control valve actuators shall be provided with SMART positioners, complete with air sets having 5-micron filters and capable intelligent design of transmitting full diagnostic and predictive maintenance data to the PLC/SCADA.

3.3.4.4 All ESD and Depressurising valves shall be pneumatically operated and compatible to process material, temperature, and pressure. SIL 1/2 rating valves shall be provided.

3.3.4.5 All valves shall be subject to NDE/NDT in accordance with ASME B16.34.

3.3.5 Analyser and Gas Chromatograph (GC) / Raman Spectrometry (RS)

3.3.5.1 Analyzer Systems shall comply with IEC 61000-4. Certification from statutory authority like BASEFFA, FM, PTB, CENELEC etc. for items of imported item and from CMRI, ERTL etc. for domestic items.

3.3.5.2 Analyzer shelter and analyser location shall be designed to minimize sampling time and easy maintenance. Complete assembly shall be mounted on a free-standing easel type frame, complete with overhead rain / sun protection canopy and clearance.

3.3.5.3 Minimum Sampling points at the blending skid (inlet of the hydrocarbon, hydrogen and outlet of the blended hydrogen).

3.3.5.4 GC/RS based analyser system is required for continuous display/record of hydrogen purity, oxygen content (ppm), moisture content (ppm), hydrocarbon components.

3.3.5.5 GC/RS system shall consist of complete set of analysers, sampling system, sample-conditioning system, internal power supplies, cabling, inter piping.

3.3.5.6 GC/RS shall be provided with redundant power supply and communication to PLC/SCADA.

3.3.6 Tubing and Fittings

3.3.6.1 All fitting shall comply with EC-79 or better standards.

3.3.6.2 Tubing: SS material, seamless having minimum 2.5% of molybdenum content and carbon content shall be less than 0.03%. Tolerance on wall thickness should be ±10%. Testing of the tubing should be in accordance with the DIN/NFA/ASTM/EN standards. It shall also comply with PNGRB T4S guidelines.

3.3.6.3 Fitting: SS material having minimum 17% of chromium, minimum 12% Ni content and carbon content shall be less than 0.05%. All component of the material shall be of same materials and etched. Fitting shall have two ferrule design with grip type. Testing of the fittings should be in accordance with the DIN/NFA/ASTM/EN standards. It shall also comply with PNGRB T4S guidelines.

3.3.6.4 Air distribution main header and all instrument air, N2 piping line shall be of minimum SS304 and tapping as per API standard.

3.3.7 Instrumentation Cable

3.3.7.1 All instrumentation cable shall be individual shielded, FRLSH and armoured.

3.3.7.2 All cables glands shall be of type 304 SS: double compression type, flame proof with Ex(d) certificate suitable for armoured cables with PVC shrouds.

3.4 Integrated Control System (ICS)

3.4.1 ICS shall comprise of following components as a minimum, but not limited to;

3.4.1.1 Controllers capable of performing algorithms and logics relating to analogue control, sequence and interlocks required during start up, shutdown and normal continuous operations.

3.4.1.2 HMI required for the operators to monitor and perform control actions as required.

3.4.1.3 Servers facilitating access to real time live data and processed/stored data for operations, maintenance and corporate needs.

3.4.1.4 Network Printers (Multi-Function, compatible to A3 and A4 paper size).

3.4.1.5 Input/Output cards with racks, communication processors and power supplies that can interface to field connect input/output devices.

3.4.1.6 Cabinets to house various electronic components with required accessories for power/signal conditioning such as MCB/MCCB, distribution, convertors, barriers and surge protection, and for cable termination and dressing. Cabinets to house the ICS related components shall be designed to ex-proof/flame-proof requirements.

3.4.1.7 Communication interfaces for connected package systems on the field-layer and data exchange to the data-layer.

3.4.1.8 Network infrastructure with firewall and cyber security and components shall be designed as per IEC 62443.

3.4.1.9 Software required for performing various control/monitoring and configuration/maintenance functions.

3.4.1.10 Shutdown related inputs shall be hardwired from the local emergency pushbuttons.

3.4.2 PLC and SCADA

3.4.2.1 All plant and equipment interlocks shall be executed through PLCs which shall communicate to SCADA/DCS through redundant Direct bus connectivity (preferred) or Modbus protocol.

3.4.2.2 QMR/TMR SIL3 PLCs system and architecture shall be used for electrolyser, rectifier, compressor, blending skid, safety system for executing trips/ interlocks.

3.4.2.3 DMR PLCs can be used for DM plant, chiller, cooling tower, utilities etc.,

3.4.2.4 Maximum Loading of Processor shall not exceed 50% Including all type of installed spare.

3.4.2.5 System Electronic cards/hardware for all third-party system, main system and packages like PLC/DCS/SCADA shall be compliant for corrosive environment severity class G3 as per ISA-S 71.04 or equivalent.

3.4.2.6 PLC based SCADA for the overall control of the hydrogen blending project to be provided. SCADA shall be able to acquire real time data of identified equipment. The SCADA should have historian and should be capable of storing at least one year data.

3.4.2.7 PLC and SCADA shall be integrated with Energy Management System (EMS). EMS is to take care of real time monitoring, operation, control, reliable and efficient performance of the hydrogen blending project.

3.4.2.8 EMS with PLC/SCADA shall have the following facilities for scheduling the electrolyser and compression system operation:

3.4.2.9 To start and stop on auto mode based on the Scheduled Generation/Time of the Day (ToD) or both.

3.4.2.10 To ramp up / ramp down the loading based on Scheduled Generation of RE power/based on the actual RE generation.

3.4.2.11 The required algorithm for the above provisions shall be finalized during engineering stage.

3.4.2.12 Selected data shall be provided any of the central offices located anywhere in India through secured web-based client or by any other means. It shall be accessed with proper authentication.

3.4.2.13 PLC/ SCADA system shall have provision for interfacing with Owner Server (Data acquisition system). Provision for OPC (optical portable communication) protocol and facility is required for any third-party interface and provide the functionality for remote operation of hydrogen blending project.

3.4.2.14 SCADA shall have facility to provide real time reporting of alarms and statistical data through SMS and e-mails. Dedicated Internet connectivity shall be provided for the control system.

3.4.2.15 Separate Wi-Fi and LAN connectivity shall be provided for the office cum switchgear building.

3.4.2.16 SCADA shall have to Interface Zone-1, in-case of the equipment placed outside the hazardous zone / Zone-0 is required in-case the equipment is placed along the hydrogen and hydrocarbon source.

3.4.3 Control System

3.4.3.1 The control room to have all facilities to monitor and control the entire hydrogen blending project without requirement of manual intervention and should have PAM (Personnel Area Monitor). PAM system should measure O2 gas and H2 gas continuously at site with required alarm annunciation for low (19.5%) and enriched (23.5%) O2 atmosphere.

3.4.3.2 All PLC/CPU shall have 100% redundancy along with power source. The complete process, together with all relevant parameters, should be constantly monitored and controlled by microprocessor(s) with Hot-standby CPU modules for bump less changeover.

3.4.3.3 Dedicated UPS system (2 x 100%) shall be provided for PLC and SCADA system.

3.4.3.4 Power System and Control System equipment's shall be designed and tested for its cyber security and the guidelines issued by Ministry of Power against Circular no. No.25-l l/6/2018-PG dated 02.07.2020 and Circular No. 12/34/2020-T&R dated 08.06.2021.

3.4.3.5 Control System shall be configured for remote monitoring and shall have all infrastructure, internet facilities, web interface portal with GUI and secured access.

3.4.3.6 Bidder shall provide one no of industrial grade laptop of min. 15-inch display with all the software's of PLC/SCADA, relays, antivirus, firewall with latest patches.

3.4.3.7 In case of malfunction of the microprocessor(s) or in an emergency, the unit should shut down immediately. Safety devices to protect microprocessor(s) against power line disturbance should be provided. The system should be capable of taking electrical surges and wide voltage.

3.4.3.8 Minimum requirements of Integrated Control System (ICS) are enclosed in Annexure-VI.

3.5 Safety Systems and Studies

3.5.1.1 Adequate safety systems are to be installed for proper monitoring and ensuring healthiness of every equipment and personnel safety on a continuous basis. The certification of all equipment to be done on a regular basis, maintaining the OEM guidelines as well as Indian and International standards. The last date of certification/calibration should be mentioned on the equipment.

3.5.1.2 Emergency Push Buttons at different locations (HOS Room, Control Room, Switchgear MCC, Electrolyser, Compressor, Blending Skid, Security, Transformer) for emergency isolation and shutdown of the system.

3.5.1.3 Temperature and humidity sensors along with air quality sensor like CO2 loggers shall be installed inside the rooms of office cum switchgear building.

3.5.1.4 The Hydrogen blending project shall be equipped with all required protections to safely shutdown/trip the station locally as well as remotely at certain distance (Area Isolation System-AIS) from the station in any case of emergencies with respect to operation of Hydrogen blending project and safety of equipment and persons. The AIS must be hardwired type to isolate the entire H2 and hydrocarbon related system.

3.5.1.5 Minimum three no's of 80-inch LED screen shall be provided in the Office cum switchgear building (a. HoS (Head of the Station) room b. Conference Room c. Control Room) for display of various real-time parameters.

3.5.1.6 Appropriate Safety devices (with 100% redundancy for critical signals) are to be provided for the entire system for safe release of hydrogen, pressure build up etc.

3.5.1.7 Hydrogen leak detection 0–100% of LEL, flame detectors, smoke detectors, heat sensors and interlock system (Alarm at 20% of LEL and Shutdown or isolation of equipment/devices at 40% of LEL) shall be provided with 100% redundancy to ensure safety with suitable alarms in the surroundings and system trip interlocks of complete hydrogen blending project.

3.5.1.8 Bidder shall take necessary regulatory approvals from Petroleum and Explosives Safety Organization (PESO) for the equipment's, components, storage and for the layout of the hydrogen blending project.

3.5.1.9 Hydrogen cylinder shall comply with Gas Cylinder Rules, 2016 and its amendments. All clearances and approvals to be done for the installed and operational hydrogen system with approval from PESO or authorized test agency as directed by PESO. All product related compliances and approvals are to be provided by the bidder within the project timelines and all site approvals would be in bidder scope.

3.5.1.10 Following safety studies shall be carried out by the bidder and any other studies as mandated by statutory guidelines/requirements.

3.5.1.11 Hazard and Operability study (HAZOP) of the whole system (Electrolysers, compressor, storage tubes, blending skid etc.) before starting of installation activity.

3.5.1.12 Fire and Gas mapping study shall be conducted for Gas, flame and smoke detection devices as per ISA standard.

3.5.1.13 Safety Integrity Level (SIL) assessment shall be performed on the complete instrumentation and control system of the project.

3.5.1.14 Quantitative Risk Assessment (QRA), Hazardous area classification (HAC) and Escape Muster and Emergency Response Analysis (EMERA) studies (Emergency response plan as per ISO 14001) for the complete system shall be carried out by the agency.

3.5.1.15 Hazard Identification Risk Assessment (HIRA) also to be conducted and report to be submitted before completion of Trial operation.

3.5.1.16 Disaster Management Plan (DMP) for the complete blending project shall be carried out (preferably).

3.5.1.17 Proper operation of hydrogen gas leak detection system (with 100% redundancy) should be tested before starting trial operation by applying sample gas.

3.5.1.18 Gas leakage determination and ventilation are based on IEC/EN 60079 standards. Response time of sensor shall be as minimum as possible.

3.5.1.19 Point detection devices and flame detection for the confined space and covering all areas of operation (Electrolyser, Compressor, Storage, blending skid, GC/RS etc.,)

3.5.1.20 Ultrasonic leak detection devices for open space (Electrolyser, Compressor, Storage, blending skid, GC/RS etc.,)

3.5.1.21 Flame detection devices at all locations (Electrolyser, Compressor, Storage, blending skid, GC/RS etc.,).

3.5.1.22 Bidder shall provide the portable ultrasonic type of hydrogen leak detectors with multiple camera, LCD for image display and hazardous area complaint.

3.5.1.23 Bidder has the responsibility to get the hydrogen blending project including office cum switchgear building layout approved from PESO and any changes being done by bidder must be approved by Owner before putting up for approval by PESO.

3.5.1.24 All high-pressure joints shall be of welded constructions and radiographed. All piping/tubing must have integrity of continuity to avoid static energy generation. Accordingly, all piping/tubing must have grounding/bonding provisions.

3.5.1.25 All major isolation and critical valves should have/must be installed for easy/proper LOTO (Lock-out/Tag-out) provisions.

3.5.1.26 The complete blending project should have adequate safety provisions required for handling of hydrogen. The system should be designed for safe operation with all the required control instruments, interlocks, alarms, etc. for full safety and emergency provisions for start-up/shutdown and normal operation. If any additional interlock for safe start-up/operation/shutdown of station is identified during design review meeting, FAT/SAT and the same shall be incorporated.

3.5.1.27 All necessary instrumentation, isolation valves and safety equipment like safety valves etc to be provided for the safe operation of the pressure vessel.

3.5.1.28 Dedicated fire suppression safety device (water sprinklers, water hydrant, CO2 flooding system) shall be provided in electrolyser, compressor, storage, blending skid, other H2 and hydrocarbon service system. Inert gas system shall be provided in control room and control equipment room. It shall be provided with automatic and manual operation.

3.5.1.29 Portable fire extinguishers of DCP, CO2 Cylinders and others shall be installed at different location of Hydrogen blending project as per PESO, IS and NFPA guidelines.

3.5.1.30 The bidder must have necessary first-aid facilities for all his employees, representatives and workmen working at the Site during the project execution and ___ Years of O&M phase.

3.5.1.31 Bidder shall display of safety sign boards, evacuation routes, warnings, layouts, MSDS do's & don'ts at locations of the station.

3.6 Civil and Architectural Works

3.6.1 Design and Layout Consideration

3.6.1.1 Depending upon the topology the climate zone of the project shall be followed.

3.6.1.2 Topographical survey and soil/geotechnical investigation results of the project location is enclosed in Annexure-___.

3.6.1.3 While preparing the detailed layout, planning station facilities, the Bidder shall ensure the following aspects:

3.6.1.4 All statutory requirements including safe distances between various facilities as per applicable rules/acts/laws including PNGRB and PESO guidelines, local byelaws are met. The reference standard shall be ISO 19880(1-8):2020.

3.6.1.5 The hydrogen blending project should have sufficient space, proper design, interior furnishing, proper ventilation, proper lighting, temperature control, dust free atmosphere, fire-fighting facilities, etc.

3.6.1.6 Design of RCC and Steel structures shall be carried out as per IS 456 and IS 800 respectively.

3.6.1.7 The buildings and allied works shall be designed to meet the requirements of NATIONAL BUILDING CODE, NFPA, IEC, relevant Indian Standards and latest ECBC standards.

3.6.1.8 The rainfall data in one hour (in mm) as per meteorological data from IMD shall be considered for the design of the drainage.

3.6.1.9 The provisions of Criteria for earthquake resistant design of structures as per IS 1893-1 shall be followed for the design of the foundation, building structure and other facilities.

3.6.1.10 The provisions for basic wind speed shall be as per Code of Practice for Design Loads (other than earthquake) for Buildings and Structures IS 875-3.

3.6.1.11 Broad layout of office cum switchgear room in enclosed in Annexure-III.

3.6.1.12 For corrosion protection, painting is to be applied following the corrosive Category (C) as per ISO 12944-2.

3.6.1.13 RCC Structure around the storage cylinders cascade with separation distances (as per CCoE) shall be provided with 4 hours fire resistant rating for structure as per IS:1642.

3.6.2 Building Materials Specifications

3.6.2.1 The details of building material are listed below is not exhaustive and indicative only. However, the bidder may propose alternative for approval of owner during detailed engineering.

3.6.2.2 Civil Work

A.	External Walls	-	Cement plaster, white cement primer, pop's etc., Exterior Emulsion Paint (Rain & Dust proof)
B.	Internal/Partition Walls	-	Acrylic Emulsion
C.	External glass curtain wall unit.	-	Double glazed unit or triple glazed
D.	External glass window unit.	-	Double glazed unit or triple glazed Aluminum door section and framing. Maximum SHGC (Solar Heat Gain Coefficient) as per super ECBC Standard.

E. Door

i. External and Internal: Door shall be fully insulated with locking system, hinges, hydraulic door closures. Fireproof doors shall be provided as per requirement.

ii. Steel Rolling Shutter (Mechanical Gear Operated), Metal rolling shutters and rolling grills as IS: 6248:1979.

iii. Collapsible Steel Gates, Clause 10.5 & Fig 10.2 CPWD SPEC Vol:1 (2009)

iv. Main Entrance door shall be provided with auto open and close operation

F. Roof - Provided with Water proofing treatment on roof with fiber glass cloth and water proofing cement compound and screened concrete

G. External Facade - Size may be changed as per the final detailed drawing.

3.6.2.3 Finishing (Designed based on Super ECBC criteria)

A. Flooring –

i. Heavy duty vitrified ceramic tiles and heavy-duty anti-skid ceramic tiles for toilets.

ii. Granite/kota stone for storeroom and steps.

iii. Cement concrete flooring with ironite hardener with 200 mm skirting. Electrical insulation coating over the floor based on IEC/ISO standards

iv. Acid/Alkali resistance tile flooring. Acid/ Alkali resistant Dado -2100 mm. above, that Acid/Alkali resistant or chlorinated rubber paint.

B. False ceiling – 15mm thick mineral fiber board with LED light fixtures, Air ducts etc.,

i. Battery room - Acid/Alkali resistant or chlorinated rubber paint.

C. Toilet & Pantry - Oil bound distemper.

Note: The above specification details are based on the preliminary design stage. There can be few changes during detailed architectural and interior design process.

D. DOCUMENTATION

The documents and drawings as listed below are to be submitted by the EPC for the approval of the Owner unless specified otherwise. The list given below is not exhaustive but indicative only.

Three sets of all necessary documentation (hardcopy, English) such as user's manual, operating manual, vendor manuals, product catalogues, wiring diagrams, drawings, termination drawing and interconnecting schematic diagram etc. for the whole system (electrolysers, compressor, storage tubes/vessels, blending skid etc.) besides their soft copies.

1. All civil, mechanical, electrical, instrumentation simulation and field studies, design data and calculations etc., shall be submitted to Owner in hard and soft copies.
2. Relevant drawing, specification, datasheets and other required to fulfil the intent of ensuring operability and the reliability of the complete system covered under this specification are to be supplied to Owner.
3. Hydrogen production curve variations at part load operation.
4. All necessary third-party certificates for all the critical components (electrolysers, compressor, blending skid, high pressure storage tubes/vessels).
5. Hazard and Operability study (HAZOP), QRA, HAC, EMERA, HIRA, SIL, DMP reports
6. Ingress Protection (IP) standard compliance certificate.
7. Report of factory/laboratory calibration certificates of devices/instrument(s).
8. All ownership certificates should be in the name of Owner.
9. As-build drawings of all mechanical, electrical, instrumentations, civil etc.,
10. Layout of Hydrogen Station and office cum switchgear building drawing as per super ECBC standard with all dimensions, simulation model along with input/output simulation report, facilities, testing facilities, cabins/ rooms/ offices, service lines, etc.
11. Design criteria, survey & investigation reports, drawing/documents of the Civil Infrastructure, Super structure and Sub-structure, foundation and underground facilities for approved of Owner/Engineer-In-Charge before the start of works.
12. All architectural drawings required for execution of construction work such as detail floor plans, detail elevations, detail sections and other miscellaneous architectural details such as finish schedule (internal and external), colour schemes (both internal and external), doors and windows, flooring details and pattern, false flooring, false ceiling, sanitary, plumbing, etc.
13. Report for various statutory requirements and their compliance of the facilities and systems etc.
14. As-Built final architectural drawings, considering Super ECBC parameters, Material test certificates.

E. O&M CONTRACT[22]

1. The next day (00.00 hrs) after completion of successful trial operation and PG test for the station will be considered as the start date of O&M contract for the bidder.

2. Scope of the bidder includes the complete O&M of the hydrogen generation, compression, storage, and blending system for the period of _____ years. All the spares and consumables required for the O&M of the system is in the scope of the bidder. The bidder directly or through their authorized agencies having experiences with equipment requiring Zone-0/Zone-1 compliance (hazardous area classification) for a period of not less than two years, will provide O&M services.

3. The O&M period may be extended with the mutual consent of owner and the bidder.

4. Performance Bank Guarantee (PBG) for the O&M of the contract shall be ___% of the O&M portion of the contract price. The PBG shall be submitted 30 days before the start of O&M of the contract by the bidder. There would be penalty, for each instance, at the rate of _____% of the O&M portion of the contract price if the below mentioned performance criteria are not met.

   a. The average availability of the system must always be above 95% annually (24 hrs x 365 days).

   b. The interruption should not be for more than two days, at a stretch.

   The system will be considered available only when it meets all the parameters of the specifications, the system is 100% safe and it is fit for blending hydrogen with hydrocarbon.

   The overall ceiling on penalty shall be ____%of the O&M portion of the contract price.

5. One complete set of tools and tackles (safety and special), portable measuring and monitoring instruments, portable gas leak detectors shall be provided by the agency at the end of O&M period.

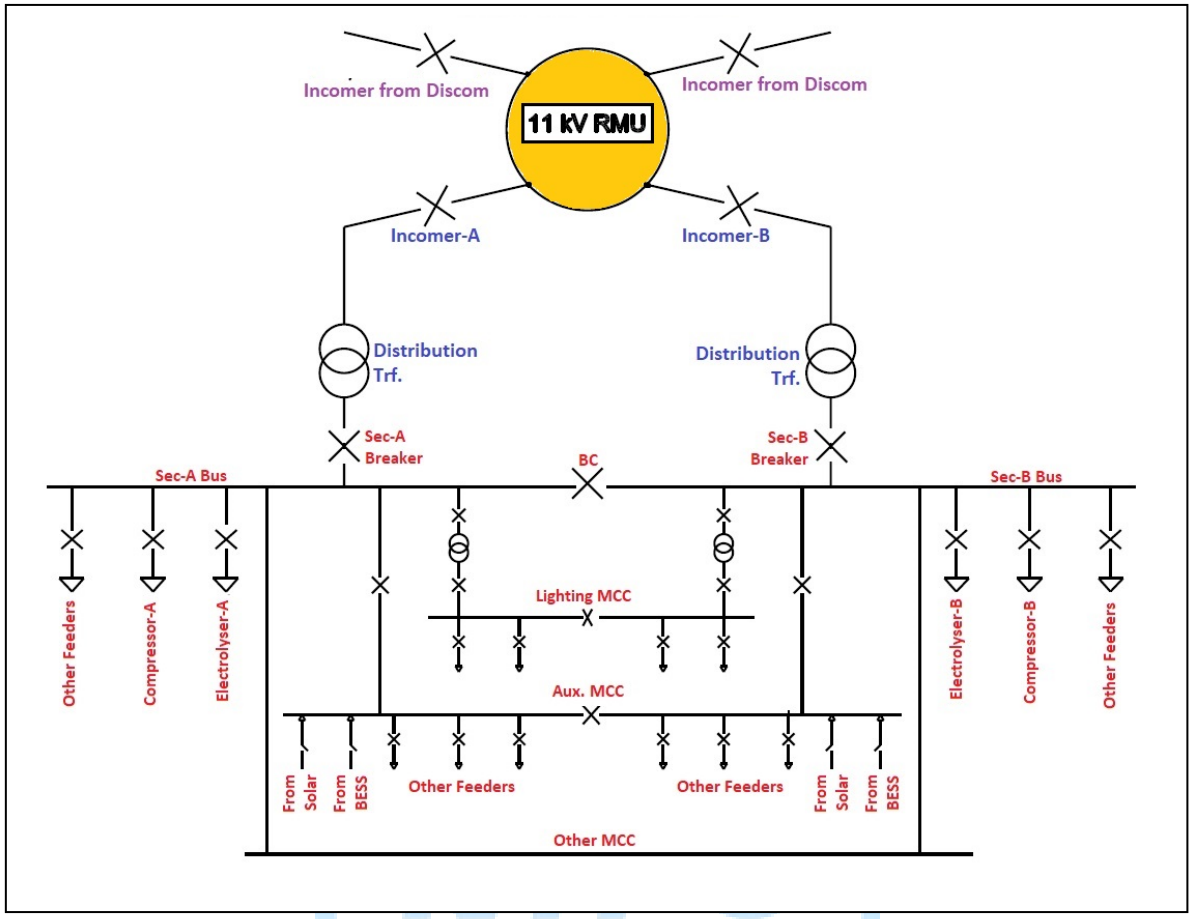
[22] The number given in the chapter are indicative guidance only. Owner shall exercise their discretion for specifying appropriate parameters.

Annexure-I: Water Quality Parameters

Sl. No.	Parameters	unit	Observed Value	Limit (Max.)	Test Methods
1	pH value		.....	.....	.....
2	Calcium hardness	mg/l as CaCO3	.....	.....	.....
3	Magnesium hardness	mg/l as CaCO3	.....	.....	.....
4	Sodium / Potassium	mg/l	.....	.....	.....
5	Total cations / Total Anions	meq/l	.....	.....	.....
6	Dissolved silica	mg/l as SiO2	.....	.....	.....
7	P-Alkalinity / M-Alkalinity	mg/l as CaCO3	.....	.....	.....
8	Chloride / Sulphate / Nitrate	mg/l	.....	.....	.....
9	Total Suspended Solid	mg/l	.....	.....	.....
10	Chemical Oxygen Demand	mg/l	.....	.....	.....
11	Biological Oxygen Demand	mg/l	.....	.....	.....
12	Total Dissolved Phosphates	As p	.....	.....	.....
13	Total Nitrogen	As N mg/l	.....	.....	.....
14	Fecal Coliform	MPN/100 ml	.....	.....	.....

Annexure-II: Basic Electrical Scheme[23]

Basic electrical scheme is as indicated below.



Note: Above electrical scheme is tentative and subject to the availability of two incoming feeders. In-case one incoming feeder is available, bidder shall be responsible to install suitable standalone breaker for all incomer breaker for transformers.

[23] Above scheme is only indicative. Owner shall provide the single line diagram of the existing or new network available for the power connectivity. Owner can also propose the electrical scheme required for this project.

Annexure-III: Broad Layout of Office cum Switchgear Room

Broad layout in Office cum Switchgear Room

S. No.	Space Name	Carpet Area* (Sq. m) (tentative)
1	Entrance Lobby & Waiting Area	--------
2	Model & Display Room	--------
3	Common Toilet - He	--------
4	Common Toilet - She	--------
5	HOS Room	--------
6	Conference & VC Room	--------
7	HOS Room - Toilet	--------
8	HOS Room – extra space	--------
9	Pantry	--------
10	Battery Room	--------
11	SCADA Room	--------
12	Control Room	--------
13	Storeroom	--------
14	Switchgear Room	--------
15	Passage Area	--------
16	Security Room	--------
17	Security Toilet	--------
	Total Area (Sq. m)	--------

*Varies based on the design and finalized during detailed engineering

A. Human Machine Interface

HMI software shall include:

1. Graphic (HMI) displays all process areas, showing equipment status (ready, not ready or running) and analog values for critical process variables.
2. There shall be multiple levels (types) of process graphics:
    a. Level 1 graphics are used for navigation between offsite locations, display KPIs (Key Performance Indicators), alarm summary, trends, and run reports.
    b. Level 2 graphics will mirror the PFDs (Process Flow Diagrams) for each offsite location for normal control operations.
    c. Level 3 graphics will mirror the P&IDs (Piping and Instrumentation Diagrams) for each offsite location for detailed control operations.
    d. Level 4 graphics will be provided as necessary for equipment specific integration screens and auxiliary information.
3. Alarm display and logs, showing the alarm tag number, title, date and time.
4. Trend displays with flexible time and process variable axes for any analog process variable.
5. Loop displays showing PID controller settings and trending of process variable, setpoint and output.
6. Password controlled multiple user access levels like Operator, Supervisor and Engineer.
7. Graphic panels shall be created to replicate process and equipment using ISA standard and/or custom build symbol library. The system shall support 3D representations with rich color combinations for static and dynamic indications.
8. Data refresh rate in graphics for hardwired IOs shall be 1-2 sec and through communication shall be 3-5 sec.
9. Reports shall support standard and custom developed allowing multiple report formats (shift-wise, daily…), scheduled and adhoc reporting.
10. Number of reports and graphics shall be based on operational needs and shall not limited by the number of licenses
11. Ability to configure and operate sequence and control functions in
    a. Auto and Manual modes
    b. Start-up Bypass and Overrides for interlocks
    c. Maintenance Modes
12. Ability to synchronize time
13. Alerts on critical alarms and/or data shall be send to key operation/maintenance personal over SMS and/or emails
14. Diagnostic details from various system components shall be presented as alarms in the system

B. SCADA Server

The SCADA Server (SCD) shall be PC based running SCADA/HMI software on a Windows Server 2019 or latest operating system. This server will collect raw data from the ICS Controller, Safety System, Fire and Gas System, and third-party PLCs to make it available to operator works stations. The SCADA servers shall be configurable as redundant pairs. The following hardware requirements apply, else virtual hardware should be assigned with similar capability.

Minimum specification for Server shall be:

- Intel I7 processor or better
- 16 GB RAM, Min. 1TB SSDs with Raid 3
- Dedicated Graphics Card, Network Card
- Single 32" Monitor, Keyboard and Mouse

C. Operator Workstation

Operator Workstation (OWS) shall be PC based running SCADA/HMI software on Windows 10 or latest operating system. Operator shall use this as a single window for the control and monitoring of the entire process and facility related input/outputs. Its shall comply with ISO 9241-5, 9241-302 and 9241-303 and ISO 11064.

Minimum specification for OWS shall be:

- Intel I7 processor or better
- 16 GB RAM, Min. 1TB SSDs
- Dedicated Graphics Card, Network Card
- Single 32" Monitor, Keyboard and Mouse.

D. Engineering Workstation

Engineering Workstation (EWS) shall be PC based running SCADA/Programming software on Windows 10 or latest operating system. A single software platform that allows configuration of controllers and SCADA HMI is preferred. EWS shall include OWS software also.

Minimum specification for EWS shall be:

- Intel I7 processor or better
- 16 GB RAM, Min. 1TB SSDs with Raid 3
- Dedicated Graphics Card, Network Card
- Single 32" Monitor, Keyboard and Mouse.

EWS shall be based on IEC-61131-3 for programming of controllers and HMI.

E. ICS - Controller

Features and requirements of CPU stated below shall be met.

a. Be of robust design using reliable components with high availability. Be compact, stand-alone din rail mountable.

b. Not include moving ports whose failure results in failure or degradation of system performance. All the performances committed shall not deteriorate in the entire range of operating temperature.

c. Support redundancy for hot-standby operations

d. Possess redundant equalizing ports (no single point failure) to exchange diagnostic/failure details to perform switchover. Switch overtime shall be of the order of 300 mSec.

e. Support multiple scan times for digital processing (50 msec), critical analogue controls (500 msec) and 1 second for the rest.

f. Capable of solving application logic, storing the application program and having an OLED status display.

g. Be based on intel or compatible microprocessor operating at speeds no less than 1GHz as the main processing element, memory mounted on the board. A min of 32Mb of retentive user memory shall be on board for user configurable application data storage and documentation storage.

h. Possess dedicated ethernet ports with speeds of 10/100/1000mbps for IO communication.

i. Be cyber secure with a certification like Achilles 2 or equivalent. Additionally, it shall include provisions around password protection, encrypted communications, encrypted firmware updates. All devices, testing and processes shall be adhered to IEC 62443.

j. Be certified CE, UL, ATEX, C1D2, ATEX Zone 2, ABS, BV, DNV, GL for operating in harsh environment.

k. Support Modbus TCP/IP, HART Passthrough, Profinet, OPC UA, DNP3 protocols for devices and/or packaged system integration

l. The CPU should have the capability to interface to the cloud and send data, if required.

F. Networking

Firewalls shall be used as a method of protection between the ICS, any third-party equipment, and the cloud/internet if applicable. The firewalls used should provide deep packet inspection of any industrial protocols used by third-party equipment. These firewalls shall operate in a redundant configuration.

Industrial Ethernet switches shall be used in the ICS cabinets that meet the environmental requirements of the site. These switches shall operate in a redundant configuration. The switches shall be L2 Managed type that supports

a. 24 VDC power input

b. 10/100 mbps copper port

c. 1000 mbps fibre port

d. The number and type of ports shall be decided based on the number of connections to the devices.

e. Industrial grade suitable for operating at 70 Deg C temperature

One router per site shall be installed in the ICS cabinets that meet the environmental requirements of the site. The router shall facilitate a wired WAN interface to connect to the local ISP's (internet service provider) modem and support a cellular interface as a backup. An outdoor antenna will be required for a strong cellular connection. These types of routers do not function as a redundant pair.

All networking devices, PLC system, service shall be in synchronization with 100% redundant external clock i.e. GPS

G. ICS – Input / Output

ICS shall include dedicated remote IO racks installed in multiple locations and connected to the centralized CPUs. IO racks shall include power supplies, communication to CPU and various types of IO cards.

IO Cards in general possess/support the following features.

a. LED indicators for Power, Healthiness of card and status of digital signals
b. Galvanic isolation between system and field to 1500 VAC
c. Noise filters
d. Hot replacement i.e., removal and insertion with power on
e. Reverse polarity protection
f. Diagnostics to detect failures and send status updates to the controller/HMI.

There shall be a maximum of 1 model number used for each of the following I/O types in the ICS to minimize the amount of spare I/O cards the customer will need to keep on hand:

a. Discrete Inputs, Discrete Outputs
b. Analog (4-20 mA) Inputs and outputs
c. RTD/TC Inputs, Pulse Inputs

The maximum number of channels allowed for AIO cards is 16 and DIO cards is 32.

H. Data Historian

SCADA server shall be capable of storing raw, computed and aggregated data as defined in a structured database for extended periods of time (one year). Data from the historian shall be used for reporting, performing analytics and shared with Owner systems. Data communication to external systems shall be using OPC protocol. Any other protocol shall be with prior approval from Owner.

I. Web Clients

Using Web Clients, the system shall facilitate remote access to the data and/or graphical/report data for the purpose of monitoring. Mobile phones, tablets or PC connected through internet from a far location shall be allowed to access with proper user authentication. Also, it shall be able to use remote access in parallel to the local access in the control center.

J. ICS – Redundancy Requirements

Listed below are the guidelines identified for the redundancy requirements of this plant.

- CPU, IO communication and power supplies shall be redundant

- Critical IO(s) and communication links shall be redundant.
- OWS shall be minimum two in numbers: 1 x OWS and 1 x OWS cum EWS.
- EWS shall be minimum one in number: 1 x EWS (excl of above)

Depending on the process operational needs additional OWS may be requested.

K. ICS – Spare Philosophy

Listed below are the minimum spare requirements.

a. IO cards shall include 10% of spare channels and shall be distributed evenly in multiple cards.

b. IO racks shall include 10% slots for installation of additional cards.

c. Power supplies shall have 20% excess capacity on top of what is required with all channels + installed spares.

d. Cabinets shall have 20% spare space to accommodate the additional installed spares/space.

e. Terminals and cable raceways shall have 20% spares on top of what is required with all channels + installed spares.

f. Accessories such as MCBs, signal conditioners, barriers and surge protectors – as applicable shall be per installed spares channel requirements.

g. Network ports shall include 20% spare ports.

h. Network loading shall not be more than 40% during normal operations.

i. CPU shall have an additional 25% capacity for future additions.

j. Licenses considered shall be on the based-on resources required for given IO with installed spares plus 25% for future expansion.

L. ICS – Single Window

The ICS shall be the single unified platform for monitoring and control needs of the entire plant including process, utilities and facilities.

- To the extent possible, all IO(s) from process and package equipment shall be wired to the ICS and controls implemented in it. Consider usage of package PLC(s) only for impossible cases with approval from the Owner.

- Provide control and monitoring details for the ICSV to develop standardized operation and control philosophy. Key documents that ICSV need from bidder or OEM, or its supplier are.

- P&ID, IO list and Summary with alarm limits and priorities

- C&E matrix, Sequence, Control narratives

- Interlocks with bypass and overrides, Cable schedule

- Entire control system shall be ordered and executed through a single entity of ICSV to ensure consistency in terms of hardware components, assembly and integration, software design with same look and feel.

Additional Information-I: List of Standards

The below list of standards to be followed for design, erection/installation/construction, commissioning & testing, O&M of equipment, building & layout etc., for entire project by the bidder. List of standards which are detailed below, and it is not limited, latest and other standards for Hydrogen Application are also applicable.

S. No.	Standards	Description
1	ISO 14687: 2019	Hydrogen fuel quality — Product specification.
2	ISO 22734: 2019	Hydrogen Generators using water electrolysis – Industrial, Commercial & Residential Applications.
3	ISO/TR 15916:2015	Basic considerations for the safety of hydrogen systems
4	ISO 12944-2:2017	Paints and varnishes — Corrosion protection of steel structures by protective paint systems
5	NFPA 2	Hydrogen Technologies Code.
6	NFPA 10	Standard for Portable Fire Extinguishers.
7	NFPA 14	Standard for the installation of Standpipe and Hose System
8	NFPA 20	Standard for Installation of Stationary Pumps for Fire Protection
9	NFPA 22	Standard for Water Tanks for Private Fire Protection
10	NFPA 24	Standard for the Installation of Private Fire Service Water Mains
11	NFPA 70	National Electrical Code
12	NFPA 2001	Standard on Clean Agent Fire Extinguishing Systems.
13	ANSI / ASME A13.1, (or) ASME A13.1: 2020	Scheme for the Identification of Piping Systems.
14	ASTM G93/G93M-19	Standard Guide for Cleanliness Levels and Cleaning Methods for Materials and Equipment Used in Oxygen-Enriched Environments.
15	IEC 60079	Electrical apparatus for explosive gas atmospheres
16	ASME B31.12:2019	Hydrogen Piping and Pipelines
17	ASME B31.1:2022	Power Piping
18	API-RP	American Petroleum Institute - Pipeline Recommended Practices (RP)
19	EC-79	European Regulations
20	ATEx & IECEx	EU directives - minimum safety requirements for workplaces and equipment used in explosive atmospheres. IECEx – The IEC System for Certification to Standards relating to Equipment for use in Explosive Atmospheres
21	BIS IS 3792: 1978(R2004)	Guide for heat insulation of non-industrial buildings.
22	IS:875 (Part 1) - 1987	Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures (Part 1 – Dead Loads)
23	IS:875 (Part 2) - 1987	Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures (Part 2 – Imposed Loads)

24	IS:875 (Part 3) - 2015	Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures (Part 3 – Wind Loads)
25	IS:875(Part 5)– 1987	Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures (Part 5 – Special loads & load combination)
26	IS:1893(Part 1) -	Criteria for Earthquake Resistant Design of Structures (Part 1 –
27	IS:1893(Part 2) - 2014	Criteria for Earthquake Resistant Design of Structures (Part 2 – General Provisions for Liquid retaining structures)
28	IS:1893(Part 3)-	Criteria for Earthquake Resistant Design of Structures (Part 3 –
29	IS:1893(Part 4) - 2015	Criteria for Earthquake Resistant Design of Structures (Part 4 – Industrial Structures including Stack-Like Structures)
30	IS:800 - 2007	Code of Practice for General Construction in Steel
31	IS:808 - 1989	Dimensions for hot rolled steel beam, column, channel and angle
32	IS:813–2018	Scheme of Symbols for Welding.
33	IS:456 - 2000	Plain and Reinforced Concrete – Code of Practice
34	IS:13920 - 2016	Code of practice for ductile detailing of reinforced concrete structures subjected to seismic forces
35	IS:1786 - 2008	Specification for high strength deformed steel bars and wires for concrete reinforcement
36	IRC:6 – 2014	Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses (Fourth Revision)
37	IRC:21 – 2000	Standard Specifications and Code of Practice for Road Bridges, Section III – Cement Concrete (Plain and Reinforced) (Third Revision)
38	IRC:58 – 2015	Guidelines for the Design of Plain Jointed Rigid Pavements for
39	IRC:15 – 2011	Standard specifications and code of practice for construction of
40	IS:3370 (Part 1) –	Concrete structures for storage of liquids – General requirements
41	IS:3370 (Part 2) –	Concrete structures for storage of liquids – Reinforced concrete
42	IS:3370(Part 4)–	Code of Practice for Concrete Structures for Storage of Liquids; Part
43	IS:1904–1986	Code of Practice for Design and Construction of Foundations in Soils
44	IS:1905 – 1987	Code of Practice for Structural use of Un-reinforced Masonry
45	IS:11089 – 1984	Code of practice for design and construction of ring foundations
46	IS:6509 – 1985	Code of practice for installation of joints in concrete pavements
47	IS:2062 -2011	Code of practice for Hot rolled medium and high tensile structural
48	IS:1080–1985	Code of Practice for Design and Construction of Shallow
49	IS:2950(Part 1)–	Code of Practice for Design and Construction of Raft Foundations
50	IS:4326–1993	Code of Practice for Earthquake Resistant Design and Construction
51	IS:11089–1984	Code of Practice for Design and Construction of Ring Foundation;
52	IS 3646:1992	Code of practice for interior illumination
53	**PESO**	**Gas cylinder Rule, 2016**
54	**PESO**	**Static & Mobile Pressure Vessel (Unfired) Rules, 2015**
55	IBR- Regulation 374	Indian Boilers Regulations - 1950, Regulations
56	IS 7861:2009	Code of practice for extreme weather concreting
57	IS 6248:1979	Metal Rolling Shutters and Rolling Grills
58	**PNGRB**	**All PNGRB T4S standards and guidelines**

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