ANNEX 1

TECHNICAL SPECIFICATIONS

FOR THE DESIGN, SUPPLY, INSTALLATION, COMMISSIONING AND TESTING

OF A P2G/L PILOT PLANT

RICERCA DI SISTEMA (RDS)- PIANO TRIENNALE 2019-2021

Table of contents

1. Purpose of the document

This document represents the technical and descriptive file, annex to the tender documentation, for the design, supply, installation, commissioning and testing of an extremely flexible P2G/L pilot plant. The pilot plant will be designed to produce methane (CH_4), methanol (CH_3OH) and dimethyl ether (DME, CH_3OCH_3) through catalytic hydrogenation of carbon dioxide (CO_2) coming from capture processes, and using hydrogen produced with electric power surplus from renewable sources.

This project is framed by the 2019-2021 Plan of the Italian Ministry of Economic Development, which defines the general purpose, themes and funding for the R&D activities on the national electric system, and particularly the theme 1.2, "Accumulators, including electrochemical and power-to-gas, and grid connections". The pilot plant will be installed in the Research Centre of Sotacarbo, Grande Miniera di Serbariu, Carbonia (Italy).

2. Minimum technical characteristics of the supply

For flexibility purposes, the plant will have to be equipped with two different reactors, one for methanol and DME synthesis and one for methane synthesis, fed by the same gas feeding system. The setup must be designed for a production of 2 – 5 kg/h of final product (methanol, methane or DME). Methane must be produced with a minimum purity of 96%. Fig. 1 shows a simplified diagram of the process.

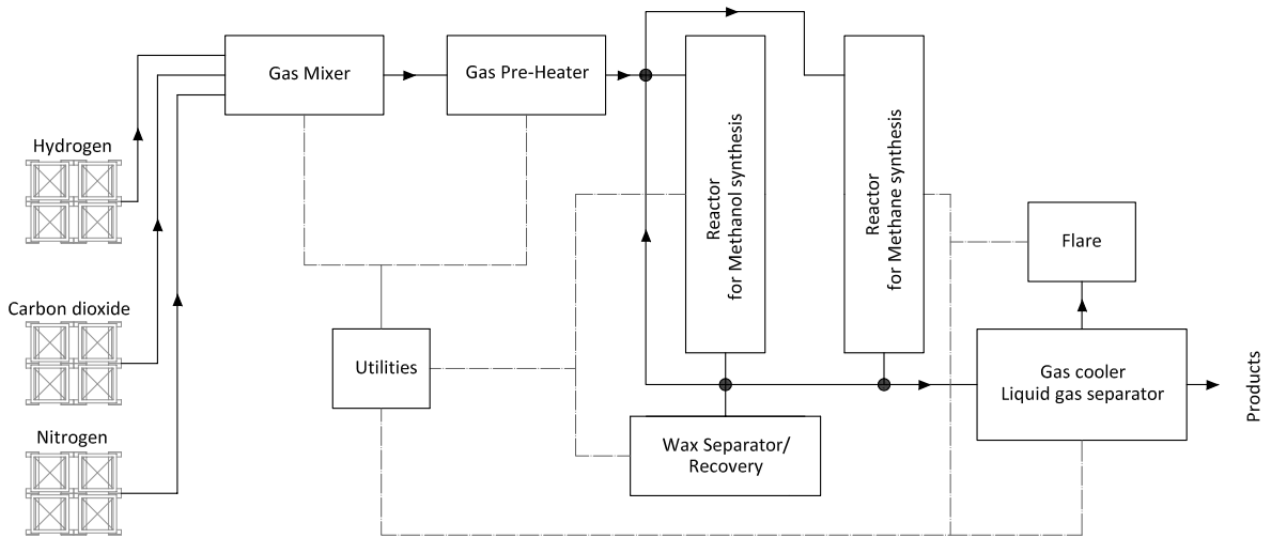

Fig. 1. Simplified diagram of the process

Specifically, the pilot plant can be conceptually divided in the following sections:

- Feeding and gas mixing system;
- Gas mixture pre-heating system;
- Reaction system (composed by two different reactors fed by the same feeding system);
- Recirculation system;
- Gas cooling system and gas-liquid separator;
- Collection system of condensable and non-condensable products;
- On-line analysis system of the flue gas;
- Off-line analysis system of the condensable products;
- Regulation and control system.

Tab. 1 reports the gases coming from the feeding systems (not included in the present supply), with the range of pressure and temperature requested.

Tab. 1. Gases from the feeding system

Gas	Pressure [bar]	Temperature [°C]
CO_2	40-60	Ambient
H_2	40-80	Ambient
N_2	40-80	Ambient

All the plant components and lines will have to be made of a material compatible with the operating conditions specified in the following paragraphs. The winning bidder will have to study the characteristics of insulation in order to respect the plant technical specifications.

The plant will have to be furnished with all the necessary devices to guarantee the correct operation and safety, in accordance with the Italian regulations, such as: ATEX – Direttiva 2014/34/UE; PED – Direttiva 2014/68/UE; etc.

2.1 Gas mixer

The plant will have to be equipped with a system that homogeneously mixes the pure gases coming from the feeding system. The gas mixture will have a composition in accordance with the ranges indicated in Tab. 2.

Tab. 2. Composition ranges for the gas mixture (upstream of the reactor)

Gas	Concentration [%vol]
CO_2	0÷50
H_2	0÷80
N_2	0÷100

2.2 Gas mixture pre-heater

The line connecting the gas mixer to the reactors will have to be equipped with a heater. The heater should be designed to raise the gas mixture temperature from ambient values to the nominal operating temperature.

2.3 Reactors

The plant will have to be equipped with two different reactors, one for the methanol and DME synthesis and one for the methane synthesis. Each reactor will have to be designed and made in conformity with the operating conditions indicated in Tab. 3.

Tab. 3. Operating conditions for the two reactors

	Methanol and DME synthesis reactor	Methane synthesis reactor
Nominal pressure	35 bar	8 bar
Maximum pressure	60 bar	25 bar
Nominal temperature	250 °C	325 °C
Maximum temperature	350 °C	500 °C

Each reactor will have to be thermally insulated and equipped with a heating system for the experimental start-up procedure. The heater and insulation should guarantee an isothermal zone inside each reactor along the catalytic bed length.

2.4 Recirculation line

In order to increase the reaction efficiency, a recirculation line must be included. The recirculation line has the function to send part of the products exiting the reactor back to the reactor inlet. The recirculation rate will have to be set by means of the control system.

2.5 Wax trap

At the methanol reactor outlet, the plant will have to be equipped with a wax trap to condensate any product with high molecular mass that could form during the reaction.

2.6 Gas cooling system

The plant will have to be equipped with a cooling system of the products exiting the reactors. The cooling system should be able to bring the product temperature to ambient values.

2.7 Liquid-gas separator

The setup will have to allow, in case of methanol synthesis, the condensation of the product liquid fraction and the separation of the non-condensable fraction (represented by the unreacted gases).

2.8 Flare

The plant will be equipped with a flare to burn the final products leaving the setup to external atmosphere. The inclusion of the torch in this supply is still to be verified. However, even in case Sotacarbo supplies the torch, the torch-setup connection is included among the required works of the winning bidder.

2.9 Instrumentation

The plant will have to be provided with all the instrumentation to measure, monitor and set the main process parameters. The minimum instrumentation required is:

- Temperature and pressure measurements downstream of the gas mixer;
- Temperature and pressure measurement at top and bottom of each reactor;
- Temperature measurement in at least three points of the catalytic bed of each reactor;
- Temperature and pressure measurements in the gas cooler / liquid-gas separator;
- Flow rate measurements for each gas entering the setup;
- Flow rate measurements of the gas mixture upstream and downstream of each reactor;
- Sampling of the gas mixture upstream and downstream of each reactor;
- Sampling of the liquid out of the gas cooler / liquid-gas separator;
- Sampling of the gas to the flare.

All the recirculation lines must be equipped with temperature, pressure and flow meters. The possibility to sample the gas mixture must also be guaranteed.

The measurement sensors must have a high accuracy class in the reference conditions (temperature and pressure ranges, flow rates, instrument positioning, etc), to be defined based on the specific process.

All the instrumentation must be capable of remote operation, through the plant regulation and control system.

2.10 Regulation and control system

The plant will have to be equipped with a monitoring, regulation and control system. The control system must allow:

- Remote operation from a dedicated control room;
- Setting of all the process parameters (heater temperatures, flow control, on/off valve operations, etc);
- Monitoring and recording of the sensor measures (temperatures, pressures, mass flows, etc) and device states.

The control system must include all the hardware and software components required for the correct plant operation and a switchboard for the power management of the devices.

3. Minimum documentation requirements

The supply must include all the documents and certifications provided by the current regulations. In particular it is required:

- Overall plant layout;
- P&ID;
- Process flow diagram;
- List of lines by gas/fluid;
- List of instruments;
- Equipment datasheets and instrumentation calibration and test certificates;
- Regulation and control system specifications and control logics;
- Electrical schemes for the power supply and control system switchboards;
- List of the loadings for the structural design (loads and moments);
- List of the plant interfaces;
- Commissioning specifications.

The characteristics of all the components must be supplied, together with the design reports for the custom-made components.

At the end of the work, the following documents must be supplied:

- *As-built* documentation, including plant layout, P&ID, process diagram, pipeline list, instrumentation list, reactor technical drawings;

- Operating and maintenance manual, including instructions, specifications and drawings relating to the plant and its components and their operation and maintenance.

All documents and certifications must be supplied in Italian language.

4. Inclusions

The supply must include:

- Transportation and installation of the plant and all its necessary components to the site located in the Sotacarbo pilot platform, Grande Miniera di Serbariu, Carbonia (Italy);
- Transportation from and to the plant site, or any handling or movement within the site, related to all the materials, equipment and vehicles necessary for the execution of the work;
- Laying of cables and cable trays and everything necessary for the correct installation and operation of the electrical system and control system;
- All the services performed as part of the supply in compliance with any provision of current regulations;
- All direct and indirect duties related to the installation, commissioning, testing and anything else required for the supply of the fully operational setup;
- All direct and indirect duties related to the on-site training;
- All the duties related to the disposal of any waste produced during the delivery, installation and commissioning phases of the supply;
- All the documentation, also that not specifically mentioned in this document, required by local or national authority or applicable as customary rule;
- Everything not specifically mentioned in this document, necessary for the execution of the work in accordance with best practice.

All the machinery and work equipment made available by the winning bidder to its workers must comply with the current regulations and be suitable for the purpose of the tasks carried out and for the health and safety of the workers.

5. Exclusions

The supply does not include:

- Gas feeding system (first stage pressure regulators, pipelines from the cylinders to the plant battery limit, battery limit valves);
- Products and materials required for the plant operation and for the execution of the experimental tests (pure gases, catalysts, etc);

- Fire prevention/suppression system and gas detectors;
- Any change to the existing structure;
- Civil works and cable conduits;
- Ground electrodes;
- Permits from the Fire Service and the local health authorities;

Sotacarbo will provide:

- Lifting equipment for receiving material and components object of the supply;
- Storage area for the components of the plant, before their installation;
- Electricity, water and compressed air needed for the work.

6. Installation, commissioning, testing and start-up assistance

The supply includes the installation of the plant and its components and the connection of the plant to the existent auxiliary systems. The winning bidder will also bear all the costs related to the preliminary inspection of the installation area and the execution of the testing activities.

At the end of the installation and commissioning phases, the plant will have to be tested according to a detailed plan defined and shared during the final phase of the design. In particular, the activity will concern:

- Verification of compliance with the project;
- Functional testing of individual components and systems and the entire plant;
- Testing of the regulation and control system.

At the end of the testing phase, a certificate of testing and compliance with the project will be prepared.

The winning bidder must guarantee a period of assistance to Sotacarbo staff for the plant start up and the first experimental tests.

7. Supply and battery limits

The winning bidder will have to supply a document with the following indications:

- Definition of the battery limits;
- List and specifications of the flows entering and exiting the battery limits;
- List and specifications of the auxiliary services necessary to the supply.