Proposal title:

"Advanced direct biogas fuel processor for robust and cost-effective decentralised hydrogen production" BioRobur^{Plus}

Topic:	FCH-02-2-2016. Development of compact reformers for distributed bio-hydrogen production
Funding scheme:	Collaborative project
Start date of project:	1st January 2017
Duration:	42 months

Deliverable: Plant Specification (process and services)

Organisation name of lead contractor for this deliverable: Hysytech srl

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Disemmination level: PU

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Versions and Changes

Version	Date	Changes	Author
1	11.08.2017	Deliverable Version 1	Luigi Marchisio
2	25.09.2017	Deliverable Final Version	Luigi Marchisio
3			
4.			

Contents

1. Executive Summary

The present deliverable contains the specifications for the overall fuel processing system of the Biorobur^{Plus} Project.

In particular are here described the process requirements for feeding flexibility and the product quality specification issued accordingly to market consideration and biogas typical availability. As far as industrial services are concerned, also the specifications of type and quantity are defined and adjusted to the availability of already present services at the instllation site in Acea.

Specifications of very preliminary plant dimensions, noise, and emissions are here defined. As well as the communication architecture and the interfaces between the sensors and the master control used for long run data logging.

2. Fuel Processor System

Referring to the conclusion concerning the BioRobur^{plus} process (Deliverable 3.1), here below is showed the Block Flow Diagram of the Fuel Processing System. The scheme shows the interconnections between the different sub-units of the plant and the battery limits (Air, Biogas, Water, H_2 and Offgas).

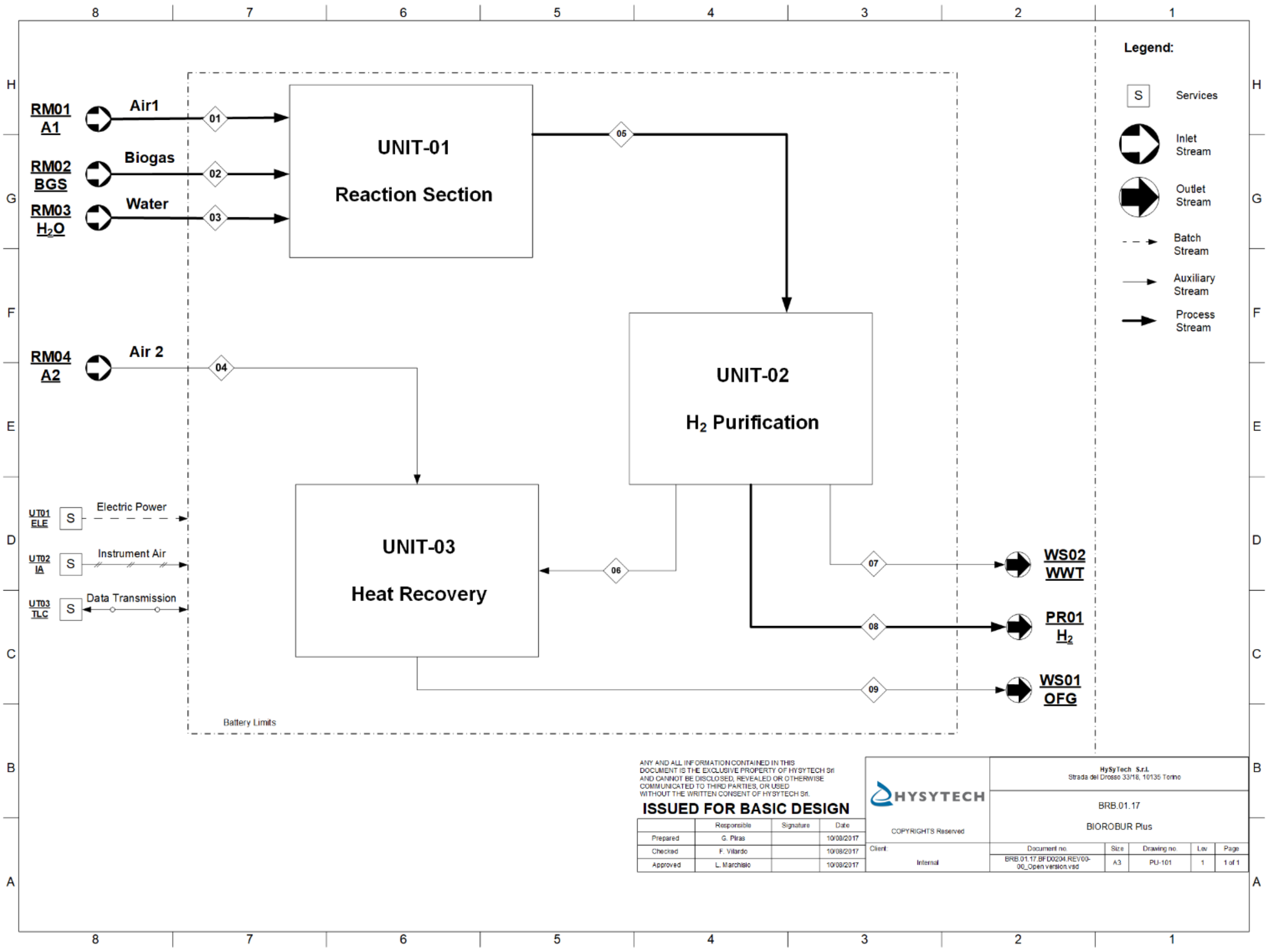

Fig. 2.1 BioRoburplus MEA-fee BFD.

3. Battery Limits Specification

The battery limits of the fuel processing system will be defined in detail (number, reference standard, dimension, position) into the Deliverable 5.2, here are defined the general specification.

The connection to the battery limits is composed of two terminal connections (for example, flanges, fittings, clamps, etc.). One of the terminals is located within the battery limits of the Biorobur Plus fuel processing system ("Plant Side"), the other is located outside the battery limits of the fuel processing system ("Site Side"). The Site Side is the biogas generation plant of ACEA, where the system will be installed and tested.

All terminal connections, both Plant side either Site side, must be made in accordance with the specification of the Deliverable 5.2 (eg. material, connector type, size, standard, etc.). The plant has the following types of Connections:

- “Process Connections”:
  - “Inlet Flows”as defined below;
  - “Outlet Flows”as defined below.
- “Services Connections”as defined below.

3.1.Inlet Specifications

The inlet flows for the fuel processing system are below specified:

1. Biogas

Biogas is a gaseous mixture consisting primarily of Methane (CH_4) but including significant quantities of Ethane (C_2H_6), Propane (C_3H_8) and higher hydrocarbons (C_xH_y) as well as Carbon Dioxide (CO_2) and Nitrogen (N_2).

Biogas is mainly obtained from:

(i) Fermentation process (digester) of:

(a) Agricultural wastes;

(b) Waste of agrifood industry;

(c) Wastewater treatment plants; or

(d) Municipal organic waste (or alike);

(ii) Landfill gas collection.

The source of the biogas influences its normal compositions (on dry basis):

Tab. 3.1 Normal composition of Biogas from different sources

	Fermentation	**Landfill**
Methane (CH_4)	58,2%	55,0%
Carbon Dioxide (CO_2)	41,2%	38,9%
Nitrogen (N_2)	0,5%	5,0%
Oxygen (O_2)	0,1%	1,0%

In particular, depending from the sources, the biogas contains not negligible quantities of compounds, as impurities, that must be taken into account during the design of the pre-treament unit of the fuel processing system.

In the Biorobur Plus project the fuel processing system will be installed into the Acea site where the biogas is obtained via fermentation. The maximum levels of impurities present on the Acea biogas are:

(i) Hydrogen Sulphide (H_2S): 1.000 mg/Sm^3 (Maximum);

(ii) Liquid Water (H_2O): Dew Point @ 40°C & 0 barg;

(iii) Aromatic Hydrocarbons: 200 mg/Sm^3;

(iv) Solid Particles Content (< 5 μm): less than 1% (Maximum);

Some of them can quickly poison the catalyst (H_2S) or compromise seriously the system capacity. A pre-treament unit is needed to reduce them to quantity that can be bear by the system. These quantities will be defined accordingly with the parters directly involved into the design of the system equipment.

The main carachteristics of the Biogas stream are:

Flowrate (Min / Nor / Max):	ns / 37,5 / 56,3 kg/h
Temperature (Min / Nor / Max):	15 / 35 / 50 °C
Pressure (Min / Nor / Max):	0,01 / 0,02 / 0,03 barg

The normal low biogas feeding pressure is not an issue for the Biorobur system because using the ejector, driven by the steam used for the reforming reactions, the biogas is sucked inside the plant.

2. *Water*

Water is here intended as demineralised water. It is used by the ATR Reactor as a reactant for the steam reforming reaction. The water is feeded to the reactor as steam which is produced trough evaporation, using the heat exchangers that recover thermal energy from the whole system.

Water must meet all the specification set below:

- Chemical Formula: H_2O;
- General Characteristics: colourless, odourless, non toxic, non flammable;
- Total Hardness: Non detectable;
- Conductivity at 25°C: < 1 μS;
- Purity: > 99,99% by weight;
- Impurities:
  - Carbon Dioxide (CO2): 1 mg/l (Maximum);
  - Iron (Fe): 0,01 mg/l (Maximum);
  - Cupper (Cu): 0,003 mg/l (Maximum);
  - Silica (SiO2): 0,02 mg/l (Maximum);
  - Potassium Permanganate (KMnO4): 5 mg/l (Maximum);
  - Oil traces: 0,2 mg/l (Maximum);

A pre-treament unit is needed to demineralize the water to avoid fouling inside the steam production heat exchangers that can compromise the system capacity.

The main carachteristics of the Water stream are:

Flowrate (Min / Nor / Max):	ns / 45 / 67,5 kg/h
Temperature (Min / Nor / Max):	10 / 20 / 30 °C
Pressure (Min / Nor / Max):	0,5 / 1 / 2 barg

3. *Air (Process Air)*

Process Air is here intended as the atmospheric air used as reactant inside the ATR Reactor to generate the thermal energy to suistain the endothermic reforming reactions.

According to the conclusions of the D3.1, Process Air is feed to an O_2 Generator that produce a stream of Oxigen (95% by volume) that flows to the ATR reactor. Process Air need to be filtered (maximum dust 0,01 μm).

Flow (Min / Nor / Max): ns / 95 / 142,5 kg/h

Temperature (Min / Nor / Max): -5 / 20 / 35 °C

Pressure (Min / Nor / Max): atm.

4. *Air2 (Combustion Air)*

Combustion Air is here intended as the atmospheric air used as oxidant inside the Off-gas Burner to generate the thermal energy needed by the system.

Combustion Air does not need any particular pre-treatment. Only a standard particulate filter shall be installed on the suction of the Combustion Air Blower.

Flow (Min / Nor / Max): ns / 43 / 64,5 kg/h

Temperature (Min / Nor / Max): -5 / 20 / 35 °C

Pressure (Min / Nor / Max): atm.

3.2. Outlet Specifications

The outlet flows for the fuel processing system are below specified:

1. *H_2 (Hydrogen)*

Hydrogen is here intended as the product of the fuel processing system. TheBiorobur Project requires the following objectives for the Hydrogen:

Characteristic: 3.0 Grade (99,9% purity by volume)

Flow (Min / Nor / Max): ns / 50,4 / ns Nm3/h

ns / 107,5 / ns kg/day

Temperature (Min / Nor / Max): 15 / 40 / 50 °C

Pressure (Min / Nor / Max): 10 / 12 / 15 barg

The Hydrogen produced by the Biorobur system does not need any further purification and can be directly fed to the storage system or to final users.

2. *Plant Offgas*

Plant Offgas is here intended as the product of the combustion between the Combustion Air and the Process Offgas (produced by the H_2 Purification Unit) into the Heat recovery unit. The Plant Offgas is the only continuous gaseous waste produced by the fuel processing system. The Plant Offgas has the following characteristic:

Flow (Min / Nor / Max):	ns / 72,6 / 108,9 Nm^3/h
	ns / 107,2 / 160,8 kg/h
Temperature (Min / Nor / Max):	120 / 150 / ns °C
Pressure (Min / Nor / Max):	0,01 / 0,02 / ns barg
Molar Composition (Normal):	

Tab. 3.2 Normal composition of Plant Off-gas

CO_2	42,4%
CH_4	0,0 %
O_2	2,5 %
N_2	36,8 %
H_2O	18,3 %
H_2	0,0 %
CO	0,0 %

3.3. Utilities Specification

Here are indicated the specifications for the industrial services (hereafter **"Services"**) required for the installation, operation, start-up and shut-down of the fuel processing system.

Tab. 3.3: Utilities list

Identification	**Description**	**Characteristics - composition**	**Type**	**Tie-in at**	**Design temperature [°c]**	**Design pressure [bar g]**	**Supply**
UT01-N2	Nitrogen (inertization)	N_2 (99,9%)	Utility	B.L.	Ambient	20	Cilinder
UT02-ELE	Electric supply	400 V AC 50 Hz	Utility	B.L.	-	-	Electrical Network
UT03-CAI	Instrument Air	Filtered - oil free- dehumidified	Utility	B.L.	Ambient	16	Piping

(i) **UT01-N2**, Nitrogen

Nitrogen will be used to inertization of the fuel processing system during start-up and shut-down procedures.

O_2 content	0.1 % vol max
Operating Pressure (barg)	5
Operating Temperature (°C)	20
Design Pressure (barg)	10
Design Temperature (°C)	60

(ii) **UT02 – ELE**, Electric supply

Line 1: 400 V ± 2,5% AC (3ph + N + G) 50 Hz

Max Power installed: 40 kW;

Estimated maximum consumption: 34 kW, ≤ 58 Amp;

Not added under emergency generator.

(iii) **UT03-CAI**, Instrument Air

Instrument Air must comply with the folliwing specifications:

Feed pressure: 8 barg (Max), 6 barg (Min);

Filtered and oil-free (maximum oil content 0,003 ppm; maximum dust 0,01 µm);

Dehumidified with due point: -3 °C (Max).

If instrument Air is not available at B.L. shall be considered to have a compressor, with filtration stage and storage vessel, inside the Battery Limit of the system.

4. Noise

This plant will be designed to minimize the noise level in order to keep it below the allowed limits. The operation of the system will do not require the presence of operators and the use of specific hearing protection (noise level < 80 dB).

Very specific requirements, related to the noise protection, will be eventually issued after the detailed engineering design. The fact that the plant will be containerized will reduces the magnitude of the consequences for the peoples and the environment.

5. Control Systems Philosophy and General Architecture

The plant of the Biorobur project had a control system (Emerson DeltaV control system) which, according with the GRANT AGREEMENT, should be completely recovered and updated and / or integrated where needed. The following figure shows the Control System Architecture of the control system:

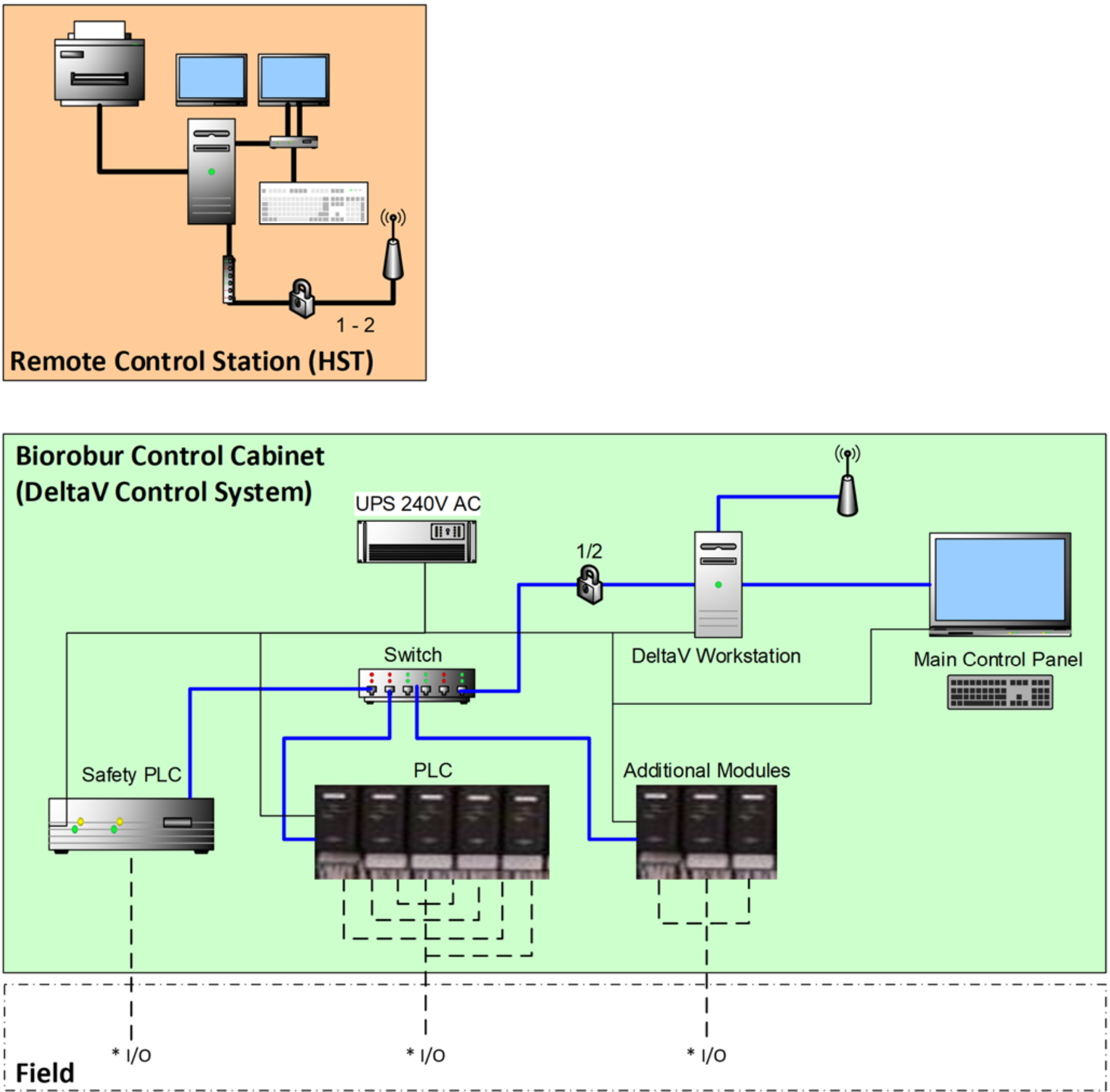

Fig. 4.1 Control System Architecture

- Network Interfaces: the system shall maintain full comunication in case any of the interfaces/COM is down. Interface shall allow comunicartion with third parties PLC's or with the remote-control station placed at Hysytech Headquarter.
- PLC: Executes both DCS funtions and logics as well as Safety functions. Additional I/Os modules will be needed to manage the additional signals of the new plant.

- DeltaV Workstation: is the PC where is installed the software and where are connected the license keys that allows the system to be programmed and operated. Datalog files are automatically generated by the control software and can be read from the PC.
- UPS: shall feed the control system for the time necessary at PLC to take the system in Emergency Shut-Down: PLC's, Workstation, communication devices and Field instrumentation and valves (Motors Excluded) are under UPS line.
- Main Control Panel: is the HMI of the plant. The control panel is conceived to monitor all the process variables, their setpoints are shown and can be read and written both from local and remote using different level passwords. The measured variables trends are shown into dedicated charts updated with a choosen frequency.

This deliverable was prepared on-time, but the issue was postponed because of the DeltaV Control System components availability inspection was ongoing. To avoid major delays was decided to issue anyway the deliverable. At the moment, the confirmation of the full recovery of the DeltaV Control System is still ongoing. In case of unavailability of key components, the Partners will decide to replace the control system (electrical cabinet, PLC, panles and software for process control) with a completely new one and this reliverable will be amended.

5.1.Instrument Specification

One of the aims of the Biorobur Plus Project is to recover as much as possible the instrumentation of the old project Biorobur. Following this principle all the new instruments (temperature, pressure, flow transmitters and indicators) shall have the same specification already used in the other project in particular regarding the communication with the control system.

Here below are listed the main specification:

- Power supply: 24 VDC;
- Signal for analogic instruments: 4..20 mA;
- Signal for digital instrument: 24 VDC (normally open);

6. Preliminary layout

One of the aims of the Biorobur Plus Project is to recover some of the equipment of the old project Biorobur.

The Biorobur plant was installed into containers and this principle will be maintained also for the Biorobur Plus project. Use of containerized plant has many advantages:

- Prefabbrications. All the equipment, valves and instrument can be pre-assembled and wired inside the container. Supplier can run preliminary Factory Acceptance Tests to do preliminary tests and decrease installation and start-up times;
- Transportability. The ISO container have standard sizes worldwide accepted handled by truck and ship;
- Quick Installation. Only the set-up of the battery limit connections (mechanical and electrical) are needed;
- Lower surface consumption related to standard plant;
- Removeability. In case of dismantlement or moving of the plant.

The detailed layout of the plant will be issued with the detailed engineering design, here is shown a preliminary version used for the permitting process:

- Reactor, WGS and Burner Container (in blue ATEX zone II due to leackage);
- H2 Purification Unit Container (in blue ATEX zone II due to leackage, in yellow ATEX zone II due to PSV);
- Flare (in orange the safety distance);

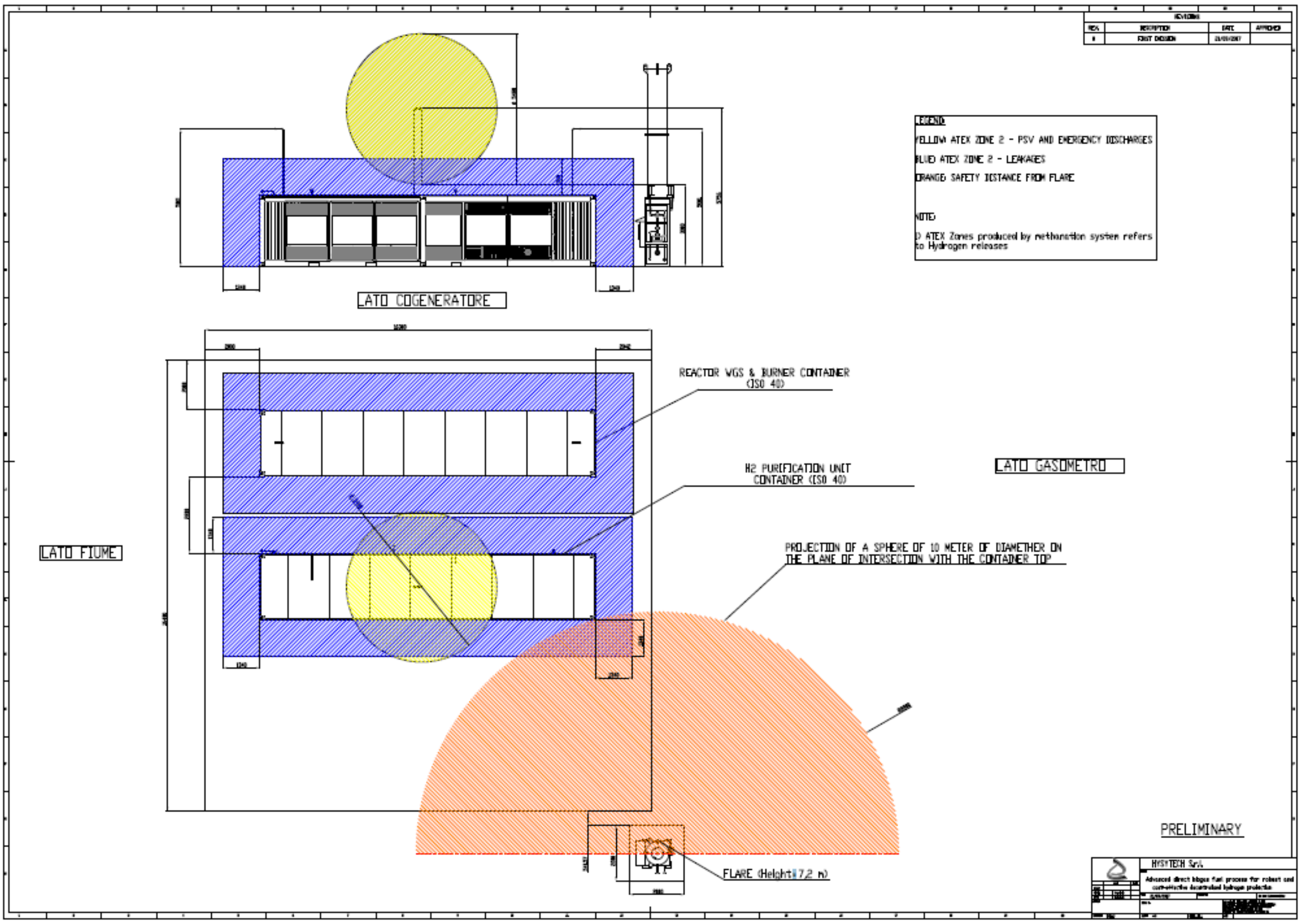

Fig. 6.1 Permitting process preliminary layout

7. Bibliography

[1] D. Fino, “FCH2 JU - proposal N° 736272 BIOROBURplus,” 2016.