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STORE&GO

Innovative large-scale energy storage technologies and Power-to-Gas concepts after optimisation

D3.3

PtG demonstration plant Solothurn commissioned

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Responsible	Andrew Lochbrunner, RES
Author(s)	Andrew Lochbrunner
Reviewer	Steffen Schirrmeister, TKIS
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Dissemination level

✘	**PU**	Public
	PP	Restricted to other programme participants (including the Commission Services)
	RE	Restricted to a group specified by the consortium (including the Commission Services)
	CO	Confidential, only for members of the consortium (including the Commission Services)

Document history

Version	Date	Author	Description
1	2019 07 27	AL/RES	

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Executive Summary

The Milestone 8 ("Demo plant in Solothurn is ready for pilot operation") was achieved in May 2019 with an overall delay of about one year compared to the original plan. Despite a 7 month delay from delivery of the biocatalyst until system startup, the system provided methane for grid injection within 4 days. The system demonstrates a high degree of automation, and high product quality in excess of 99% methane. Despite two remaining mechanical defects, gas production, grid injection and work toward grant obligations can be continued during close out of remaining mechanical and control issues.

The reasons for the delay in this work package are manifold:

The initial delay in the work package resulted from a delay in ordering the plant from ELEC's manufacturing vendor. Negotiations with the vendor were required to accommodate the timing of project financing available to the project and which was not aligned with the vendor's requirement that 80% of the contract capital to be paid in the first 9 months of the construction contract. Therefore, construction was delayed from the completion of basic engineering in early 2017 until an agreement was reached among RES, ELEC and DVGW regarding timing of payments for the completion of the plant construction, in June 2017. Ordering of long lead time items and construction of the plant began after payments were distributed in August, 2017.

The biological methanation plant itself was delivered with delay to the Solothurn site at end of August 2018. At this stage there were still technical works to be finalised on the plant (incomplete insulation, many leakage problems, delivery of dosing skid and agitator). The agitator for the reactor was delivered and installed separately by another vendor in November 2018, allowing initial on site evaluation of the system into January, 2019. Completion of controls programming, system testing and remaining technical issues was delayed until April 2019 due to negotiations with the vendors for the correction of mechanical and control defects and to align the controls logic for more automated control of the reactor to match site conditions. These repairs and improvements delayed the start of the main commissioning phase until May 2019.

The commissioning phase was split into the following stages:

- Adaption of the existing systems in the Hybrid Plant and the water treatment plant ZASE
- Preparing the integration of the Methanation Plant into the Hybrid plant
- Erection of the Methanation Plant on site
- Completing the installation of the delivered plant
- Connection of the methanation plant to the Hybrid plant installations
- Refining and adjusting the control systems of all the subsystems

The erection and installation phase was completed with receiving the following certificates:

- Certificate of Conformity
- SINA (safety case of electrical installations)
- TISG approval

After this installation phase, operation of the plant was initiated, testing the different subsystems, instruments and the interaction of the different control systems.

All components, with exception of the level control and the dosing systems, were successfully tested. The automation grade is very high and operation can be initiated by simply choosing the desired mode and letting the control system perform the required steps.

Up to date 1410 kg of SNG have been injected into the local grid, with Injection of SNG being initiated on the 06.06.2019 at 14:30, reaching a gas quality with a CH_4 content > 99%. So far, 145 hrs of operation and 85 hrs of grid injection have been accumulated.

The intention is to have an automated operation of the plant, running 24/7 if required and performing the required maintenance during the day, The plant has safety systems which will ensure the plant shuts down to a safe state, in case of any kind of component failure or error. Operator monitoring and checking is required daily to ensure best results.

In order to reach this goal, focus of the activities within the next weeks from now is to resolve remaining technical issues with the level control and the dosing unit.

1 Introduction

Unlike the other sites in this project, Falkenhagen, Germany and Troia, Italy, Solothurn uses a biological methanation process. Instead of alkaline electrolysers, PEM electrolysers are installed for H_2 production.

1.1 Biological Methanation

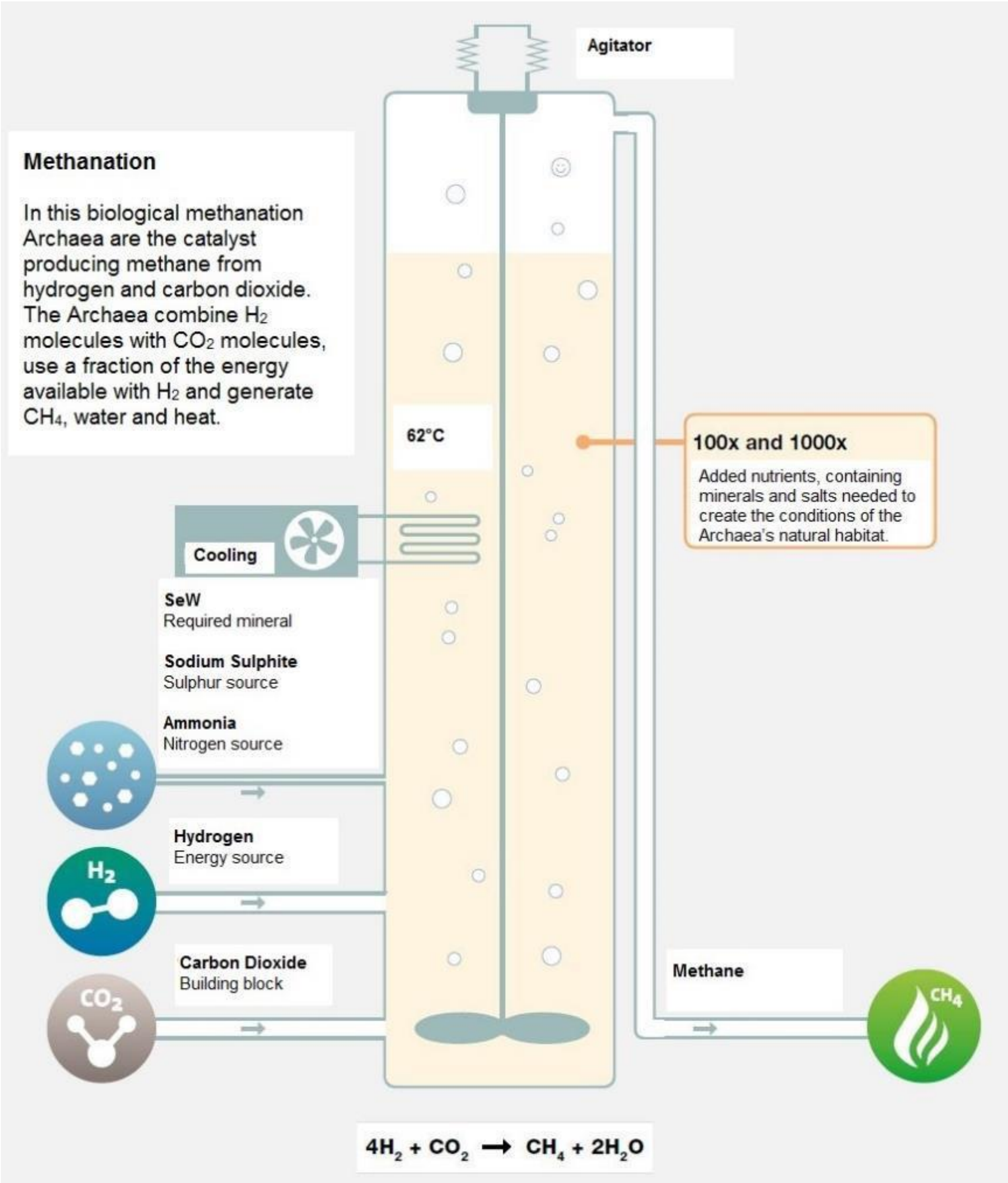


Figure 1-1: Schematic of biological reactor

Figure 1-1 shows the principle of the biological methanation.

The Archaea are kept in a vertical reactor. CO_2 and H_2 are mixed at a specific ratio and fed to the reactor at the bottom. In order to minimise the bubble size and increase the retention time between gas and biocat (Archaea), an agitator is mounted on top of the reactor, equipped with impellers reaching to the bottom of the vessel.

The reaction is exothermal. In order to initiate the reaction, the contents need to be heated up to 62 °C before adding the mix gas feed.

Once the methanation process has started, cooling is required to avoid overheating of the reactor.

In order to optimise gas production and to guarantee a steady reproduction of the Archaea, different nutrients are fed to the reactor.

1.2 Proton Exchange Membrane (PEM) Water Electrolysis

PEM water electrolysis simply splits deionized water (H_2O) into its constituent parts, hydrogen (H_2) and oxygen (O_2), on either side of a solid polymer electrolyte membrane. When a DC voltage is applied to the electrolyzer, water fed to the anode (or oxygen electrode) is oxidized to oxygen and protons, while electrons are released. The protons (H+ ions) pass through the PEM to the cathode (or hydrogen electrode), where they meet electrons from the other side of the circuit, and are reduced to hydrogen gas. Thus, the only possible constitutes of the streams would be hydrogen gas (H_2), oxygen (O_2) and water vapor or moisture.

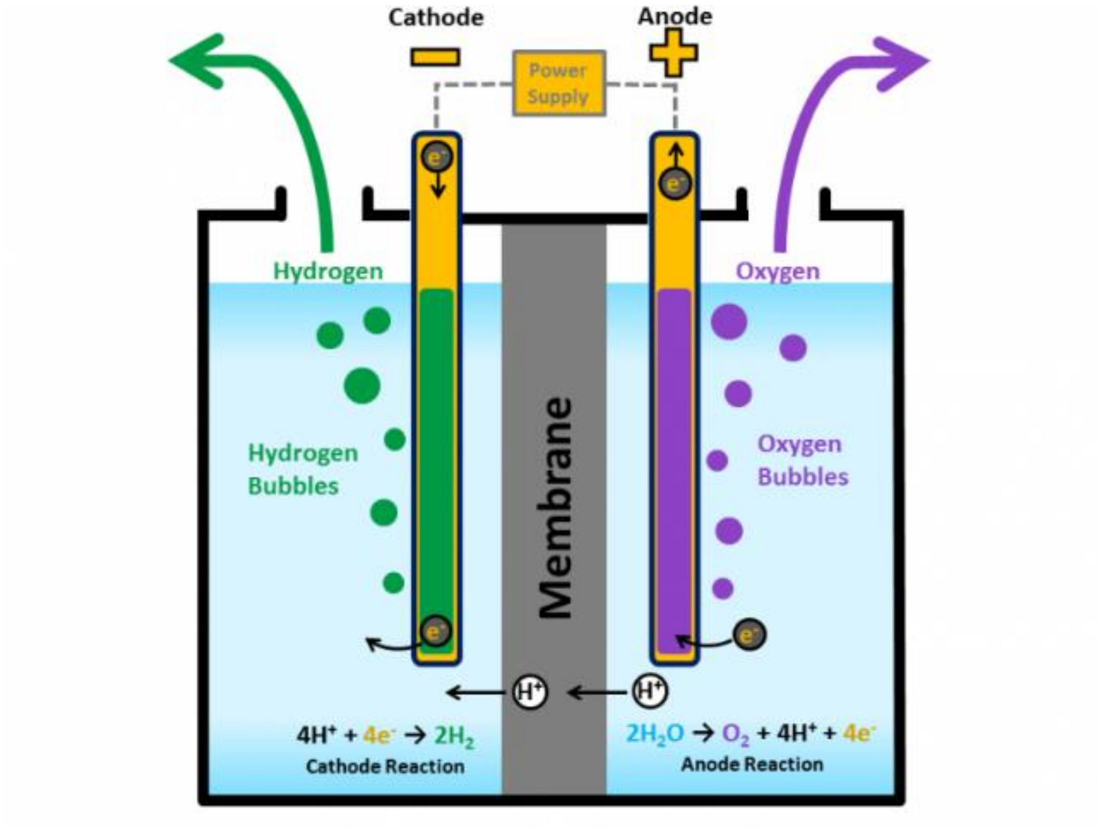


Figure 1-2: PEM working principle

[1] https://www.energy.gov/eere/fuelcells/hydrogen-production-electrolysis

2 Process Description

This methanation process is designed to convert hydrogen and carbon dioxide gas to methane gas with a reaction that is biologically catalysed by Archaea microorganisms according to the following reaction

$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$.

The microbes metabolize better in a reducing state (i.e., excess H_2), therefore a key design point for the two gas inlet streams is to ensure a range of stoichiometry from hydrogen relative to carbon dioxide up to 6:1.

For the process a stream of so called carbon feed (mainly CO_2) at a pressure of 13.5 bar(g) is mixed with hydrogen at a pressure of 13.5 bar(g) and then introduced into the base of the reactor where it is dispersed within the bio liquid. As the gas rises through the reactor, staged agitation ensures good gas/liquid mass transfer throughout the reactor volume. The feed carbon dioxide and hydrogen dissolve into the aqueous broth and diffuse to the Archaea, where the feed gas is converted to methane and water. The product methane diffuses from the Archaea and transfers to the gas phase. The reactor configuration and operating conditions are chosen to maximize the extent of carbon dioxide consumption while minimizing the required amount of excess hydrogen. With stoichiometric conversion of the reactive gases (H_2 and CO_2) the CH_4 product gas volume is 20% of the reactive gas input and the majority of the water product stays in the liquid phase, depending on reactor pressure.

In certain cases, the reactor's conversion of CO_2 could reduce quickly. This results in a significant increase of gas flow out of the reactor. If conversion were lost entirely, the volume of gas in the reactor head space would increase by approximately 500% if the reactor is processing pure CO_2 as the feed gas. The system design accounts for significant changes in conversion at any operating point. This requires thorough safety and process considerations.

The reacted gas is separated from the liquid at the top of the column before it exits the Reactor. Further downstream there is a foam trap (supplied by customer) where the foam is supressed. The gas stream is then conditioned in the H_2S removal vessels A&B before separating the excess hydrogen and drying in the CH_4 enrichment system. The permeate stream, containing the excess hydrogen, water and some methane is sent to the flare. The product gas stream is then throttled to control the upstream system pressure in the reactor headspace.

The product gas is analysed and allowed to either enter the natural gas grid or is flared.

The heat of reaction is removed by means of a cooling loop inside bio reactor that is sized to maintain the reaction media between 61 °C and 65 °C.

Nutrient addition, make up reactor media and anti-foam will be pumped periodically into the reactor as required.

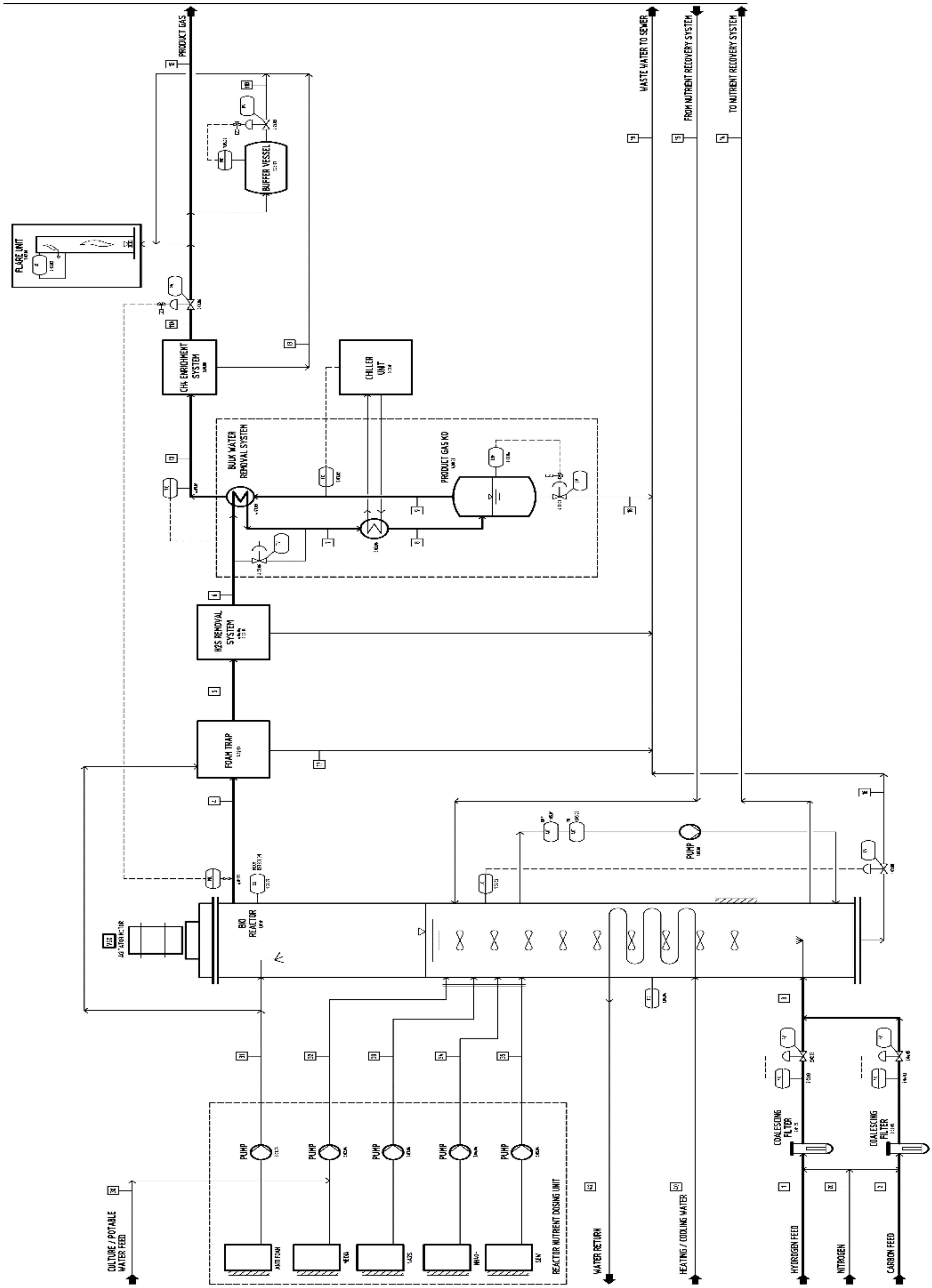


Figure 2-1: PFD Methanation Plant

2.1 Feed Lines

The feed gases hydrogen and carbon dioxide enter the plant via battery limits respectively. The gases are mixed in static mixer and their composition is measured with gas analyser. Their composition and volume flow are regulated with pneumatic valves. Both feed lines are equipped with a coriolis flowmeter to have an accurate flow measurement.

2.2 Reactor

The methanation reaction takes place in the reactor where the feed gases are mixed into the bio liquid and were progressed by the microorganisms. The product gas leaves the reactor at the top, surplus water (formed by the reaction and supplied from the dosing units) leaves the reactor via level control valve. The level is measured with the differential pressure transmitter with the geostatic height. Inside the reactor foam generation has to be expected, therefore a foam detector will start the dosing of anti-foam agent into the reactor. The pressure in the reactor is measured with pressure transmitter and regulated with a valve.

2.3 Agitator

For the mixing of the bioliquid inside the reactor an agitator is installed on top. The motor of the agitator is driven with a frequency converter to adjust the rotating speed of the agitator to the process requirements.

A by-pass line for measuring pH and ORP is also installed and is driven by a small pump.

2.4 Cooling/heating water/glycol cycle

To regulate the temperature, measured with temperature transmitter 1.04.04., inside the reactor 1.01.01 (normally cooling during normal process and heating during start up and shut down periods) the reactor 1.01.01 is equipped with an internal coil. The heating and cooling system is situated in the technical area of the plant. The excess heat during operation is released to the ambient. Possible use could be to transfer the heat to the return line of the disctrict heating.

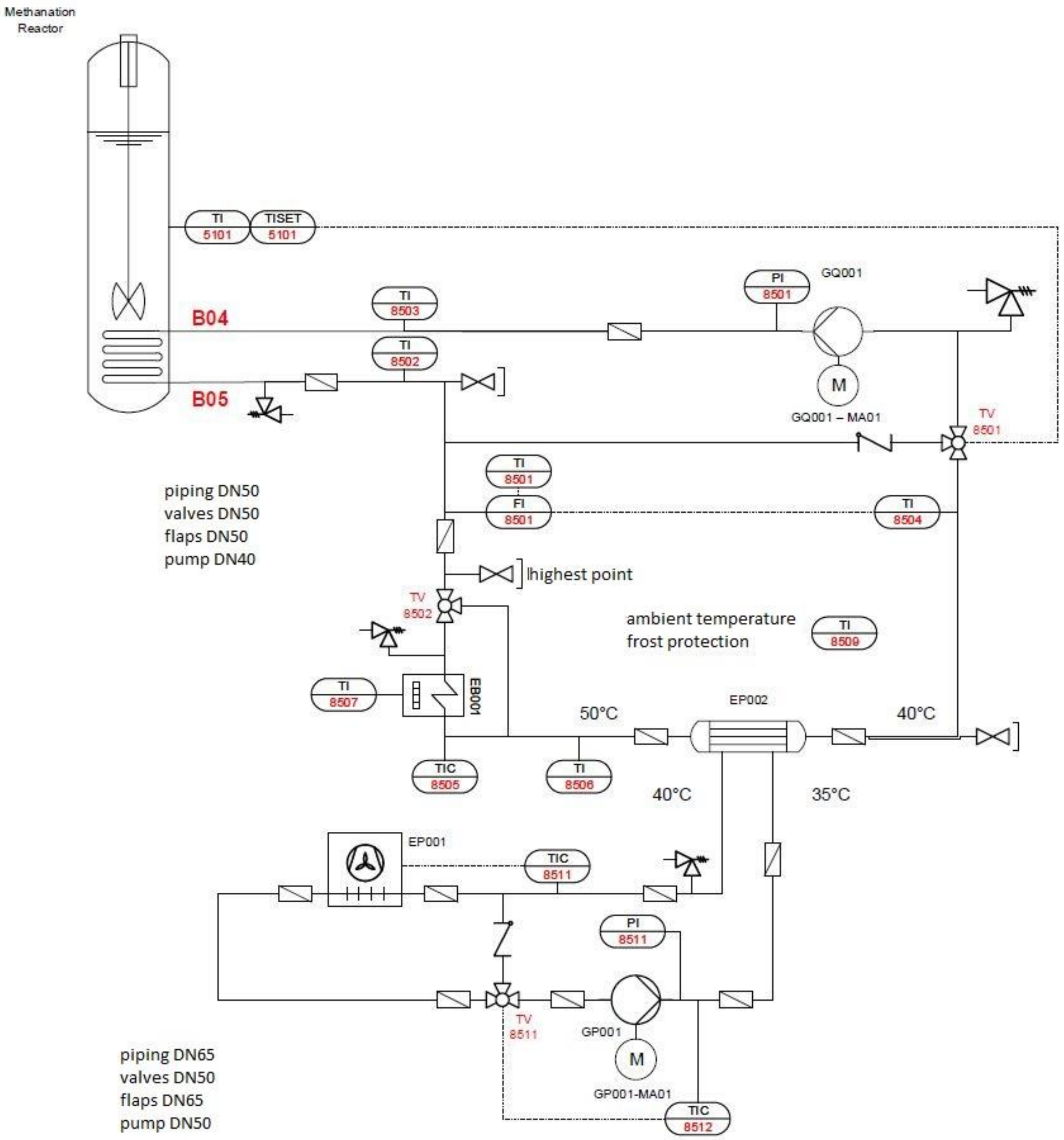


Figure 2-2: PID heating/cooling loop

2.4.1 Heating Mode

The required heat input is regulated by 5 clocked heating inserts, EB001, 8 kW each, and bypass valve TV8502, enabling precise temperature regulation.

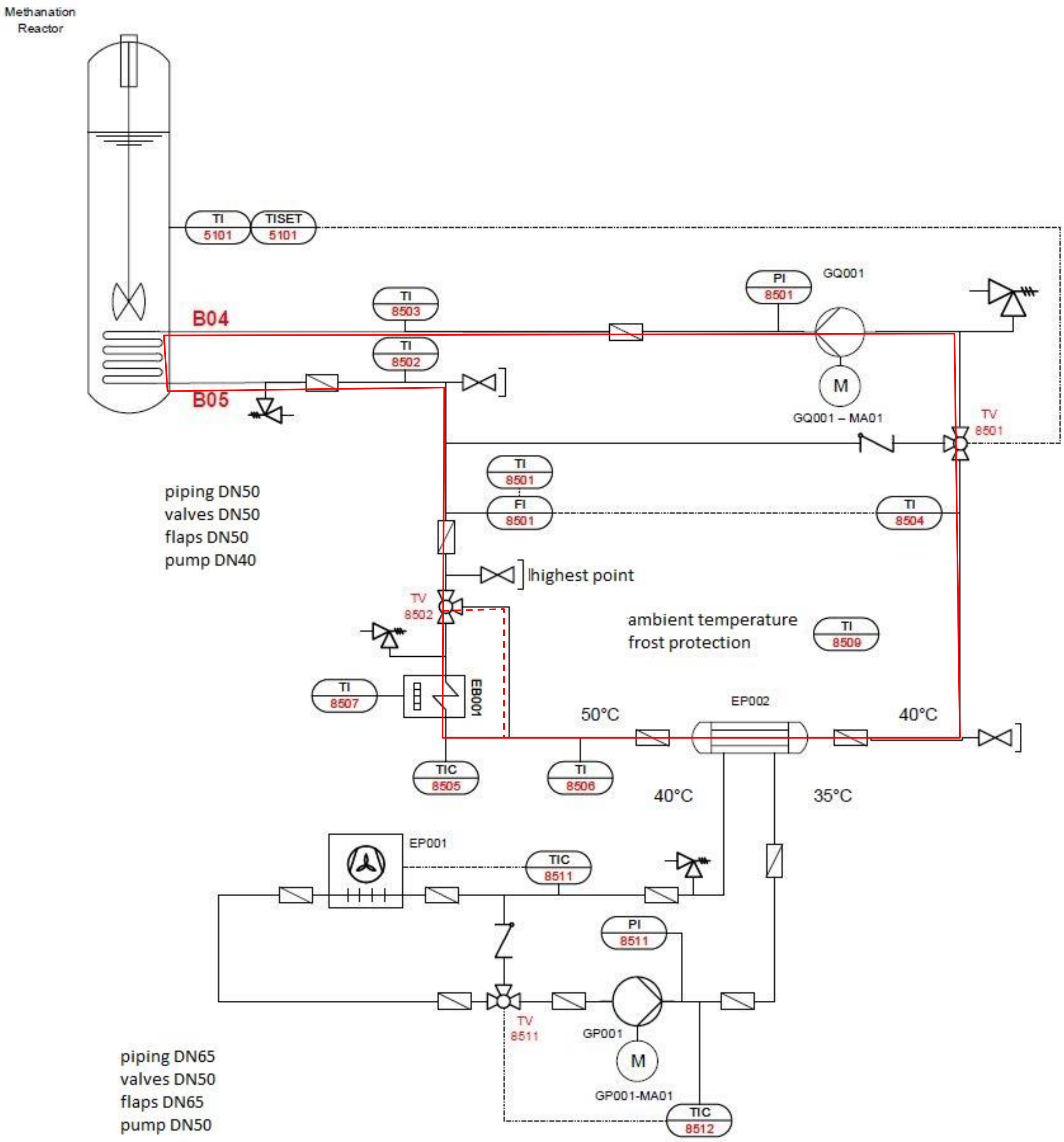


Figure 2-3: Heating loop

2.4.2 Cooling Mode

As the cooling requirement highly depends on the ambient temperature and the plant operational load, the cooling needs to cover a vast range from minimum to maximum.

Cooling stage 1: heat losses of piping system

Cooling stage 2: heat losses of extra piping system, regulation by TV8501

Cooling stage 3: heat losses of extra piping system, heat transfer by exchanger EP002 regulation by TV8511, min. open

Cooling stage 4: heat losses of extra piping system, heat transfer by exchanger EP002 regulation by TV8511, max. open

Cooling stage 5: heat losses of extra piping system, heat transfer by exchanger EP002 regulation by TV8511, max. open, glycol cooled by VFD operated fans.

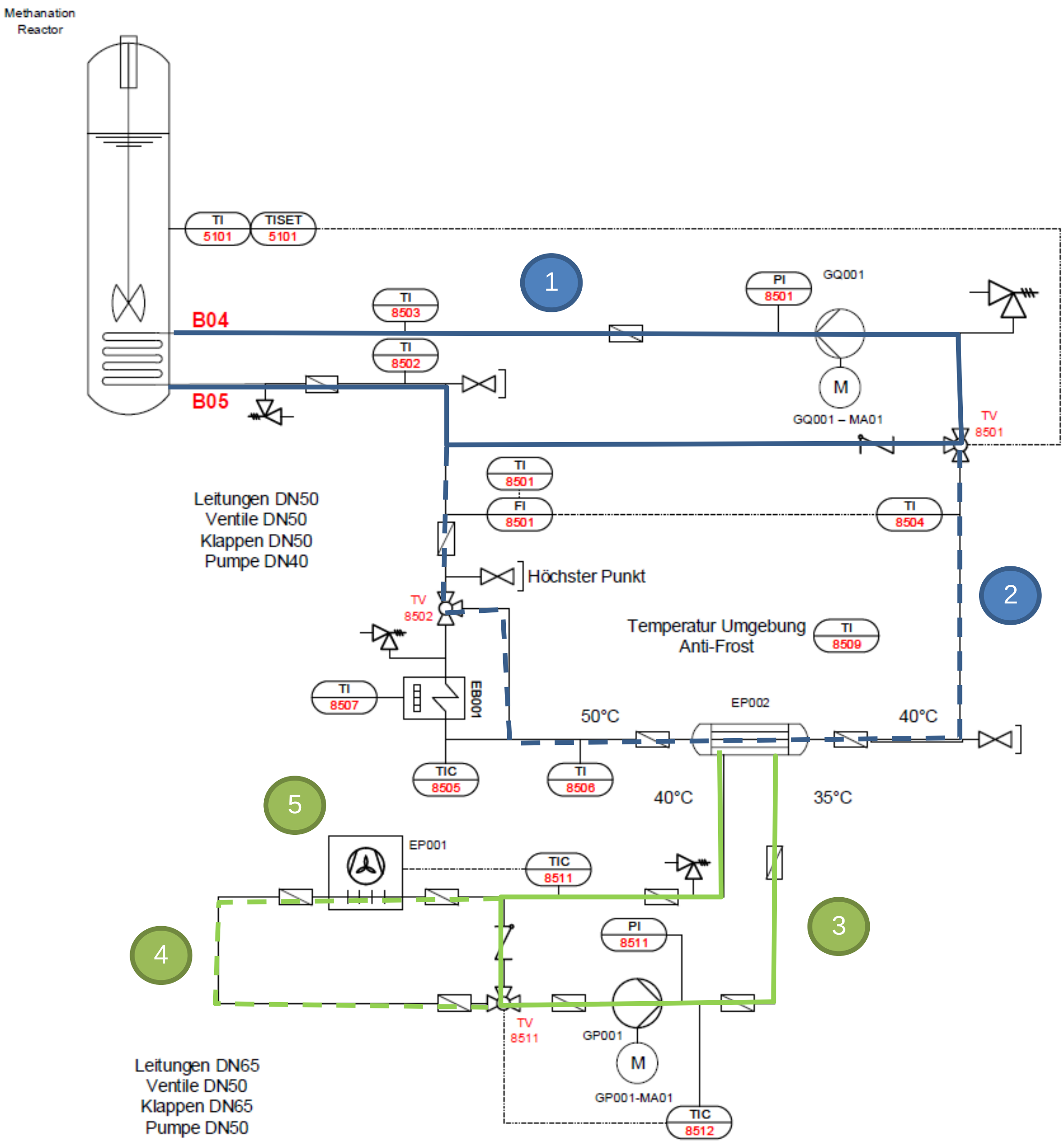


Figure 2-4: Different cooling stages

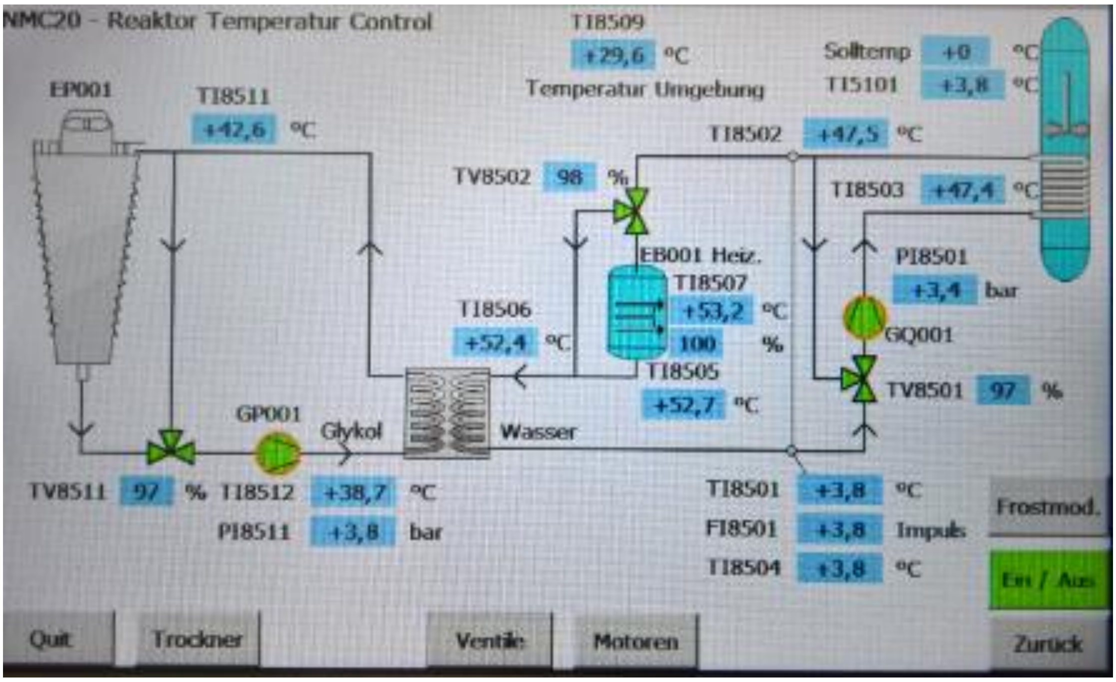


Figure 2-5: HMI heating/cooling

2.5 Nutrient Recovery System

The drained water from the reactor can be conditioned in a nutrient recovery system.

2.6 Dosing Unit

The microorganisms in reactor are supplied with nutrients and the bioliquid itself is conditioned with five dosing units.

2.7 Foam Trap

In case the foam leaves the reactor in spite of the foam detector and the dosing of anti-foam agent directly into the reactor, a foam trap is installed downstream. The vessel is equipped with automated level control and a foam detector.

2.8 H2S Removal Vessels

The gas stream coming from the Reactor can contain sulphur components, which would damage the downstream membranes and this has to be removed from the product stream. Therefore two H_2S removal vessels, filled with a catalyst, are installed downstream of the foam trap. The hand valves installed around the H_2S removal vessels enable a parallel and in-series flow of the gas stream as well as disconnecting one or two vessels from the process.

2.9 Knock-out System

The gas stream leaving the Reactor is saturated with water. The gas stream needs to be dried up-stream of the membranes to avoid any condensation inside the membrane vessels. The gas stream is cooled with two heat exchangers: Post process recuperator and raw gas cooler.

In raw gas cooler the stream is cooled with a water/glycol mixture supplied by Post process chiller. The condensate is collected in the Product gas KO vessel. The level is controlled with level switch and valve.

Downstream of the product gas KO vessel the gas stream is heated with the upstream gas stream inside post process recuperator.

2.10 Membrane Unit

In case the required CH_4 level cannot be achieved, the gas is sent to three membranes which are installed in parallel. The enriched retentate is routed downstream. The stream can be routed over a bypass valve in case the gas is not allowed to pass through the membranes.

2.11 Drier

After the membranes the gas stream is sent to the drier, which is equipped with four pressure vessels filled with zeolite (80 litres each) arranged in two parallel banks. In case the one bank is depleted, the second one can be set online and the depleted one can be regenerated.

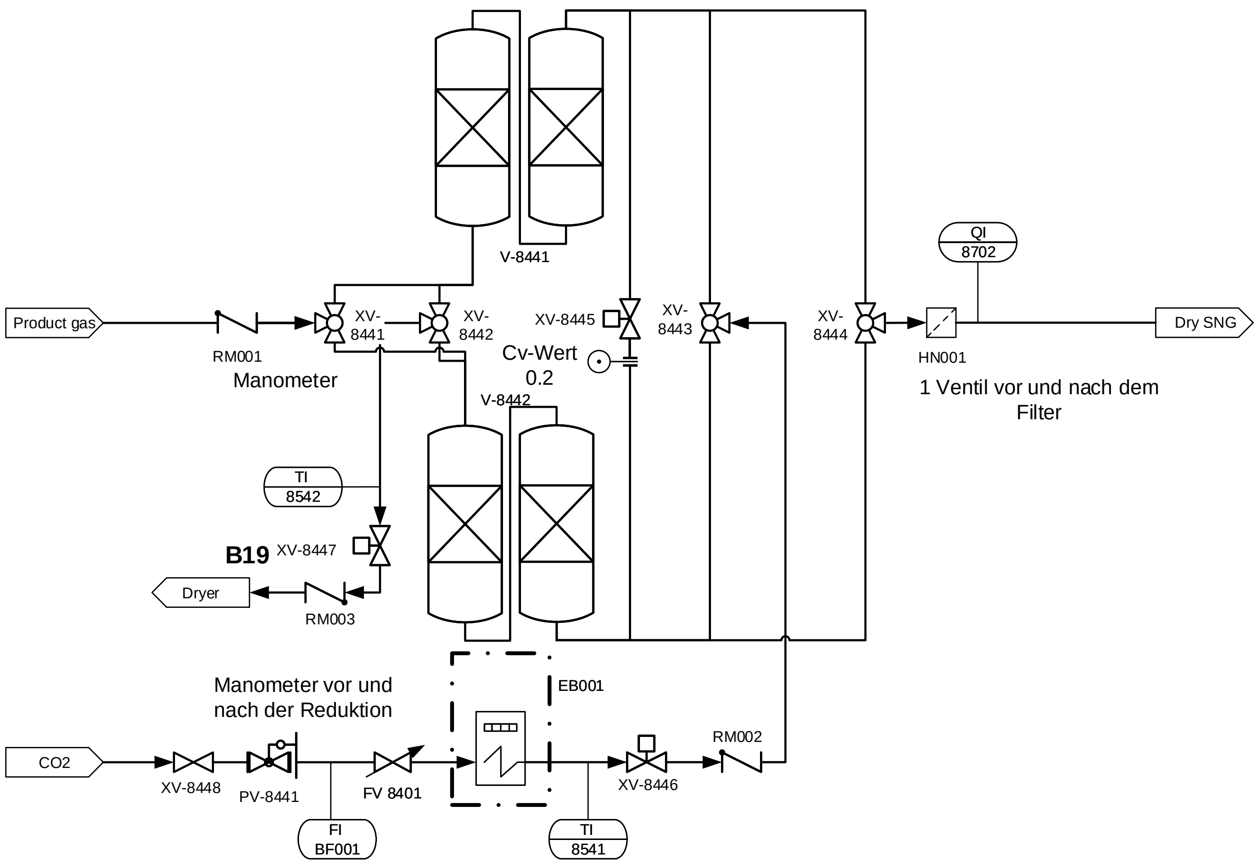


Figure 2-6: PID SNG drier

Steps	operatio-nal condition	XV 8441 (L-Port A)	XV 8442 (L-Port A)	XV 8445 (on/off)	XV 8446 (on/off)	XV 8447 (on/off)	XV 8443 (L-Port A)	XV 8444 (L-Port A)	electri-cal heater	Change
1	V8441 adsorp V8442 reg	1	2	off	on	on	1	2	on	if TI 8542 > 90 °C
1a	V8441 adsorp V8442 standby	1	2	off	off	off	1	2	off	if QI 8702 > - 30 °C
2	V8441 adsorp V8442 vent	1	2	on	off	off	1	2	off	after 60 seconds
2a	V8441 adsorp V8442 press	1	2	on	off	off	1	2	off	after 180 seconds
3	V8441 vent V8442 adsorp	2	1	off	off	on	2	1	off	after 60 seconds
4	V8441 reg V8442 adsorp	2	1	off	on	on	2	1	on	if TI 8542 > 90 °C
4a	V8441 standby V8442 adsorp	2	1	off	off	off	2	1	off	if QI 8702 > - 30 °C
5	V8441 vent V8442 adsorp	2	1	on	off	off	2	1	off	after 60 seconds
5a	V8441 press V8442 adsorp	2	1	on	off	off	2	1	off	after 180 seconds
6	V8441 adsorp V8442 vent	1	2	off	off	on	1	2	off	after 60 seconds
1	V8441 adsorp V8442 reg	1	2	off	on	on	1	2	on	if TI 8542 > 90 °C

Figure 2-7: Valve settings for different steps

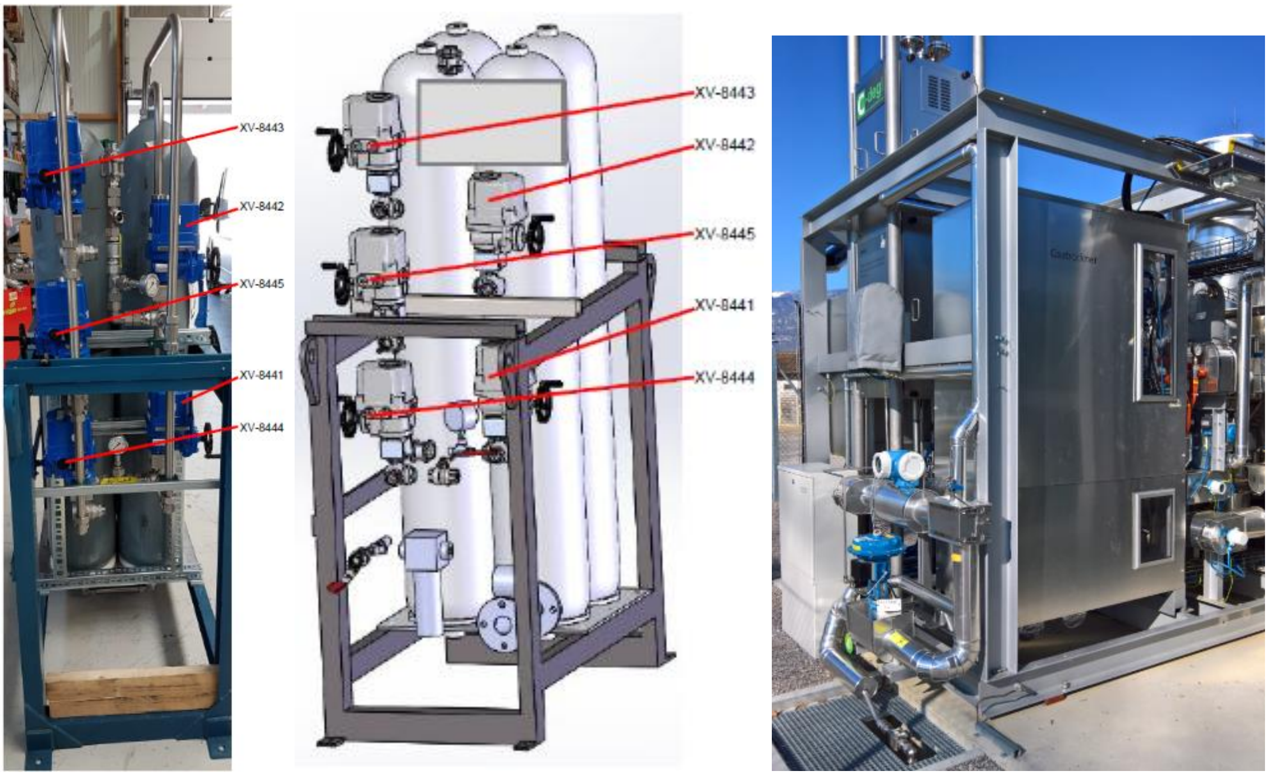


Figure 2-8: Setup drier and integration in skid

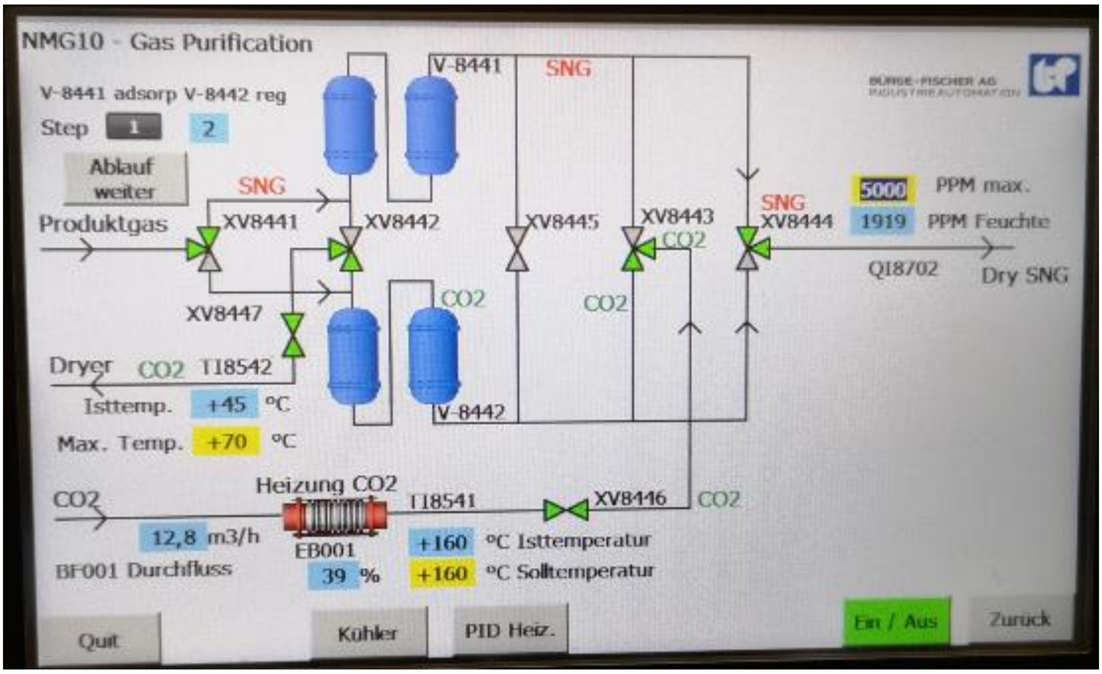


Figure 2-9: HMI gas drier

2.12 Gas Analyser

Inside the plant there are two analysing points, the first is positioned upstream of the reactor, the second upstream of the membranes. One of the streams can be sent to the gas analyser, supplied by Awite. A second analyser is installed to monitor the gas quality before grid injection, not reaching the minimum requirements will result in flaring the gas.

2.13 Flare

During normal operation the flare burns the permeate of the membranes. In case the product gas is not matching the requirement or during un-normal process conditions (e.g. start-up), the product gas stream is burned in the flare after passing the buffer tank. The buffer tank shall dampen pressure fluctuations and peaks. During operation of the plant a pilot flame is burning inside the flare.

2.14 Drain and Vent System

The drained waste water from the reactor, the foam trap, both H_2S removal vessels, the product gas KO vessel as well as the nutrient recovery system is collected in the vent separator. The liquid is relieved of the process pressure to atmospheric conditions, degassed and sent to the drain battery limit. The plant can be manually vented downstream of both feed battery limits, downstream of the mixing point, at each H_2S removal vessels, downstream the Product gas KO vessel, on the retentate side of membranes and right upstream of the product battery limit. The gas streams are collected in a vent line inside Skid 2, which is always purged with a small flow of nitrogen. This vent line also collects the vent gas from the drier. The vent line terminates into the vent separator, where it is sent to atmosphere at the top of the methanation tower (skid 1). In case the liquid degasifies inside the syphon of the vent separator the gas is vented in a second vent line which is also located in Skid 1. The vent from the highpoint of the plant downstream of the reactor is directly connected to the first vent line. An automated venting of the process gas is possible.

2.15 Nitrogen System

To render the system inert, blanket the motor seal system and to purge the vent line, nitrogen is available at the battery limit. A part of the stream is also connected to the flare. A second battery limit for nitrogen is for blanketing of the chemical tanks of the five dosing units.

2.16 Instrument Air

Compressed, clean free of oil, and dry air is received at the plant battery limit via ball valve. Impurities with certain particle size might be prevented by the filter integrated in pressure reducer PCV. Actual instrument air pressure is supervised for a minimum and also shown locally.

2.17 Process Control System

The operation and control of the plant is largely done by software switches on the process control system. The different operations are automatically started after the operating personnel activated the respective functions. The process control system ensures safe operation of the plant with a minimum personnel requirement.

The main states of operation and process parameters are visualized on the computer screens of the operator station.

All important process parameters are measured in the plant and these signals are transferred to the process control system. Based on the programmed interlocking and the process parameter data, the plant is operated and supervised automatically.

As process control system “PCS7” is used together with an integrated control and visualisation system.

For communication between field devices EExi type and the PLC, distributed I/O modules (also known as Remote I/O) are used. Inside the CP cabinets, they are pre- assembled on rack backplane. In the field, they are made of explosion proof components and assembled in weatherproof housings for field installation in hazardous areas inside the skids.

The communication between the PLC and the Remote I/O stations is performed via Profibus DP.

Signals in EExd or EExe type are cabled to conventional junction boxes and connected to the CP/MCC by multicore signal cables.

Beside the common remote I/O system, safety related switches, especially if required by special regulations, are hardwired.

3 Contractors/Suppliers

3.1 baderpartner AG

Company in charge of the whole permitting process of the plant, planning and execution of civil works.

3.2 Caloric GmbH

Manufacturer of the plant, including the control system, built according to the specification of Electrochaea

3.3 EKATO AG

Supplier of the agitator.

3.4 Apex AG

Supplier of the CO_2 compressors at ZASE and the SNG drier, engineered by HSR/RES.

3.5 Bürge-Fischer AG

Manufacturer and programmer of the control system for the heating/cooling and the CO_2 drier.

3.6 Fischer Rohrleitungsbau AG

In charge of all piping and connection between the Hybrid and Methanation plant, injection line and finalising the required piping within the plant, supplier of the CO_2 buffer tank.

3.7 Carbagas AG

Supplier of the H_2 storage expansion and the H_2 gas train.

3.8 Haug Kompressoren AG

Supplier of the CO_2 and instrument air compressor.

3.9 Endress-Hauser AG

Supplier of pressure and temperature measurement instruments and the flow measurements for SNG and H_2.

3.10 Awite Bioenergie GmbH

Supplier of the two gas analysers mounted inside a container.

3.11 Enerconom/Regio Energie Solothurn

Engineering and supplier of the installations in the technical area

3.12 TISG

In charge of the general plant permitting, setting the standards, rules and defining the required certificates for the plant acceptance.

3.13 TÜV SÜD Industrie Servic GmbH

Reviewing of all pressure equipment related certificates, ensuring that all values are met according to specification. Verification of performed pressure test, including onsite technical inspection, issuing the required "Certificate of Conformity".

ZERTIFIKAT ◆ CERTIFICATE ◆ 認 証 証 書 ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

Industrie Service

ZERTIFIKAT

(EU-Konformitätsbescheinigung)

Certificate of Conformity

Konformität auf der Grundlage einer Einzelprüfung (Modul G) nach Richtlinie 2014/68/EU

Conformity based on unit verification (Module G) according to Directive 2014/68/EU

Zertifikat-Nr.: *Certificate No.:* **Z-IS-AN3-STG-19-02-2899413-05051236**

Name und Anschrift des Herstellers: *Name and address of manufacturer:* **Regio Energie Solothurn, Rötistr. 17, CH-4502 Solothurn**

Hiermit wird bescheinigt, dass die unten genannte Baugruppe die Anforderungen der Richtlinie 2014/68/EU erfüllt. Sie ist mit unserer Kennnummer gemäß dem abgebildeten CE-Kennzeichen gekennzeichnet:

We herewith certify that the assembly meets the requirements of the Directive 2014/68/EU. It carries our identification number next to the CE-marking as illustrated:

CE 0036

Prüfbericht Nr.: *Test report No.:* **P-IS-AN3-STG-19-02-2899413-05051236**

Geltungsbereich: *Scope of examination:* **Baugruppe (Methanisierungsanlage)**

Fabrik-Nr: *Serial No:* **15256**

Fertigungsstätte: *Manufacturing plant:* **Regio Energie Solothurn, Allmendweg 17, CH-4502 Solothurn**

Filderstadt, 05.02.2019

(Ort, Datum) *(Place, date)*

TÜV SÜD Industrie Service GmbH
Zertifizierungsstelle für Druckgeräte

TÜV SÜD Industrie Service GmbH 0036 Notifizierte Stelle

Dirk Walter

Echtheitsprüfung durch App TÜV SÜD Verify
Verification of Certificate by TÜV SÜD App Verify

Notifizierte Stelle,Kennnummer 0036
Notified Body, No. 0036
TÜV SÜD Industrie Service GmbH
Westendstr. 199
80686 München
GERMANY

Dokument ID: 2899413Y2702c

0711 7005-260
guntram.schnotz@tuev-sued.de

Seite 1 zum Zertifikat Nr. / Page 1 of the certificate No. Z-IS-AN3-STG-19-02-2899413-05051236

TÜV®

Figure 3-1: Certificate of Conformity

4 Plant Layout

4.1 Development Phase

The first step towards initiating the building process on site was defining the plot size of the plant, which was a rather lengthy process as equipment sizes would only be clear after the detailed engineering. Additionally regulations defining the minimum distance to the existing buildings, and future plans for expanding the Hybrid plant needed to be respected. Last but not least the blasting radius of two safety relieve valves had to be considered. As these were taken out of service during the design process, the resulting restrictions disappeared and the layout could be adapted and finalised accordingly.

The following pictures give an impression of this lengthy design process.

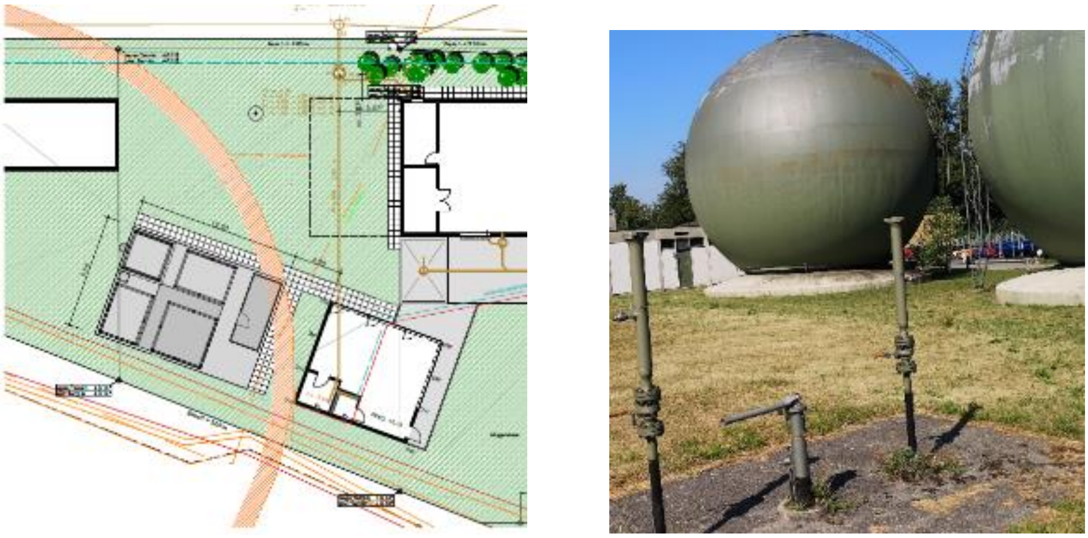


Figure 4-1: Blast area of pressure relief valves

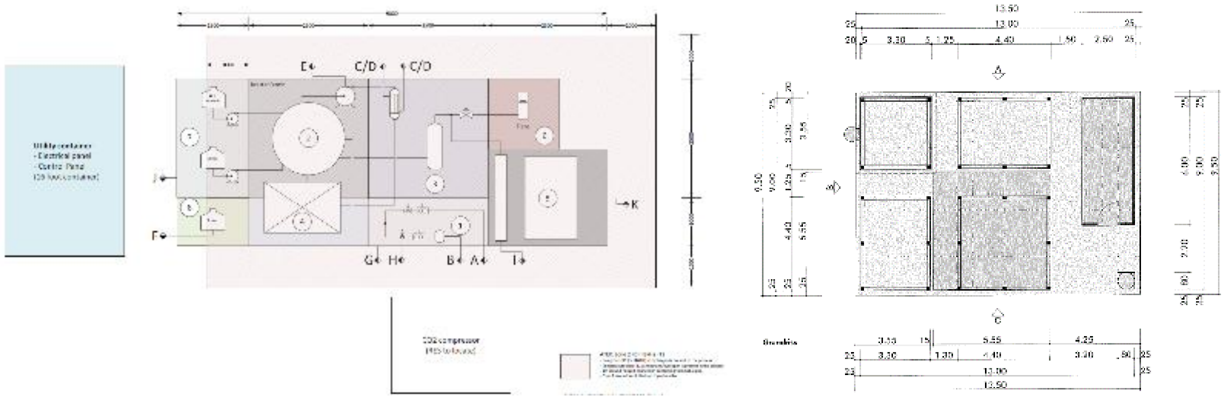


Figure 4-2: First general layouts

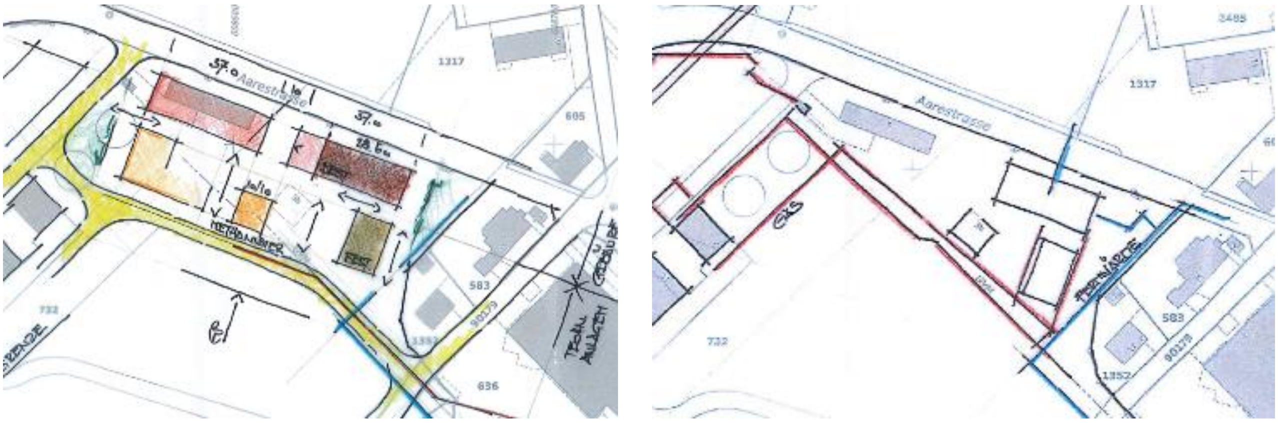


Figure 4-3: Different integration version of the new plant

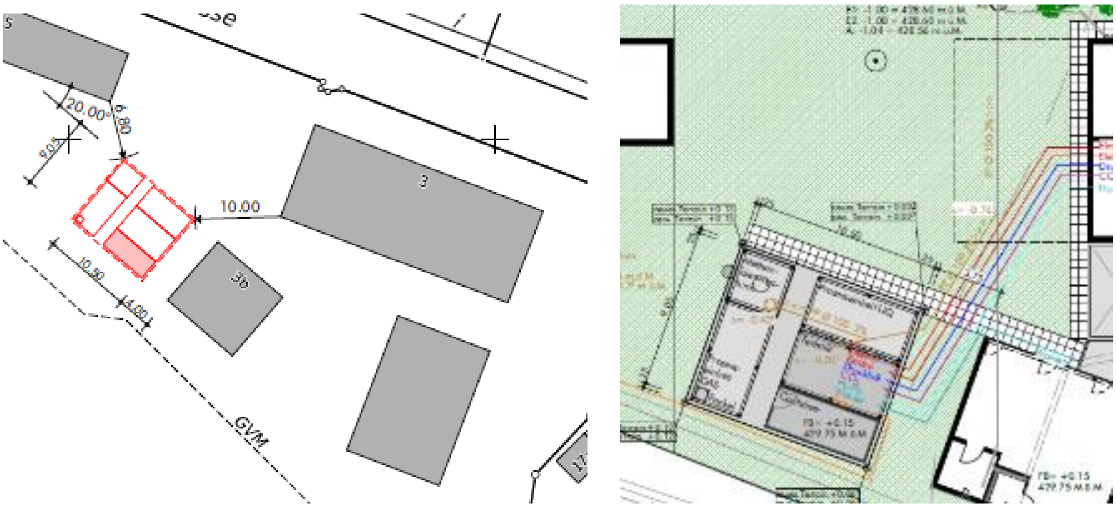


Figure 4-4: Final layout handed in for permitting (partial view)

With the plot size being fixed, all design parameters defined in the Basic Engineering document, and after receiving the building permit, 23rd May 2017 works could be initiated.

4.2 Final Setup

The methanation plant needed to be integrated into the existing hybrid plant, housing the two electrolysers and the buffer tanks. Located close to a residential area, special caution had to be taken concerning any sort of emissions.

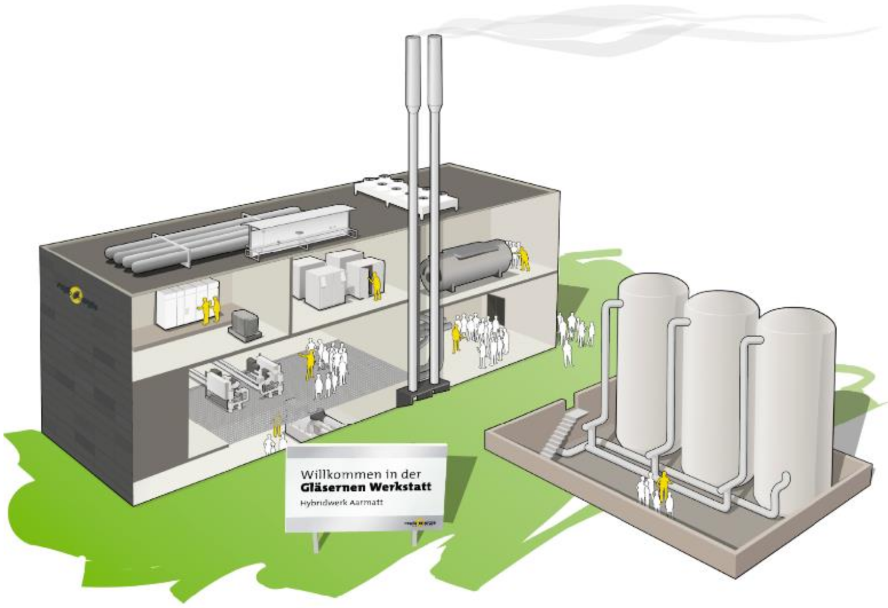


Figure 4-5: Hybrid plant with existing electrolysers and buffer tanks

Apart from integration to the site on Aarmatt, the CO_2 source, which is situated 2.5 km away from the plant at the water treatment plant ZASE, needed to be connected to the methanation plant. An extra pipe, which was laid during the expansion of the district heating system, could be used for this purpose.

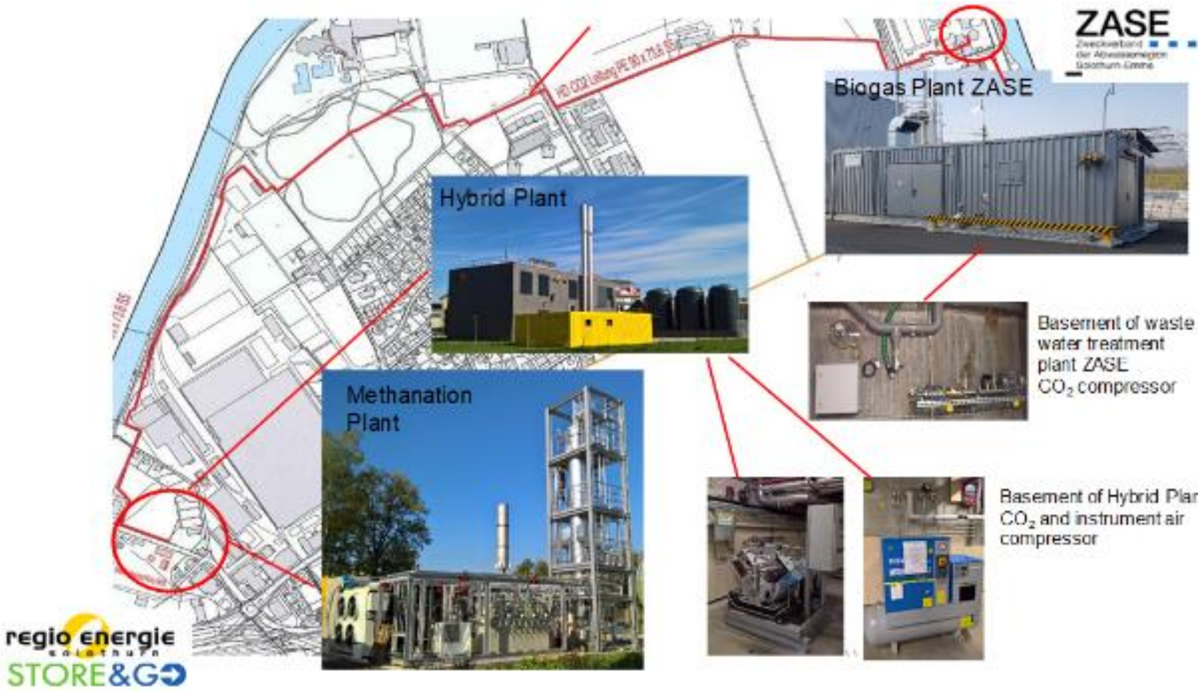


Figure 4-6: Overview interconnection ZASE – Hybrid Plant

The different sections of the plant can be taken from the following figures:

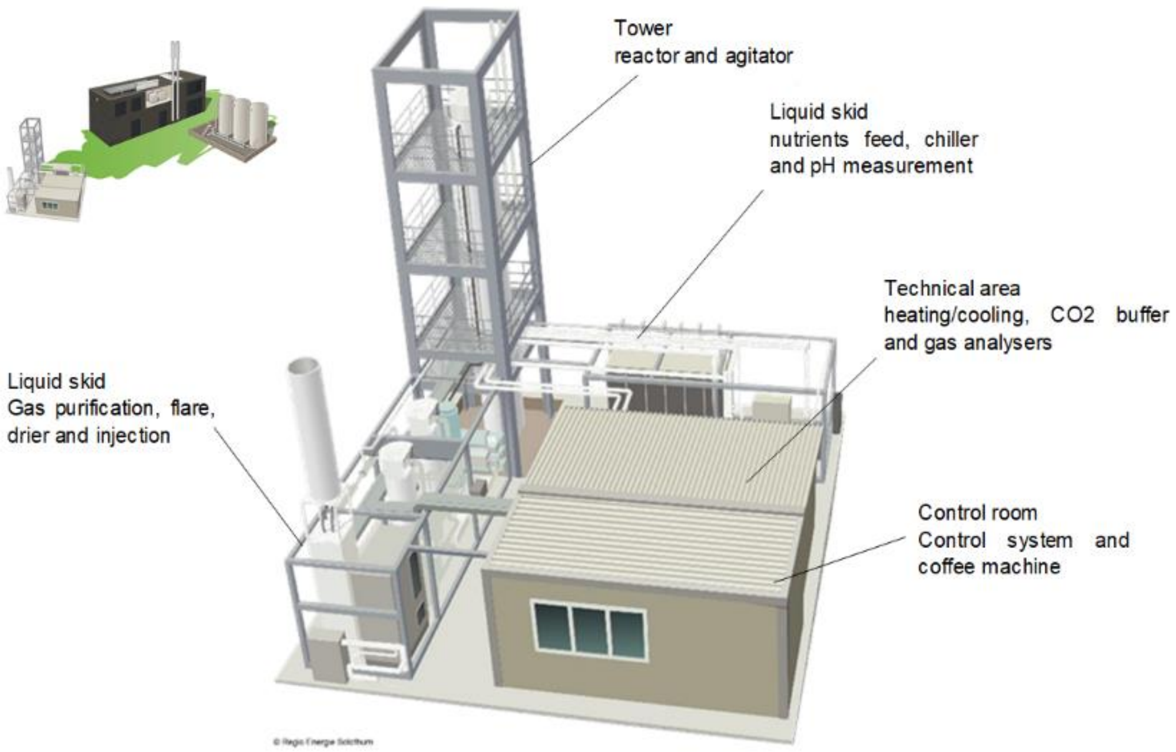


Figure 4-7: Setup of the methanation plant

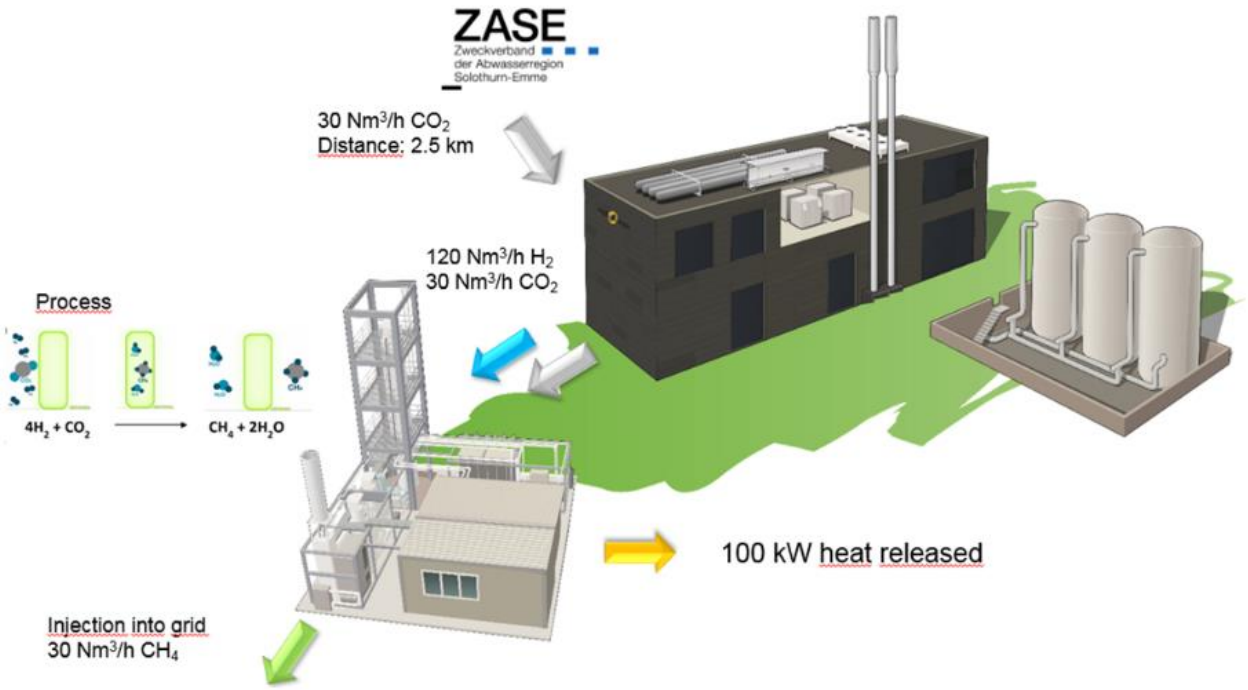


Figure 4-8: Integration into the Hybrid plant, including main process streams at 100% load

4.3 Plant Data

Biological methanation using Archaea

Installed H_2 buffer tanks: 8 x 2.4 m^3, max. operating gauge pressure 30 bar

Reactor capacity: 3.5 m^3

Operational gauge pressure: 10 barg

Gauge pressure at battery limit: 13.5 barg

	50% Load	**100% Load (operation for approx. 5h using storage)**
H_2 Feed [Nm^3/h]	60	120
Power Supply [kW]	350	700
CO_2 Feed [Nm^3/h]	15	30
SNG Feed [Nm^3/h]	15	30
Dissipated Heat [kW]	50	100

5 Plant Erection

The following figure gives an overview of the main achievements up to date.

2016	Mar	1		Project Start
	Apr	2		
	May	3		
	Jun	4		
	Jul	5		
	Aug	6		
	Sep	7		
	Oct	8		
	Nov	9		
	Dec	10		
2017	Jan	11		
	Feb	12	02.02.2017	Handing in Building Application
	Mar	13	02.03.2017	Receiving Building Permit
	Apr	14	04.05.2017	Ground Breaking
	May	15		
	Jun	16		
	Jul	17		
	Aug	18		
	Sep	19		
	Oct	20	20.10.2017	Completion of Civil Works
	Nov	21	13.11.2017	Installation of CO2 Compressor Hybrid
			23.11.2017	Expansion H2 Storage First Attempt
	Dec	22		
2018	Jan	23		
	Feb	24		
	Mar	25	22.03.2018	Expansion H2 Storage Second Attempt
	Apr	26		
	May	27		
	Jun	28	29.06.2018	Installation Technical Area
	Jul	29	30.07.2018	Installation of CO2 Compressor ZASE
			17.08.2018	Delivery of CO2 Dryer
	Aug	30	30.08.2019	Delivery and Erection of Plant
	Sep	31	20.09.2018	Delivery and Installation of Analyser Container
	Oct	32		
	Nov	33		
	Dec	34	06.12.2018	Delivery&Installation of Agitator
2019	Jan	35	07.01.2019	Completion Plant Insulation
			18.01.2019	Final Adaptions Agitator
			28.01.2019	Official Plant Inauguration
	Feb	36	06.02.2019	Inoculation Day
			07.02.2019	Halt of Commissioning Activities
	Mar	37		
	Apr	38		
	May	39	20.05.2019	Resumption of Commissioning Activities
	Jun	40		Commissioning
	Jul	41		Final Commissioning
	Aug	42		
	Sep	43		
	Oct	44		
	Nov	45		
	Dec	46		
2020	Jan	47		
	Feb	48		

Figure 5-1: Major achievements

With the civil works being completed in October 2017, including the interconnecting piping between ZASE, Hybrid Plant and Methanation Plant, erection of the different components could be initiated.

Figure 5-2: Civil works

5.1 Installation of Control Room Container

Subsequent to finalising the civil works, the control room container was placed on the concrete slab.

Figure 5-3: Delivery of the container

5.2 Installation of CO_2 and Instrument Air Compressor

As this component was one of the long lead items, the order was placed 21.06.2017, shortly after all the battery limits conditions had been confirmed.

Figure 5-4: Delivery of the compressors, instrument air (left) CO_2 (right)

In order to be able to install the compressors in the basement of the Hybrid Plant, the cover panels at one of the access doors needed to be removed.

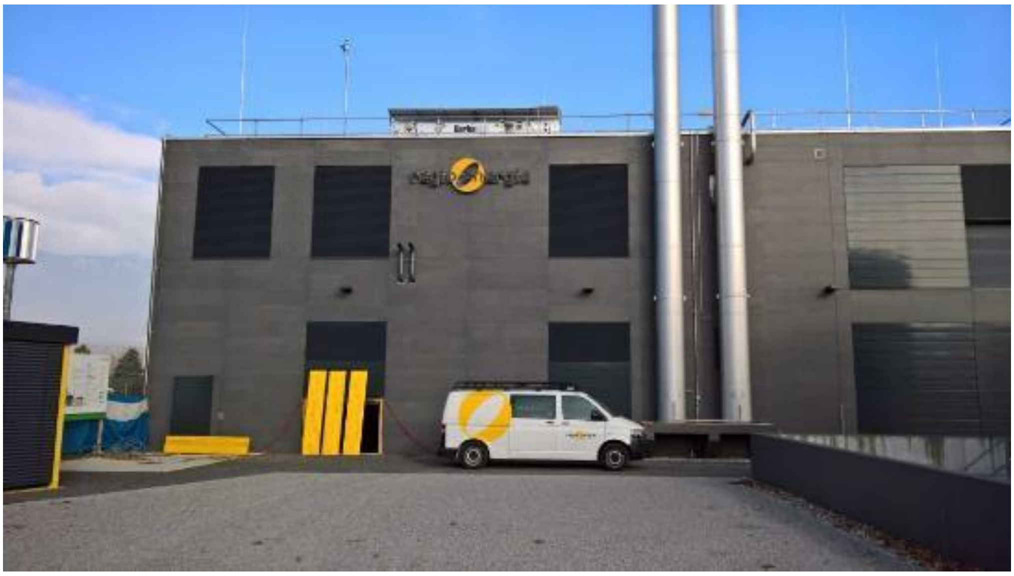


Figure 5-5: Removal of access door for installation

The compressors were moved into the building using a fork lift and lowered into the basement using the overhead crane of the Hybrid Plant.

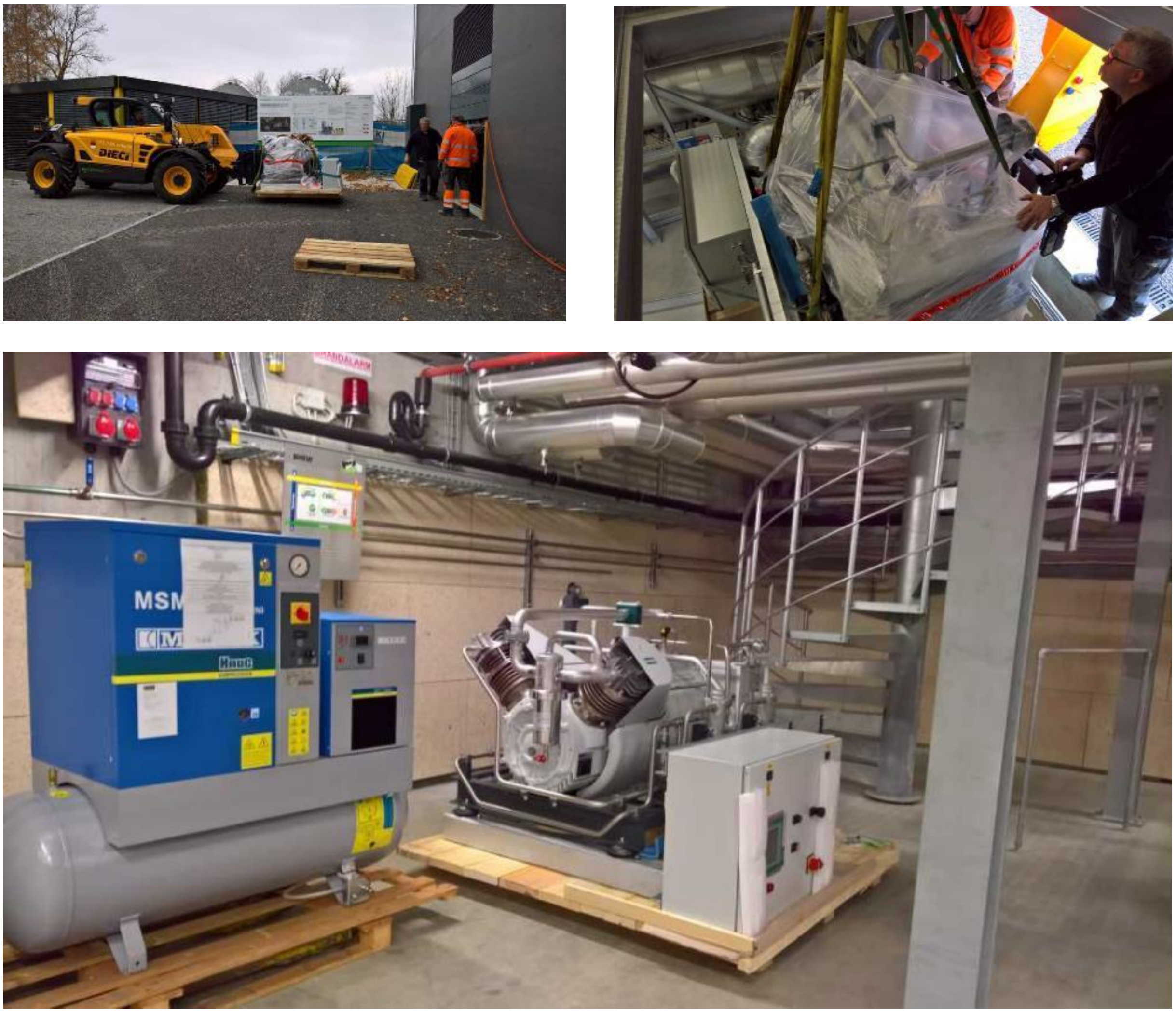


Figure 5-6: Installation of the compressors

5.3 Installation Technical Area

The technical area comprises the CO_2 buffer (2 m^3), the heating and cooling equipment and the analyser container.

Figure 5-7: Technical area installation

5.4 Installation of CO_2 Compressor ZASE

In order to feed the CO_2 the 2.5 km distance to the compressor in the basement of the Hybrid Plant, an additional compressor needed to be installed at the ZASE site.

Figure 5-8: Compressor at ZASE

5.5 Delivery and Erection of Methanation Plant

The delivery and erection of the methanation plant required two days to complete.

Figure 5-9: Plant erection

5.6 Delivery and Installation of Analyser Container

Figure 5-10: Unloading and placing of analyser container

5.7 Delivery and Installation of Agitator

As there had been a mismatch between the agitator and reactor bearing connections, the agitator was delivered three months after the plant.

Figure 5-11: Installation of the agitator

5.8 Official Plant Inauguration

The official inauguration of the plant took place on 28 January 2019 and was attended by over 100 people, and being reported on the local and national media including Swiss TV.

Figure 5-12: Impressions of the official inauguration

More details about the event can be found under the following link (German):

https://www.regioenergie.ch/de/regio-energie-solothurn/hybridwerk/storego/

5.9 Inoculation Day

The inoculation day marks the end of the erection and first commissioning phase. The Archaea had already been delivered on 9 November 2018 and kept at ambient temperature transfer into the reactor vessel.

Figure 5-13: Bugs arriving from Denmark

Finally, on 6 February 2019, the inoculation took place and the bugs were pumped into the reactor. Luckily the smell was not recorded with the picture.

Figure 5-14: Inoculation, pumping the bugs into the reactor

6 Commissioning Activities

The first phase of commissioning started immediately after the erection of the plant in August 2018 and comprised the following activities:

- Installation and connection of all different components
- Laying and connecting of all required cables
- Performing leakages test and removal of all defects found
- Testing the control system and interaction of all subsystems.

The first commissioning phase came to halt the day after the inoculation took place. The reason for this interruption were the required adaptions to be performed on the existing control system of the methanation plant.

6.1 Cabling Works

The cabling works were far more effort than expected, as there was a lot of cables to be routed within the skids. We expected to only connect the existing cables from each skid to the MCC in the control container. This is not what we received though, a lot of cables needed routing, some cables still needed to be purchased. The cabling works were completed at the end of 2018 and approved by a performed SINA (Sicherheitsnachweis = safety case of electrical installations).

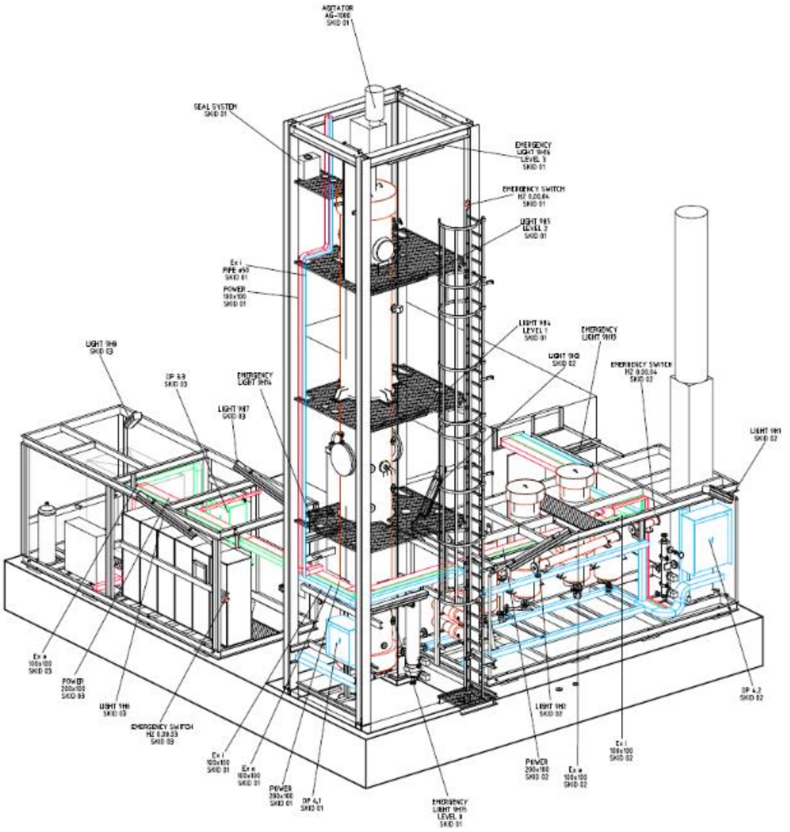


Figure 6-1: Cabling plan

Figure 6-2: Power supply

regio energie

Sicherheitsnachweis Elektroinstallation (SiNa)

gemäss Verordnung über elektrische Niederspannungsinstallationen (NIV, SR 734.27)
Pro Zählerstromkreis ein Sicherheitsnachweis

Kontrollnummer: AK EX 117/18
Projektnummer: 11185552
Nummer 321700452.01

Eigentümer Tel.-Nr 0326269494
Name 1 Regio Energie Solothurn
Name 2
Strasse, Nr. Rötistr. 17
PLZ / Ort 4500 Solothurn

Verwaltung Tel.-Nr
Name 1
Name 2
Strasse, Nr.
PLZ / Ort

Elektro-Installateur Tel.-Nr 032 626 94 94
Name 1 Regio Energie Solothurn
Name 2
Strasse, Nr. Rötistrasse 17
PLZ / Ort 4500 Solothurn
Bewilligungs-Nr. I - 03164

Unabhängiges Kontrollorgan Tel.-Nr
Name 1 Mollet & Co. AG
Name 2 Elektro- Technisches Büro
Strasse, Nr. Lättackerstrasse 2
PLZ / Ort 4534 Flumenthal
Bewilligungs-Nr. SIS0098

Ort der Installation
Strasse, Nr. Aarestrasse 3
PLZ / Ort 4528 Zuchwil
Gebäudeart Mehrzweckgebäude
Bemerkung

Anlage
Stockw., Lage Store & Go
Stromkunde Regio Energie Solothurn
Zähler-Nr. 38323 Anl.-Nr.
Nutzung und Kontrollperiode(n) Gewerbe
Jahre 5
PK ausgeführt ☐ ☐ ☐

Prüfgrund
☒ Neuanlage
☒ Bestehende Anlage
☐ Änderung
☒ Erweiterung
☐

Durchgeführte Kontrolle
☒ Schlusskontrolle
☐ Abnahmekontrolle
☐ Periodische Kontrolle
Inst.-Anzeige Nr / Jahr /
Datum 18.05.2018

Kontrollumfang / ausgeführte Installation
Installationen für Store & Go ab separater Messung bezogen ab NSHV im OG. Ausbau Leistungsschalter mit geeichtem messwerk erfolgt am 13.06.2018 durch SLL-AG.

Datum der Kontrolle 12.12.2018 12.12.2018
☐ Plomben wurden entfernt

Technische Angaben
Schutz-System
☒ TN-S
☐ TN-C
☐ TN-C-S
☐

Anschlussüberstromunterbrecher I_N 250 A
Überstrom-Schutzorgan am Anschlusspkt. d. Inst. ab HV Hybridwerk
I_N 250 A Art, Charakteristik Leistungschalter
$I_{K\,Anf.\,L\text{-}PE}$ 5560 A $I_{K\,Ende\,L\text{-}PE}$ 201 A $I_{K\,Anf.\,L\text{-}N}$ A
R_{ISO} 5.86 MΩ I_{Leck} mA
Besonderheiten Siehe Mess- und Prüfprotokoll

Die Unterzeichneten bestätigen, dass die Installationen gemäss NIV (insb. Art. 3 und 4) und den gültigen Normen geprüft wurden und den anerkannten Regeln der Technik entsprechen.

Dieses Dokument bildet den Sicherheitsnachweis im Sinne der NIV für die erwähnten elektrischen Installationen und ist von deren Eigentümer aufzubewahren. Wer vorgeschriebene Kontrollen nicht oder in schwerwiegender Weise nicht korrekt ausführt oder Installationen mit gefährlichen Mängeln dem Eigentümer übergibt, macht sich strafbar (NIV Art. 42 c).

Unterschriften Elektro-Installateur
Datum 25.03.2019
Elektrokontrolleur: P. Urben — Pascal Urben (Vorname Name (Blockschrift))
Bewilligungs-Inhaber: R. Berthel — Réne Berthel (Vorname Name (Blockschrift))

Unterschriften unabhängiges Kontrollorgan
Datum 04.04.2019
Elektrokontrolleur: Janick Christen (Vorname Name (Blockschrift))
Bewilligungs-Inhaber: Christian Mollet (Vorname Name (Blockschrift))

Beilagen ☒ Mess- + Prüfprotokoll
☐

Verteiler ☒ SiNa + Zusatzdokumente an Eigentümer/Verwaltung
☒ SiNa an Netzbetreiberin/Inspektorat
☐

Netzbetreiberin / Inspektorat
Eingang am
Bemerkungen
Stichprobe ☐ Ja ☐ Nein
☐ Keine Mängel festgestellt
☐ Mängelbericht erstellt
☐ Anlage plombiert
☐ Massgebend für nächste PK
Datum
Visum

SiNa 2011

Gedruckt mit dem Programm 'ElektroForm' von Brunner Informatik AG, Worblaufen

Figure 6-3: SINA for the electrical installations

6.2 Piping Works

The piping works were limited to connecting the skid interconnecting lines and the feed lines for the required fluids:

No.	Medium	Flange Connection (DIN EN 1092-1)			
		DN	PN	Seal face	Material
B01	Hydrogen (H2)	25	40	B1	1.4571
B02	Carbon Feed (CO2)	15	40	B1	1.4571
~~B03~~	~~Hot Water (HW)~~	~~50~~	~~16~~	~~B1~~	~~P250GH~~
B04	Heating/Cooling Water (CW)	50	40	B1	P250GH
B05	Water Return (CW)	50	40	B1	P250GH
B06	Culture / Water (DW)	15	40	B1	1.4571
B07	Instrument Air (IA)	15	40	B1	1.4571
B08	Nitrogen (N2)	15	40	B1	1.4571
B09	Product Gas (NG)	25	40	B1	1.4571
B10	Methane (NG)	15	40	B1	1.4571
~~B11~~	~~Raw gas Sample (RG)~~	~~HOLD~~	~~HOLD~~	~~HOLD~~	~~HOLD~~
B12	From Nut. Rec. Sys-tem	50	40	B1	1.4571
B13	To Nut. Rec. System	50	40	B1	1.4571
B14	Drain (WW)	-	-	-	-
B15	To Gas Drier (NG)	25	40	B1	1.4571
B16	From Gas Drier (NG)	25	40	B1	1.4571
B18	RES Gas Analyser (VG)	EO 10	HOLD	HOLD	HOLD
B19	Vent Gas Drier	15	40	B1	1.4571
B20	Nitrogen for Dosing Unit (N2)	HOLD	HOLD	HOLD	HOLD
B25	Filtered Water (WW)	15	40	B1	14.571

Figure 6-4: Battery limit list

Additionally misaligned and wrong connections needed to be adapted. The following pictures show some examples of the required on site works.

Figure 6-5: Misaligned lines (left), fastening bolts (425 Nm) of H_2S removal vessel

Figure 6-6: In- and outlet of gas analyser pressure reduction train connected the wrong way

Figure 6-7: Carbon steel valves used in stainless steel line

6.3 Leakage Tests

The leakage test were very time consuming as many leakages and defects were discovered in the process. Reaching from wrong gaskets, lose connections to faulty equipment, we listed over 100 defects.

6.3.1 Defects

The following pictures show some of the defects encountered.

Figure 6-8: Leaking filter due do misalignment of top and bottom part

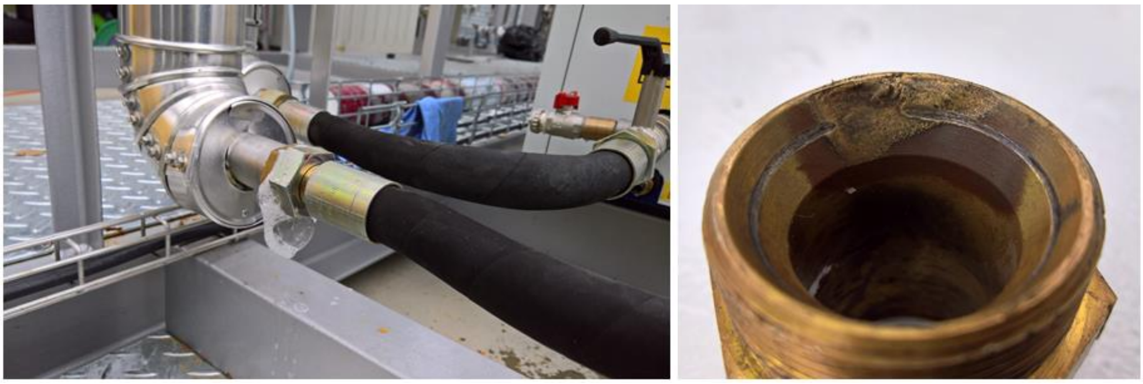


Figure 6-9: Leakage of the chiller lines due to faulty fitting, additionally the hoses had to be replaced (too rigid)

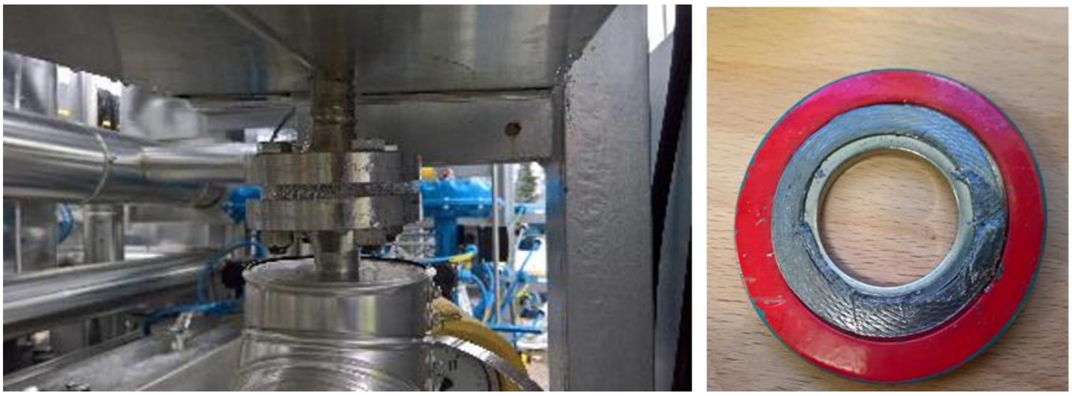


Figure 6-10: Wrong size in the wrong place

Figure 6-11: Insufficiently tightened connection

6.3.2 Tests performed

The leakage test were performed section for section, until all leaks were detected.

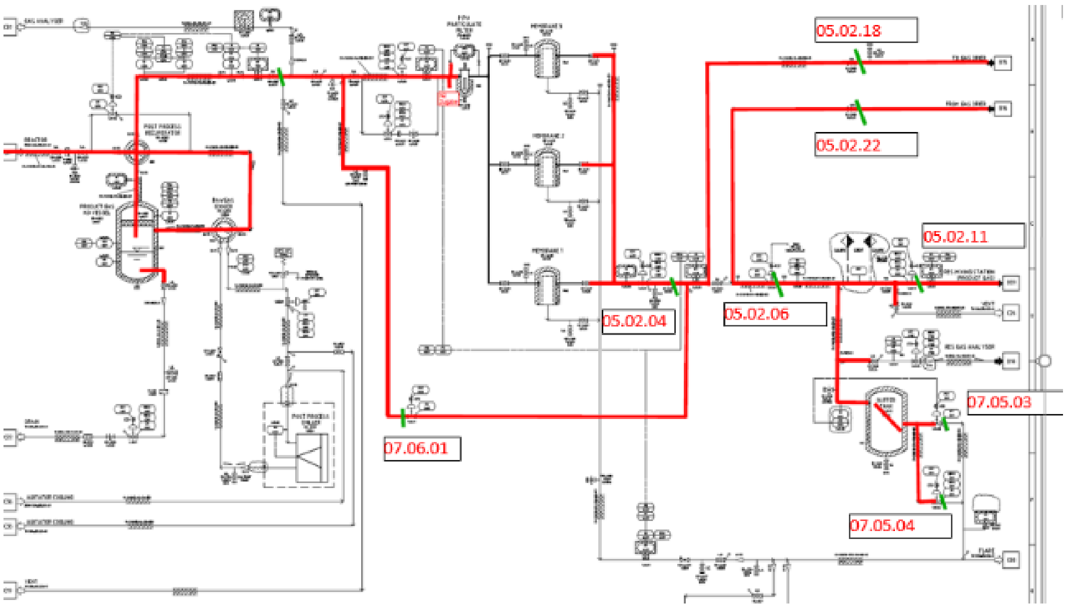


Figure 6-12: Blocking of different sections for leakage detection

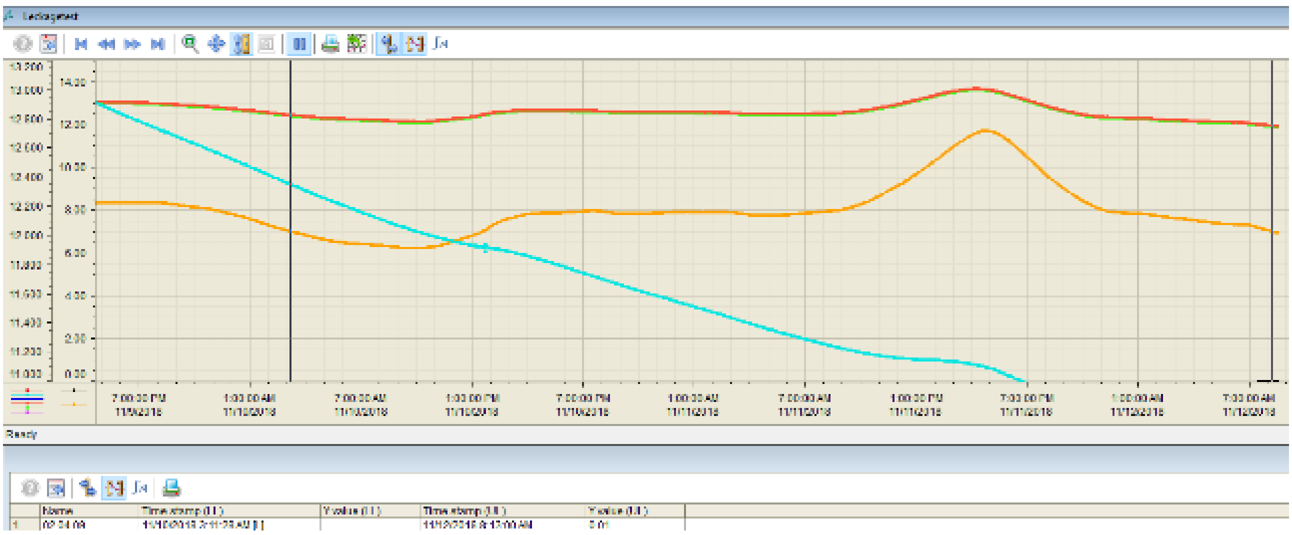


Figure 6-13: Recording of pressure trend over time

6.4 Insulation Works

The insulation works took over a month to be completed, the final works were completed in January 2019. The material for completion of the insulation was delivered with the plant, but the parts could not be assigned to the relevant part to be insulated.

6.5 Plant Test Runs with water

During these test runs, the different components were tested with the reactor being filled with water. Unfortunately, problems with the agitator arose, the tower started to vibrate slightly and a squeaking noise synchronous with the rotation of the agitator was audible. All possible sources such as temperature and level measurements checked, without getting to the source of the noise.

Consequently EKATO, the supplier was called on site to verify the bearing installation.

After opening the two manhole and inspecting the bearing, the misalignment between the shaft and the middle bearing was clearly visible. All struts were removed, adjusted and reassembled again.

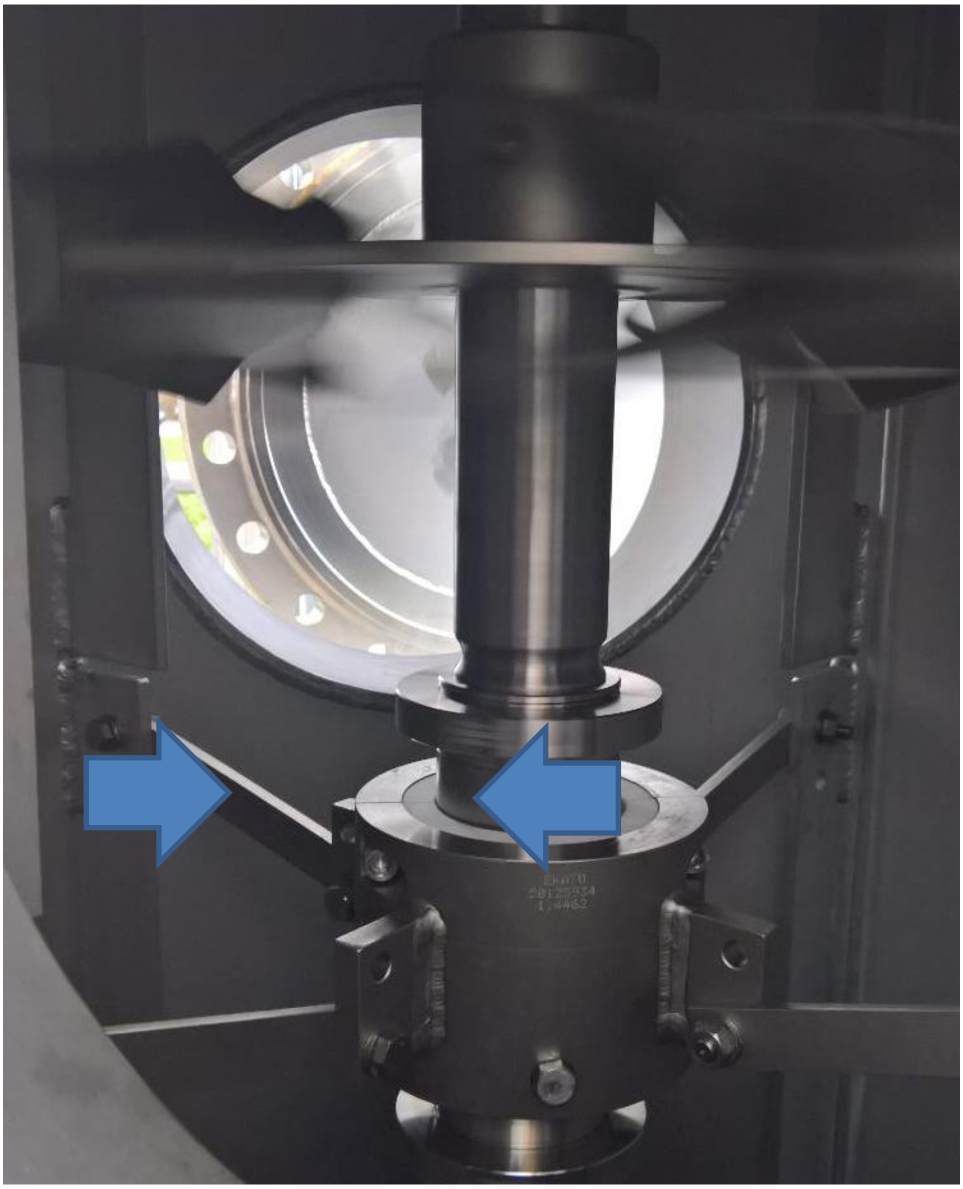


Figure 6-14: Misalignment clearly visible comparing the left to the right

Figure 6-15: Reassembling and aligning the bearing

The first test runs showed no improvement though, the noise was still present. A camera was inserted into the reactor to check for any loose parts, but nothing irregular could be found.

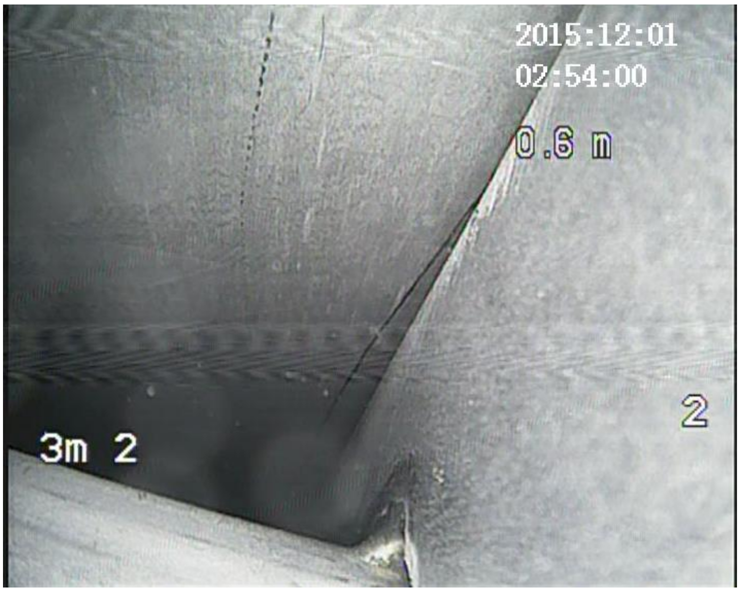


Figure 6-16: Inside view of the reactor

In order to record the noise, the plant was run continuously and repeatedly at different frequencies, until the noise suddenly disappeared.

Operating the agitator “healed” the bearing, equalling the uneven wear present due to the misalignment of the first installation.

6.6 Plant Operation

In the early stages of commissioning was several issues were found during a safety review, and Electrochaea and the contractor Caloric took measures to reassess the control system on a wholistic basis. This process led to delays in the commissioning, but an improved automation package.

Work on site was resumed on 20 May, adjusting the control system for the switch over from the different sequences from cold stand-by to injection.

6.6.1 Problems Encountered

During the following weeks, several additional problems were encountered:

6.6.1.1 Level Measurement

The level measurement installed is a differential pressure measurement, the pressure from the top being transduced by means of an oil filled capillary to the membrane at the bottom measurement. As the oil in this capillary expands with rising temperature the measurement is very sensitive to temperature changes, this sensitivity could not be compensated by any means. As a temporarily workaround, a pressure difference check has been made which compares the mix feed pressure and the headspace pressure to determine the static level. A camera was also installed enabling the level monitoring from the control room. These measures are in place while troubleshooting of the main level measurement device is completed.

Figure 6-17: Sight glass

6.6.1.2 pH Probe

The pH probe proved to be very sensitive to the pressure fluctuations resulting from the membrane pump. Both probes broke within 3 weeks, having a lead time of 5 weeks. After the second probe broke a standard in stock version was purchased, which has been in operation ever since. Additionally the flow in the measuring line was reduced in order to reduce the pressure peaks.

28.05.2019: first probe out of service
17.06.2019: second probe out of service

Currently the same probe is still in use.

6.6.1.3 Loss of CO_2

Due to a defective solenoid valve on the CO_2 compressor we lost CO_2 on 04.06.2019. The problem could be solved by replacing the coil and operation was resumed the next day. As the source of the failure was not the coil itself but a groove in the valve sleeve, the whole valve including coil needed replacement some weeks later.

Figure 6-18: Defective solenoid valve

6.6.1.4 Nutrient Feed

The feeding of the different nutrients causes alarms, indicating the formation of bubbles. This has been caused under certain conditions where the high ambient temperature causes the ammonia the start boiling, A second issue is that the 100X media precipitates in the day tank. Electrochaea are currently testing the mixing recipes and testing water. In winter the antifoam requires better heating and insulation, due to the high viscosity at low temperatures.

7 Training

The plant works really well on a high automation grade. Two detailed training sessions have been conducted by Electrochaea and have focused on theory, practical, and safety aspects. Before RES/HSR can take over the operation, a training needs to completed, ensuring a safe operation of the plant. A third and final one to take place in the coming weeks once the remaining issues are closed out.

7.1.1 Operating Experience

Up to date 1410 kg of SNG have been injected into the local grid, with Injection of SNG being initiated on the 06.06.2019 at 14:30, reaching a gas quality with a CH_4 content > 99%. So far, 145 hrs of operation and 85 hrs of grid injection have been accumulated so far. This is a major achievement when considering the short period that the plant has been operational.

The main experiences made are as follows:

- Biocatalyst growth/methanation immediately started after feeding with H_2/CO_2 was started
- 96% methane content in product gas after 4 days of interrupted operation
- Grid injection started after 1.5 weeks of interrupted operation
- Start-up procedure currently takes 15min until grid injection starts
- At nominal 15 m^3/h (NTP) CO_2 gas flow is stable and complete conversion of CO_2 is achieved

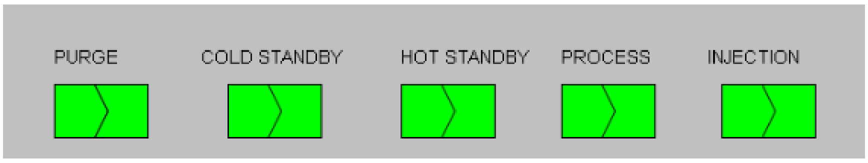
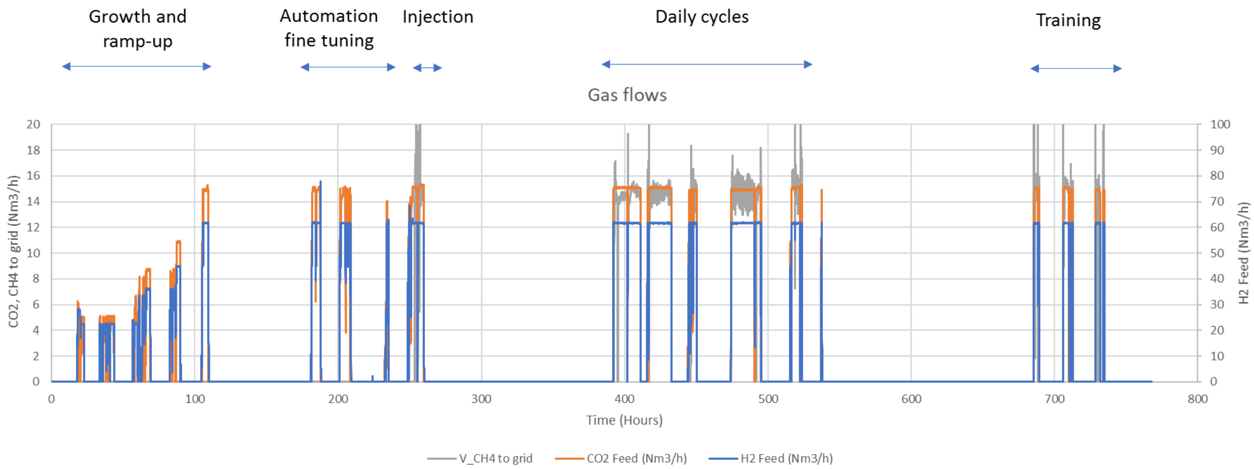


Figure 7-1: Automation Steps, green = current operation mode

The different operation stages can simply be set by clicking on the desired mode. If all required conditions are met the plant will automatically move to the desired mode.



~1:1 match between CO2 processed and CH4 injected

Figure 7-2: Gas flows during commissioning

8 Next Steps

The next steps will focus on resolving the problems mentioned in the last section, the main target being an unattended operation mode and reaching a minimum of 2000 h operational hours.

Additionally the following tasks are still pending:

- Testing the procedure of ramping from nominal 15 m^3/h (CO_2) to nominal 30 m^3/h (CO_2) operational mode (normal temperature and pressure, NTP).

- Completion of operator training

- Operating the plant according to the profiles established in WP 5

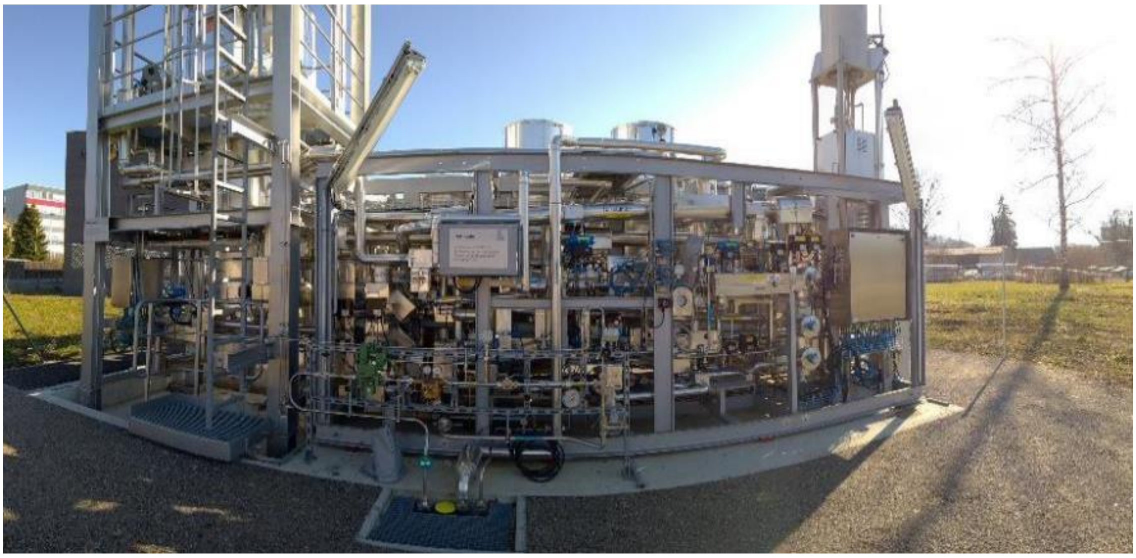


Figure 8-1: View on the gas skid, tower left, flair on the right

Figure 8-2: Gas drier left, plant tower holding reactor and agitator