Use of hydrogen in energy-intensive sector

Tilen Sever

HRASTNIK1860

Outline

About The Company

Hrastnik1860 is developing and manufacturing world-class engineered glass products, distinguished by some of the clearest glass in the world.

Hrastnik1860 is based in Slovenia and offers wide range of products that include **premium and super premium glass containers,** primarily dedicated to the spirit, perfumery and cosmetics market.

It focuses on flexible and excellent service, short time to the market and innovative tailor-made solutions.

1. **285 t** daily production capacity
2. **600** employees
3. export to more then **50** countries worldwide
4. **full service** solution
5. **160 years** of tradition

SPIRIT GLASS
PACKAGING

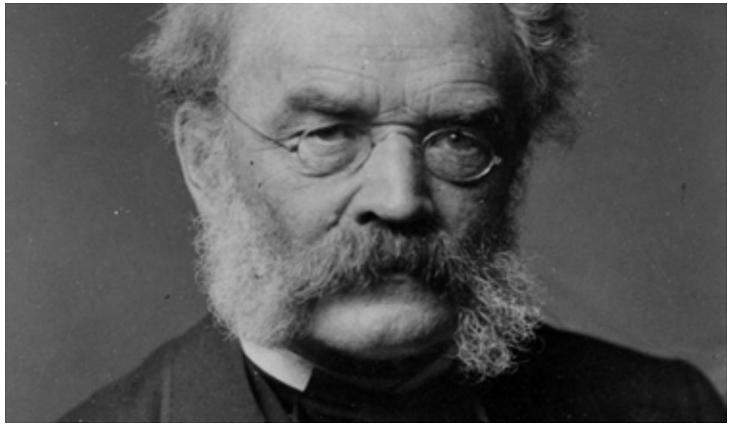
PREMIUM WATER
GLASS PACKAGING

PERFUMERY AND
COSMETICS
FLACONS

History

160 YEARS OF TRADITION

FROM MANUAL,
TO STATE OF THE ART
TECHNOLOGY



WERNER VON SIEMENS
1873 INNOVATION STARTS

HRASTNIK1860

HRASTNIK1860

VISION

To be the **most inspiring** and **most sustainable glass packaging** company on the planet.

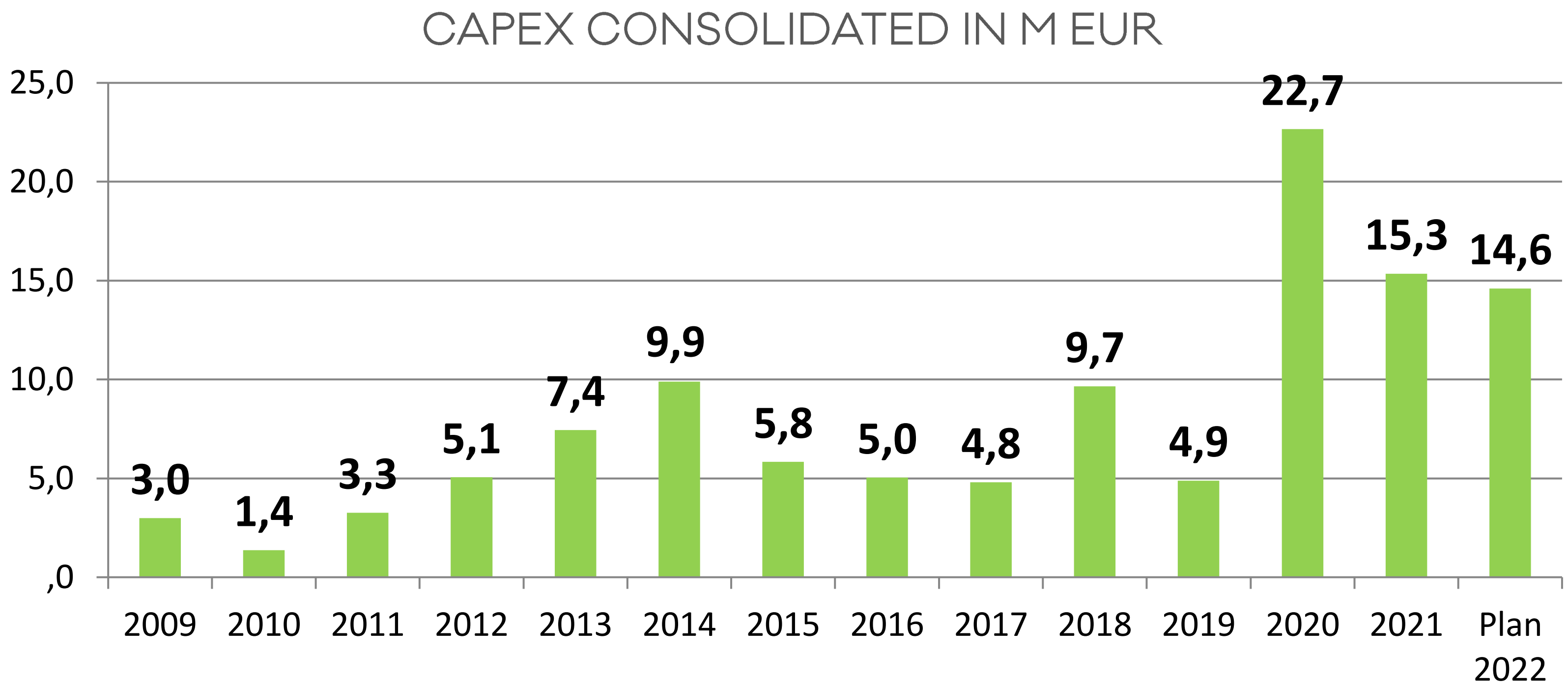
Challenge

Neutrality by 2050

Dramatically improved technologies needed

Innovations are of key importance

Sustainable Growth



INVESTMENTS

TECHNOLOGY
INNOVATION
SUSTAINABILITY

2009-2021: 98 mio EUR

HRASTNIK1860

HRASTNIK1860

GREEN TRANSFORMATION

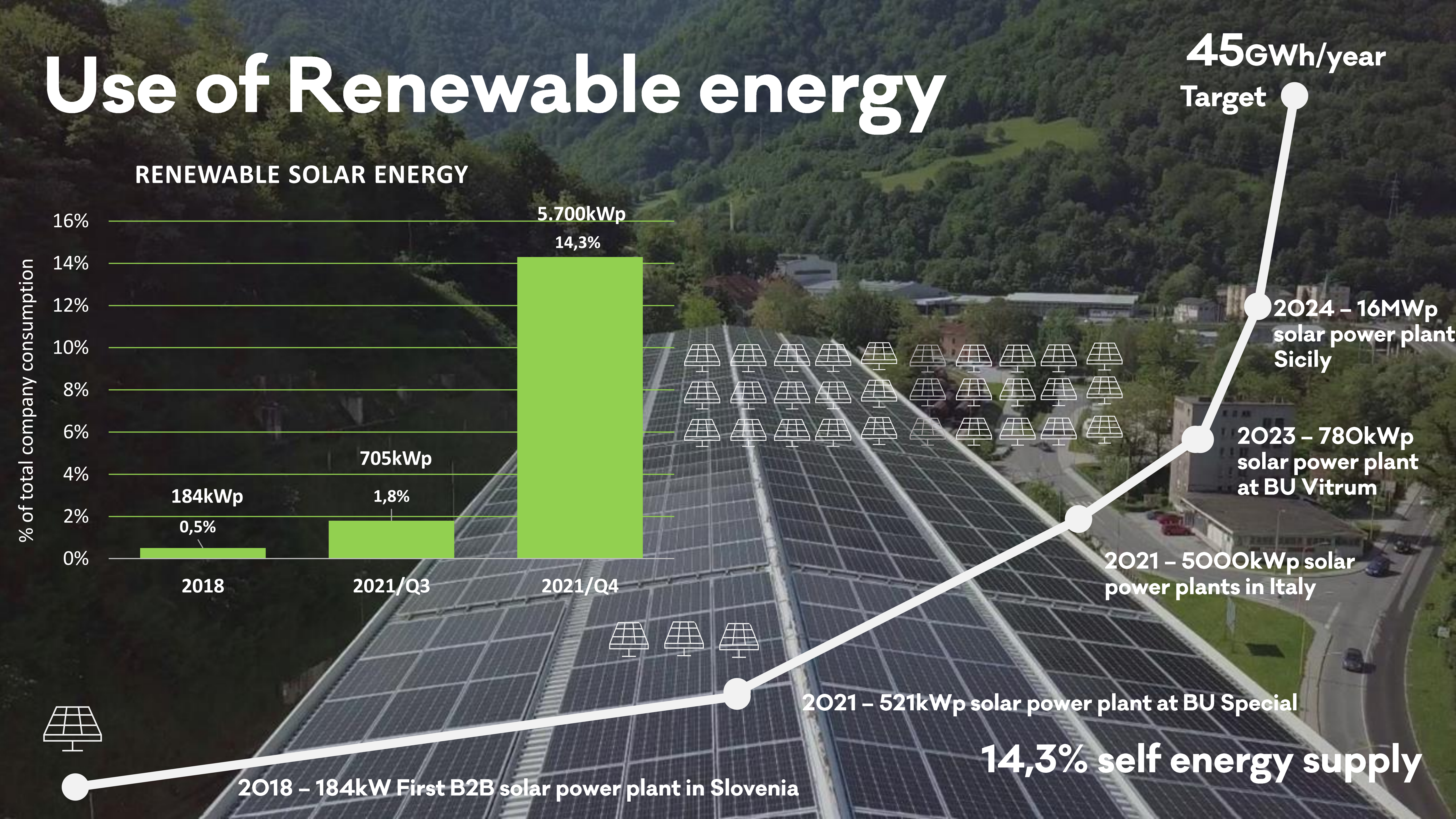
Use of renewable energy sources

Improving energy efficiency

Electrification

Renewable fuels

Green innovation


Use of Renewable energy
RENEWABLE SOLAR ENERGY
% of total company consumption
16%
14%
12%
10%
8%
6%
4%
2%
0%
184kWp
0,5%
705kWp
1,8%
5.700kWp
14,3%
2018
2021/Q3
2021/Q4
45GWh/year
Target
2024 – 16MWp
solar power plant
Sicily
2023 – 780kWp
solar power plant
at BU Vitrum
2021 – 5000kWp solar
power plants in Italy
2021 – 521kWp solar power plant at BU Special
14,3% self energy supply
2018 – 184kW First B2B solar power plant in Slovenia

PV Plant – Steklarna Hrastnik 1

Date: 2018

Power: 184,2 kWp

Energy production: 176 MWh/ year

HRASTNIK1860

PV Plant – Steklarna Hrastnik 2

Date: 2021

Power: 521,4 kWp

Energy production: 488 MWh/ year

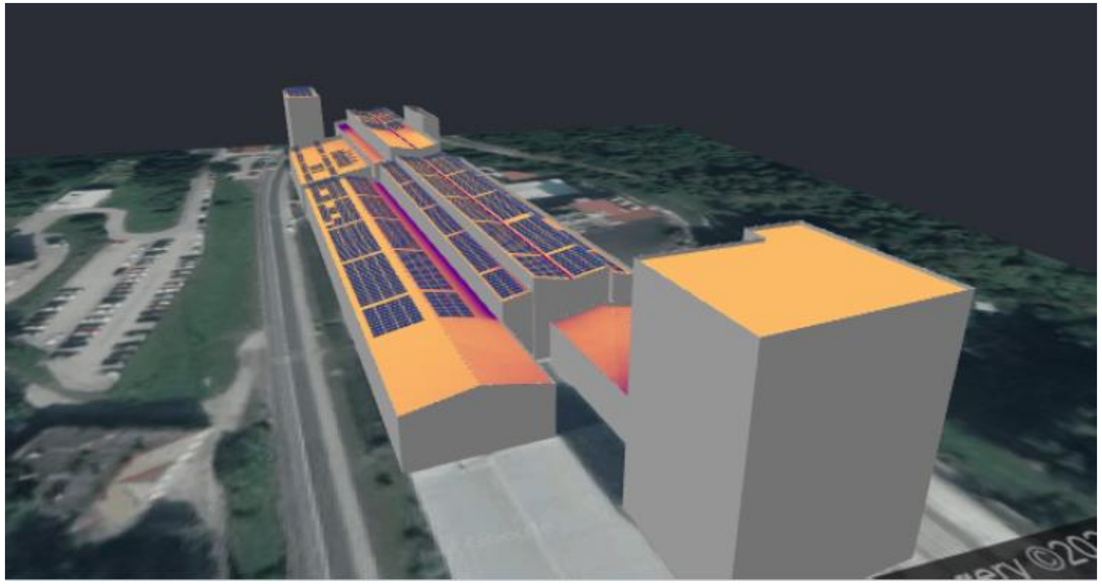
Renewable energy

PV Plant – Steklarna Hrastnik 3

Date: 2023

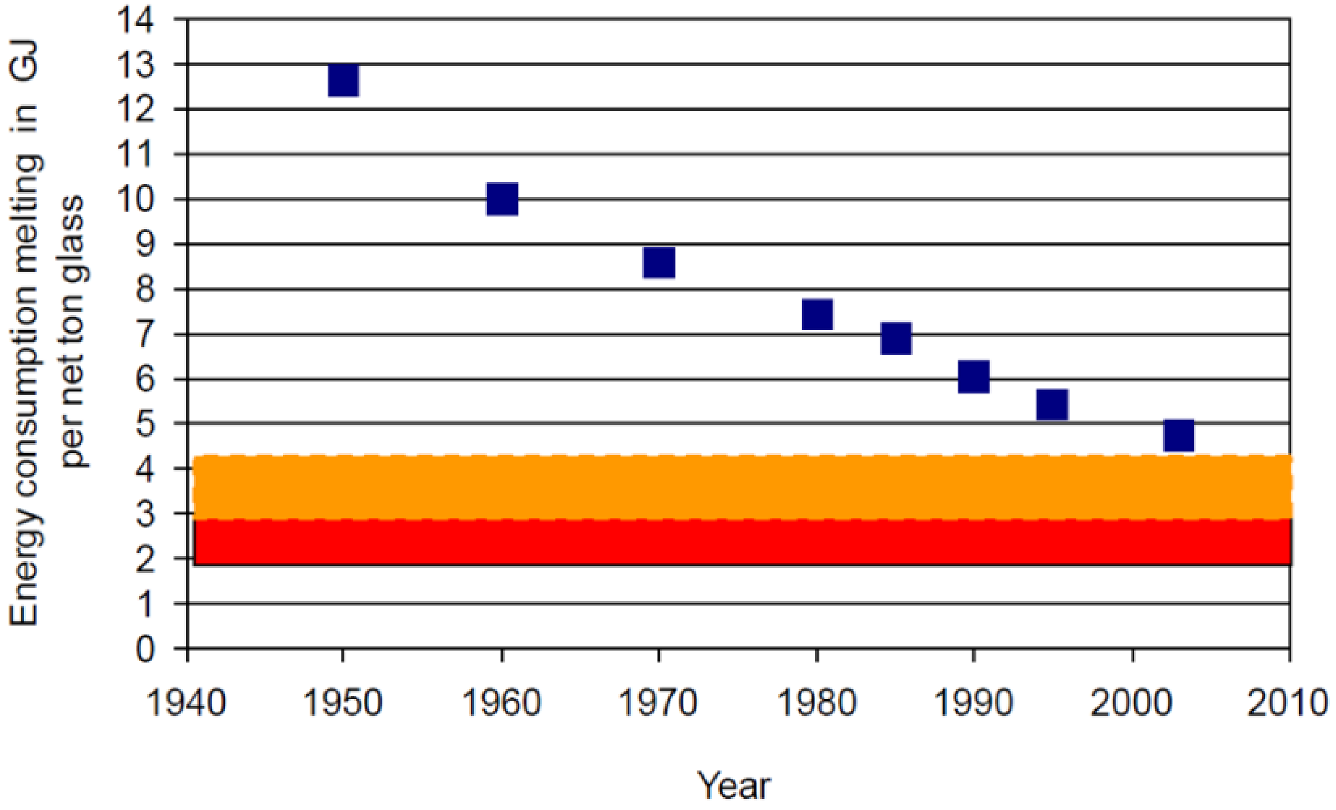
Power: 773,96 kWp

Energy production: 782 MWh/ year



THE "PLATEAU OF DIMINISHING RETURNS"

red bar: range of theoretical low-limit based on thermodynamics for melting and heating of glass (1350 °C) for 100 % batch (upper range) and 100 % cullet (lower range)
orange bar: best practical limits, no wall heat losses

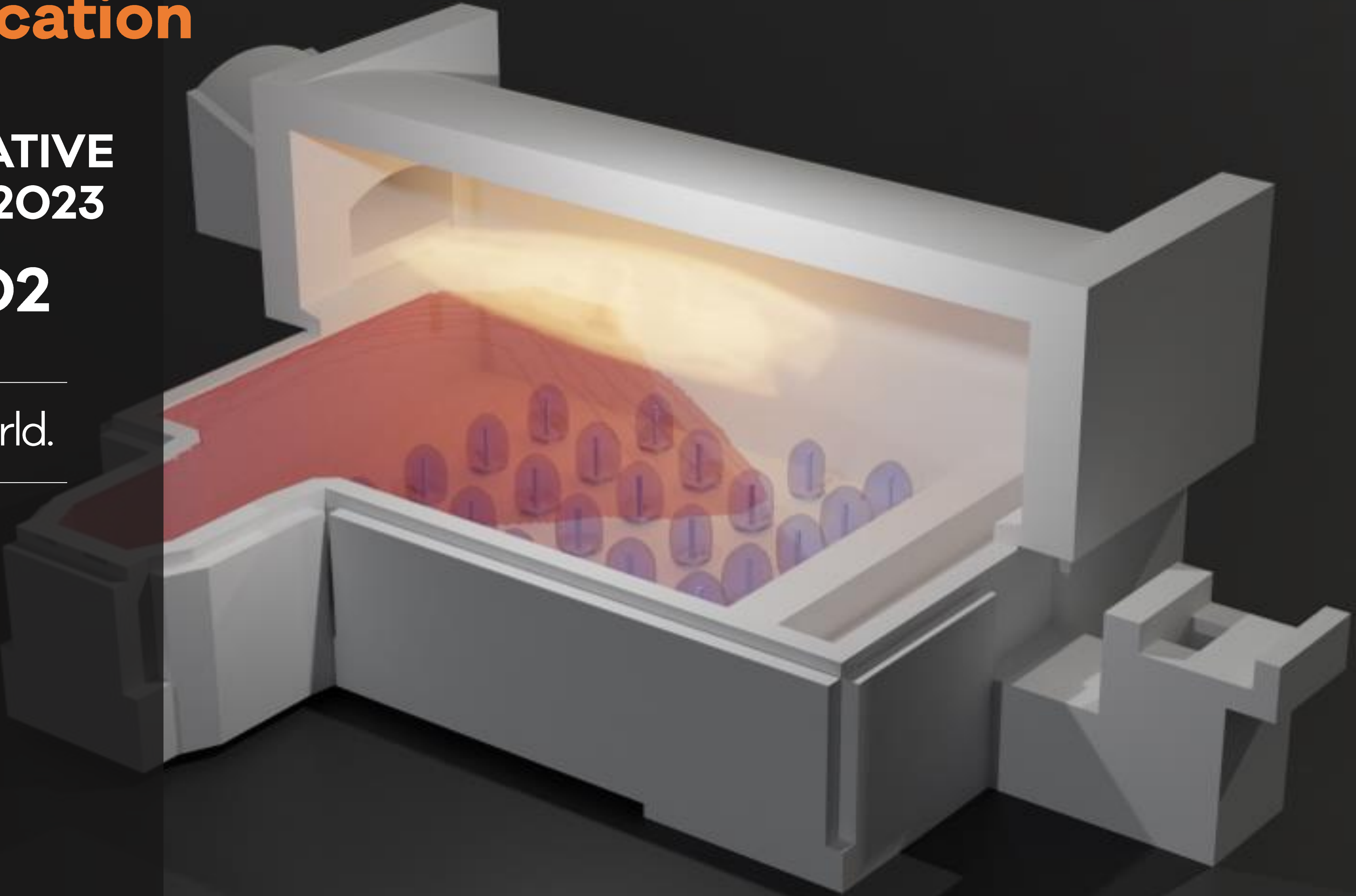


Electrification

HYBRID REGENARATIVE FURNACE 2023

-40% CO_2

First in the world.



HRASTNIK1860

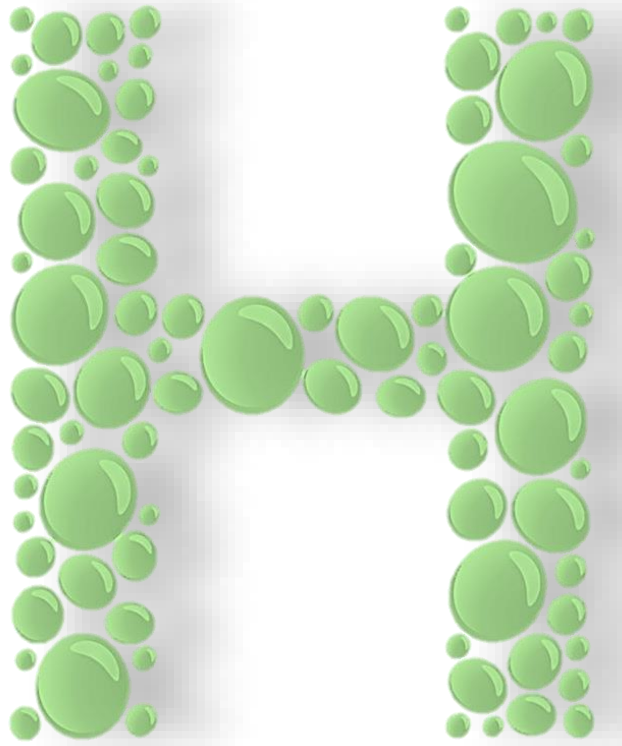
1 Background

CHALLENGE

- ✓ THE EUROPEAN GREEN DEAL REQUIRES THE TIGHTENING OF GHG EMISSION REDUCTION TARGETS BY **AT LEAST -50%** FOR THE PERIOD **1990/2030**. THE PROPOSED EUROPEAN CLIMATE LAW, HOWEVER, DICTATES **CLIMATE NEUTRALITY BY 2050**.
- ✓ **GHG EMISSIONS** ARE THUS ONE OF THE KEY CHALLENGES OF THE ENERGY-INTENSIVE INDUSTRY. THE **GLASS INDUSTRY WILL HAVE TO DECARBONIZE** COMPLETELY OVER THE NEXT 30 YEARS.
- ✓ IN ORDER TO ACHIEVE THESE REDUCTION LEVELS, CURRENT PRODUCTION TECHNOLOGIES NEED TO BE **DRAMATICALLY IMPROVED**, AND NEW TECHNOLOGIES NEED TO BE DEVELOPED AT THE **INDUSTRIAL LEVEL**.
- ✓ THE AVERAGE LIFE SPAN OF THE **GLASS FURNACE**, WHERE **90% OF ALL GHG EMISSIONS ARE PRODUCED**, IS 8-10 YEARS. IT IS, THEREFORE, THE PRESSING NEED TO **START INNOVATING** AND TO TRANSIT TO **NEW TECHNOLOGIES** AS 2050 IS ONLY A FEW FURNACES AWAY.

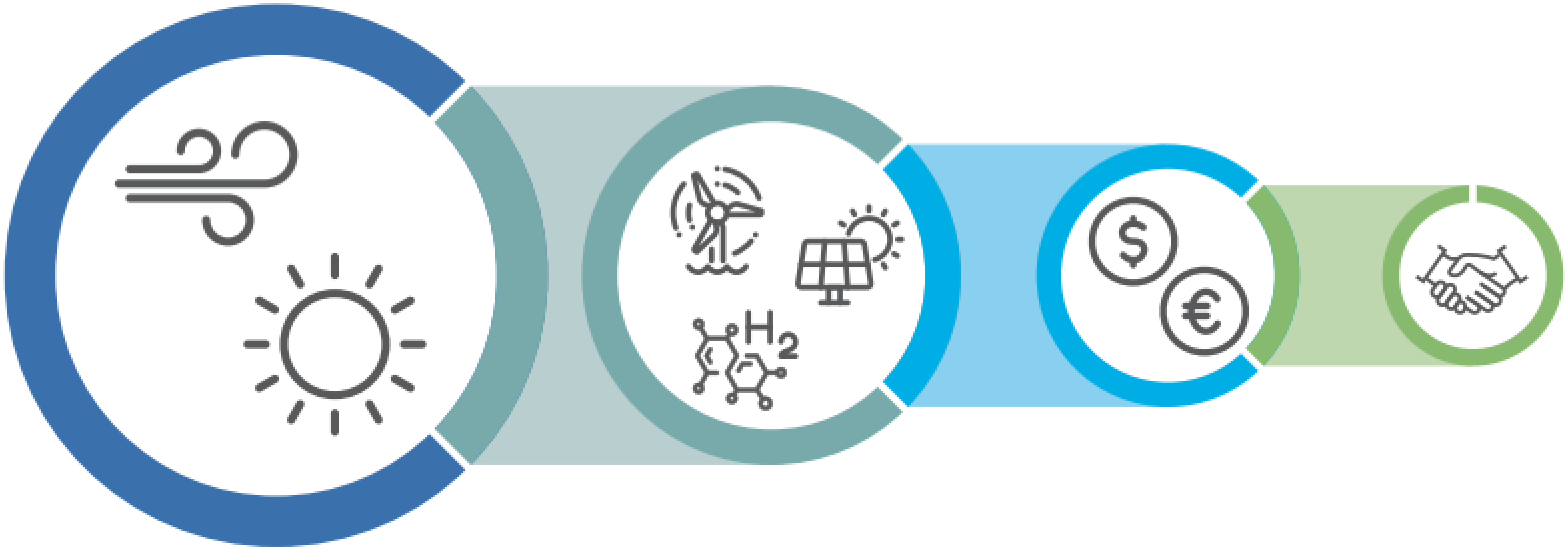
Why hydrogen?

- ✓ **HYDROGEN** FROM RENEWABLE POWER IS TECHNICALLY VIABLE TODAY AND IS QUICKLY APPROACHING **ECONOMIC COMPETITIVENESS**
- ✓ **HYDROGEN** AS RENEWABLE FUEL CAN BE RELATIVELY EASILY APPLIED TO EXISTING FURNACES THAT USE NATURAL GAS AS PRIMARY FUEL
- ✓ **HYDROGEN COMBUSTION** DOESN'T AFFECT FURNACE LIFESPAN TO A LARGE EXTENT
- ✓ HYDROGEN CAN ENABLE OUTSTANDING ENERGY FLEXIBILITY BETWEEN NATURAL GAS AND ELECTRICITY
- ✓ HYDROGEN CAN OFFER FURTHER REDUCTION OF FOSSIL FUEL CONSUMPTION ONCE 80% ELECTRICITY IS DEMONSTRATED TO REALIZE **ZERO GHG EMISSION MELTING**.
- ✓ HYDROGEN IS COMPLEMENTAL TO **HYBRID MELTING**, AND IS IMPORTANT FOR **CCUS** AND **POWER-2-X SOLUTIONS**



But?

Theoretical potential → **Technical potential** → **Economic potential** → **Market potential**



Theoretical potential
- Energy content of all wind and solar resources which could theoretically be transformed into green hydrogen.

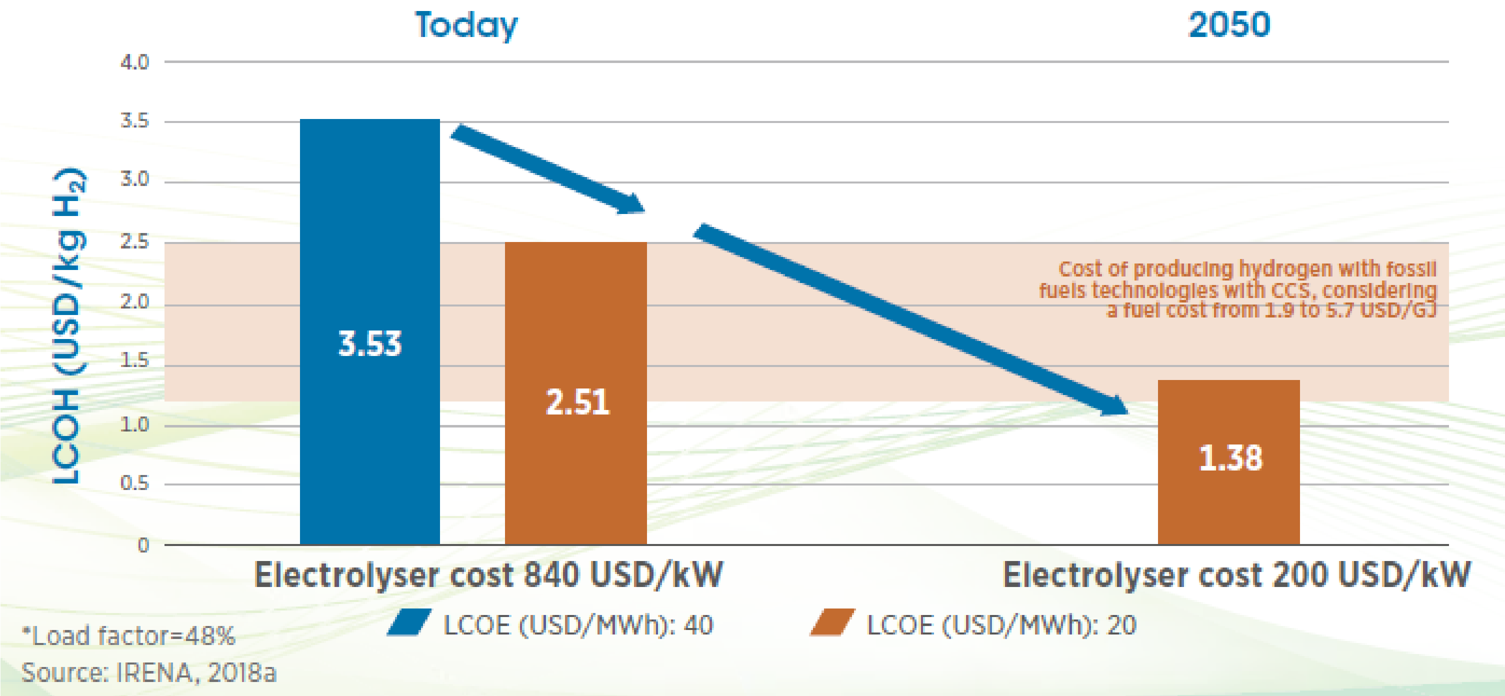
Technical potential
- Solar and wind energy that can be effectively harvested through wind parks and utility-scale PV.
- Theoretical potential reduced by technology characteristics and land eligibility constraints.

Economic potential
- Not all hydrogen technical potential production may present competitive LCOH.

Market potential
- Dictated by the presence of green hydrogen offtakers.
- Competition between direct sale of clean energy and sale of green hydrogen produced with that energy.

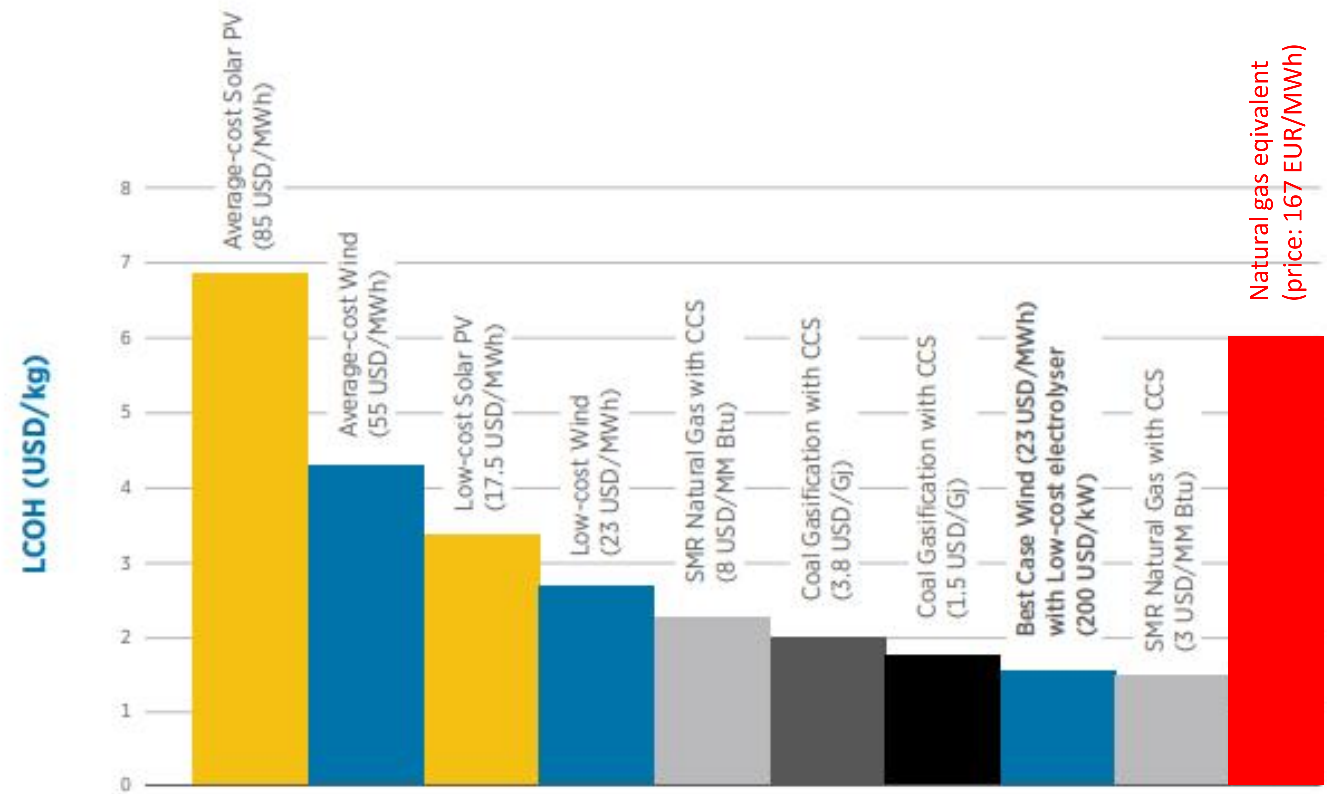
Source: IRENA Global Hydrogen Trade Costs 2022

Green Hydrogen



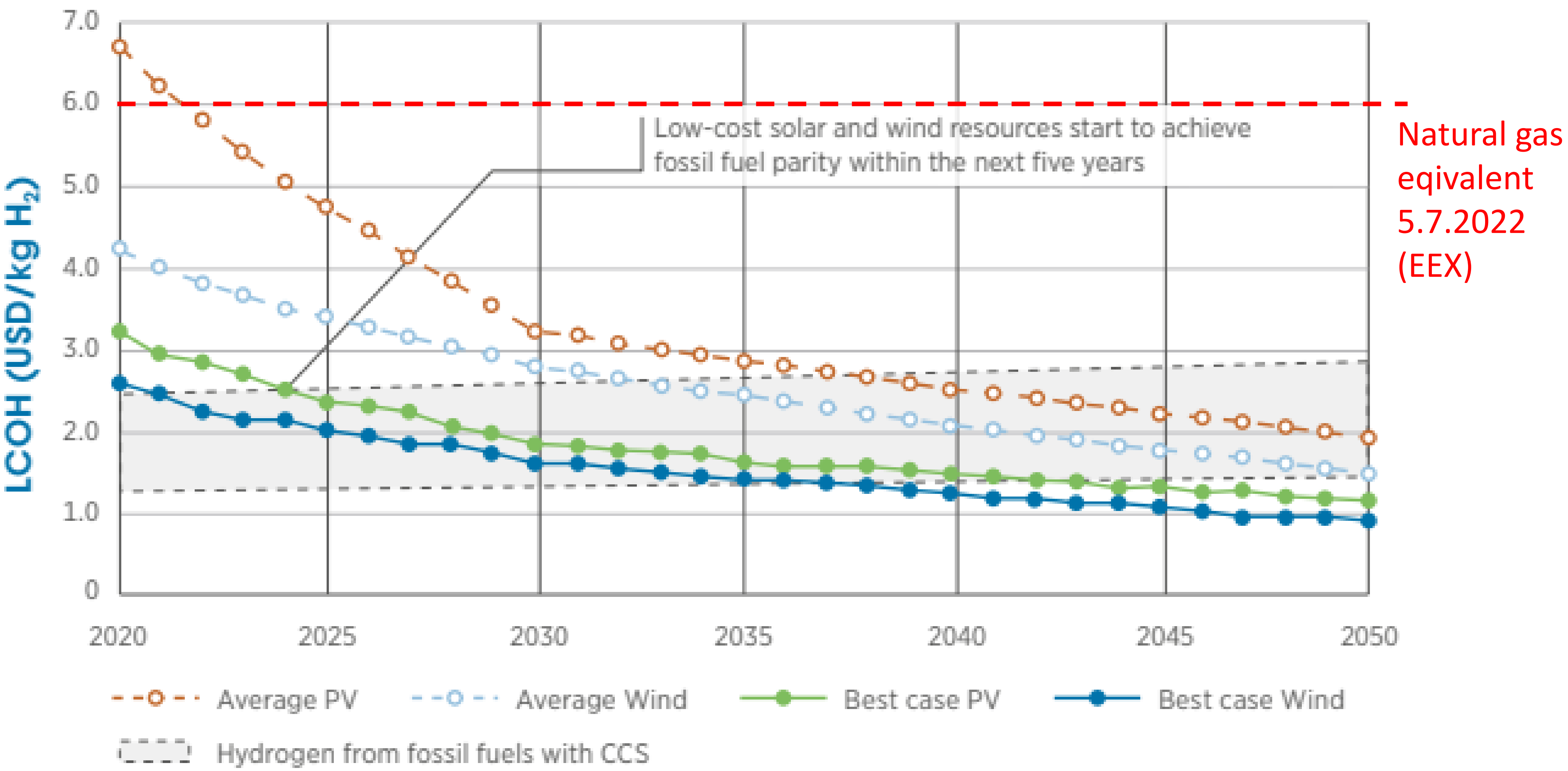
Renewable hydrogen will soon become the cheapest clean hydrogen supply option for many greenfield applications.

Competitiveness of renewable hydrogen today

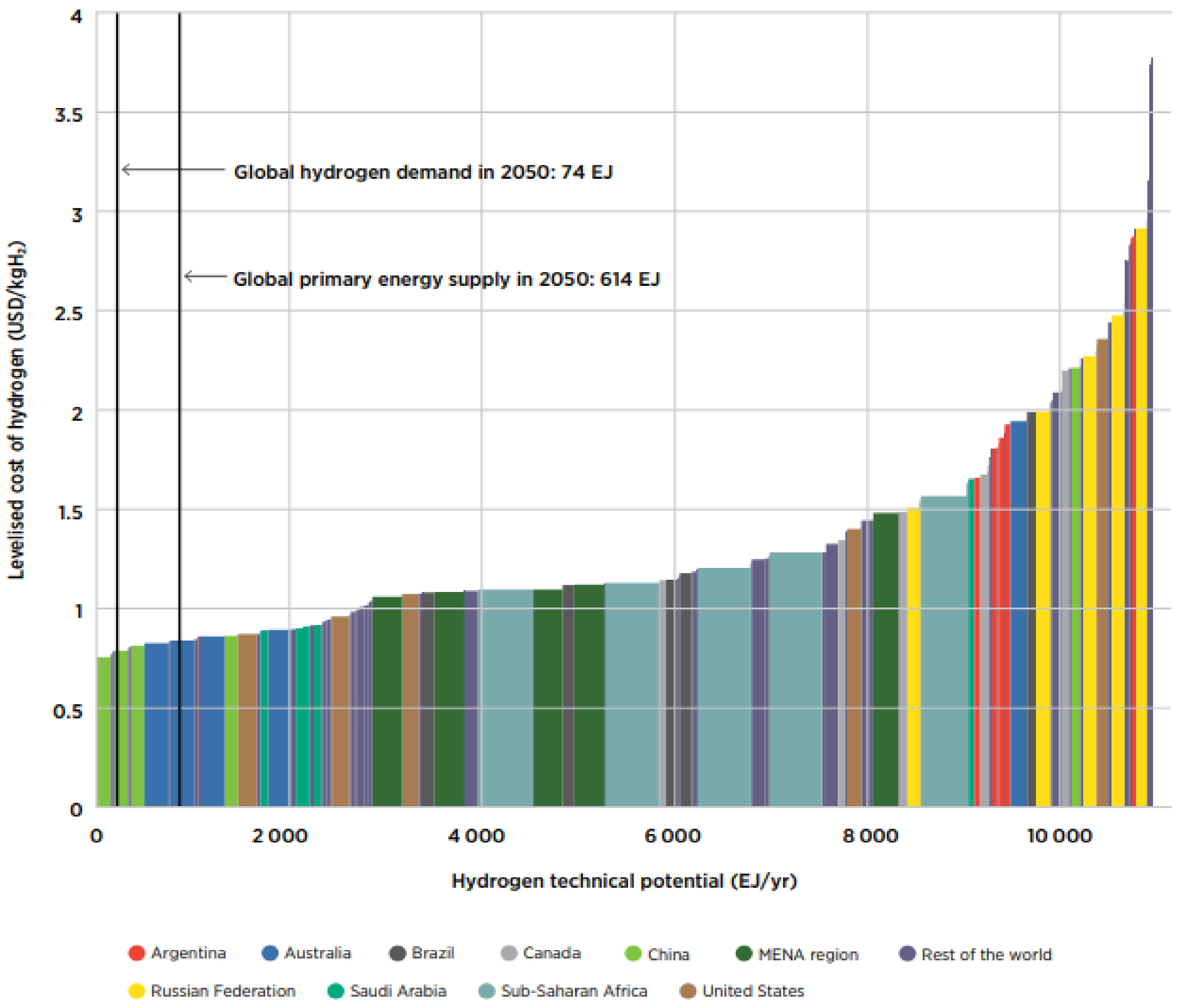


Notes: Electrolyser capex: USD 840/kW; Efficiency: 65%; Electrolyser load factor equals to either solar or wind referencence capacity factors. For sake of simplicity, all reference capacity factors are set at 48% for wind farms and 26% for solar Pv PV systems.
Source: IRENA analysis

Competitiveness of renewable hydrogen

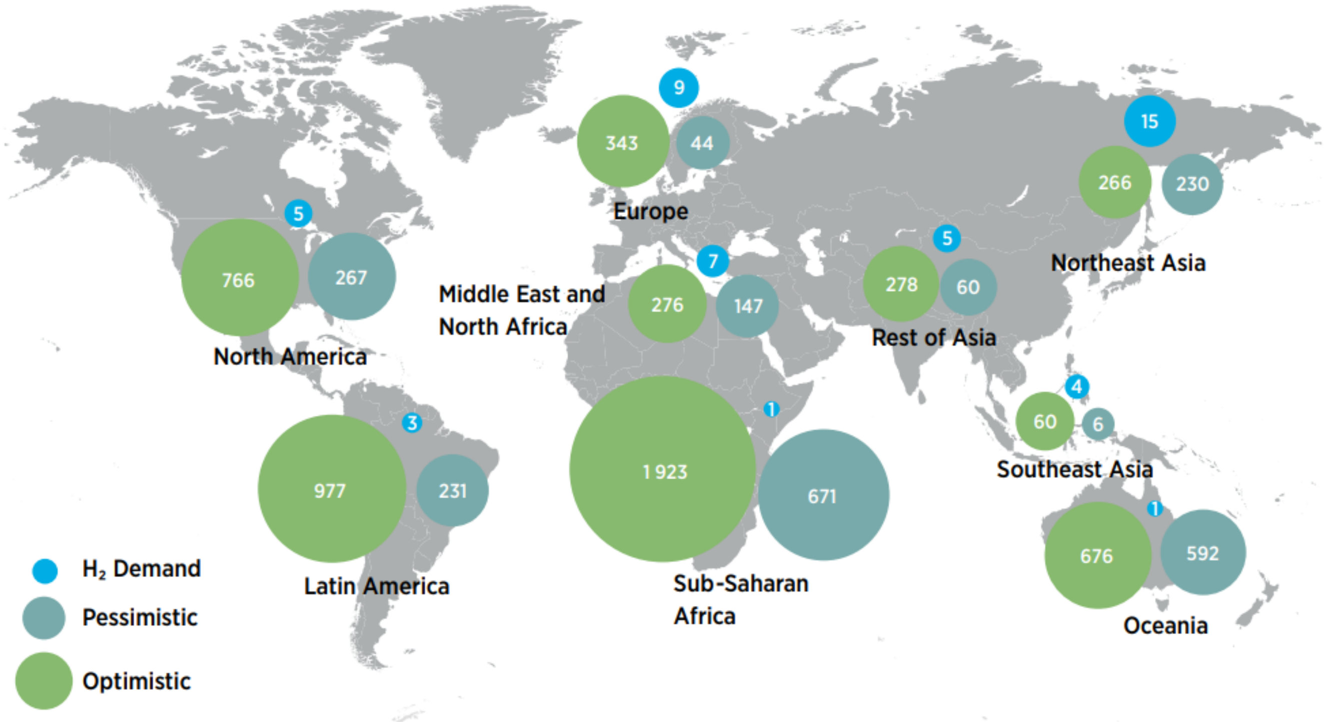


Competitiveness of renewable hydrogen in 2050



Source: IRENA Global Hydrogen Trade Costs 2022

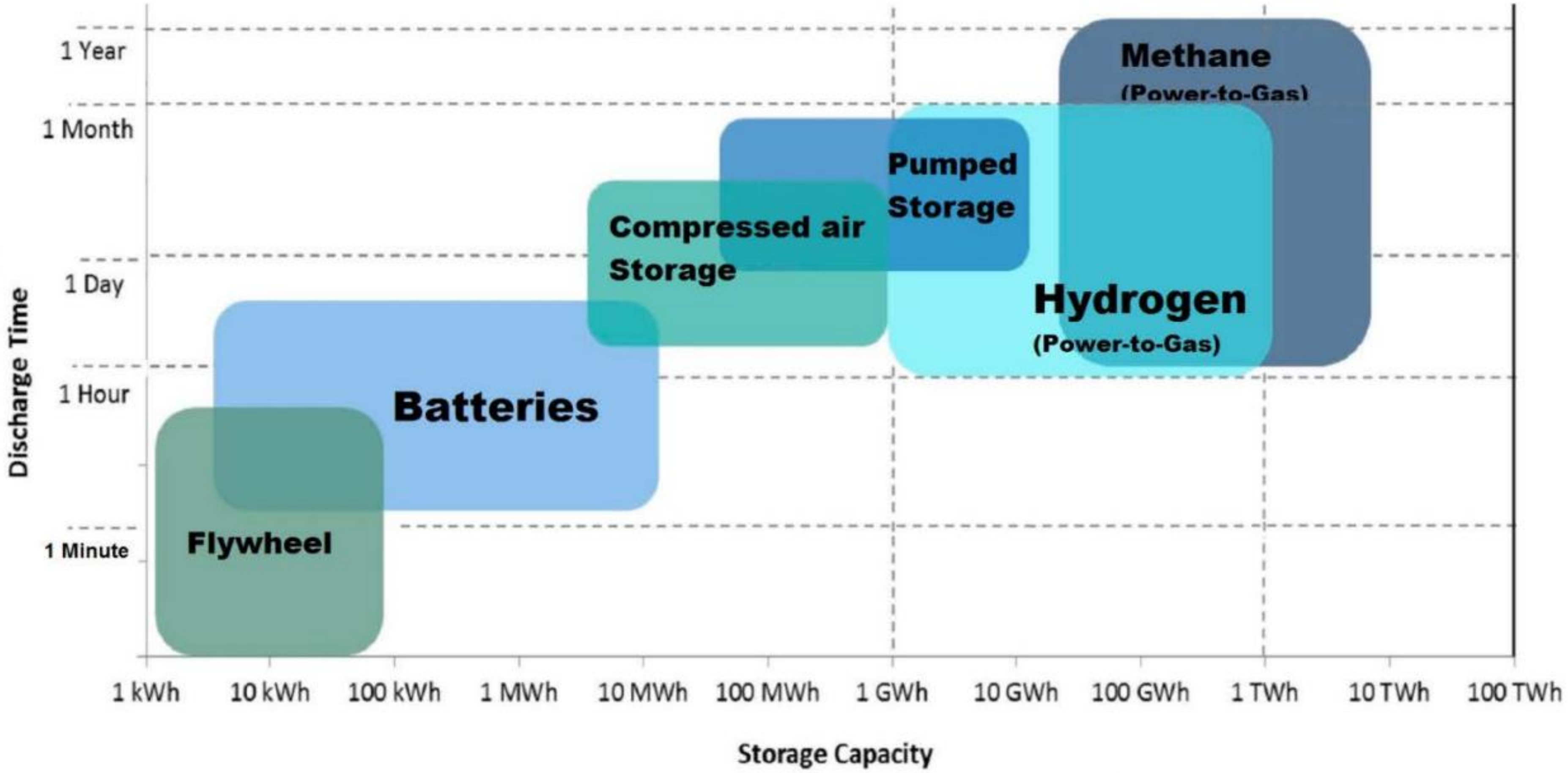
Potential of green hydrogen supply below and forecasted hydrogen demand



Notes: Assumptions for CAPEX 2050 are as follows: optimistic, PV: USD 225/kW to USD 455/kW; onshore wind: USD 700/kW to USD 1070/kW; offshore wind: USD 1275/kW to USD 1745/kW. Pessimistic, PV: USD 271/kW to USD 551/kW; onshore wind: USD 775/kW to USD 1191/kW; offshore wind: USD 1317/kW to USD 1799/kW. WACC: optimistic, per 2020 values without technology risks across regions. Pessimistic, per 2020 values with technology risks across regions. Technical potential has been calculated based on land availability considering several exclusion zones (protected areas, forests, permanent wetlands, croplands, urban areas, slope of 5% [PV] and 20% [onshore wind], population density and water stress). Total hydrogen demand, not including power sector (24 EJ/year), is equal to 50 EJ/year.

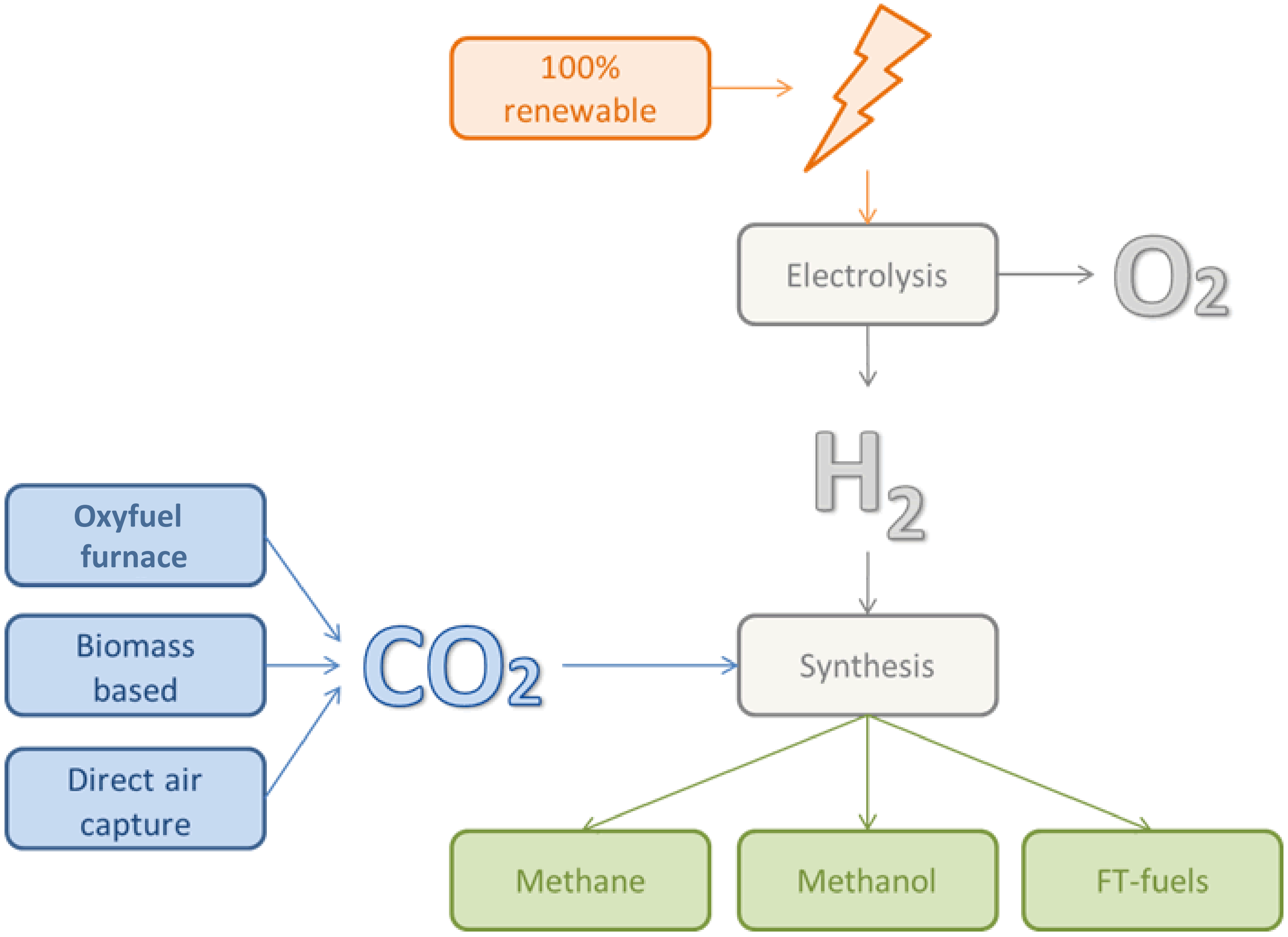
Source: IRENA Global Hydrogen Trade Costs 2022

Hydrogen for RE storage



Source: School of Engineering, RMIT University (2015)

CCUS and e-fuels

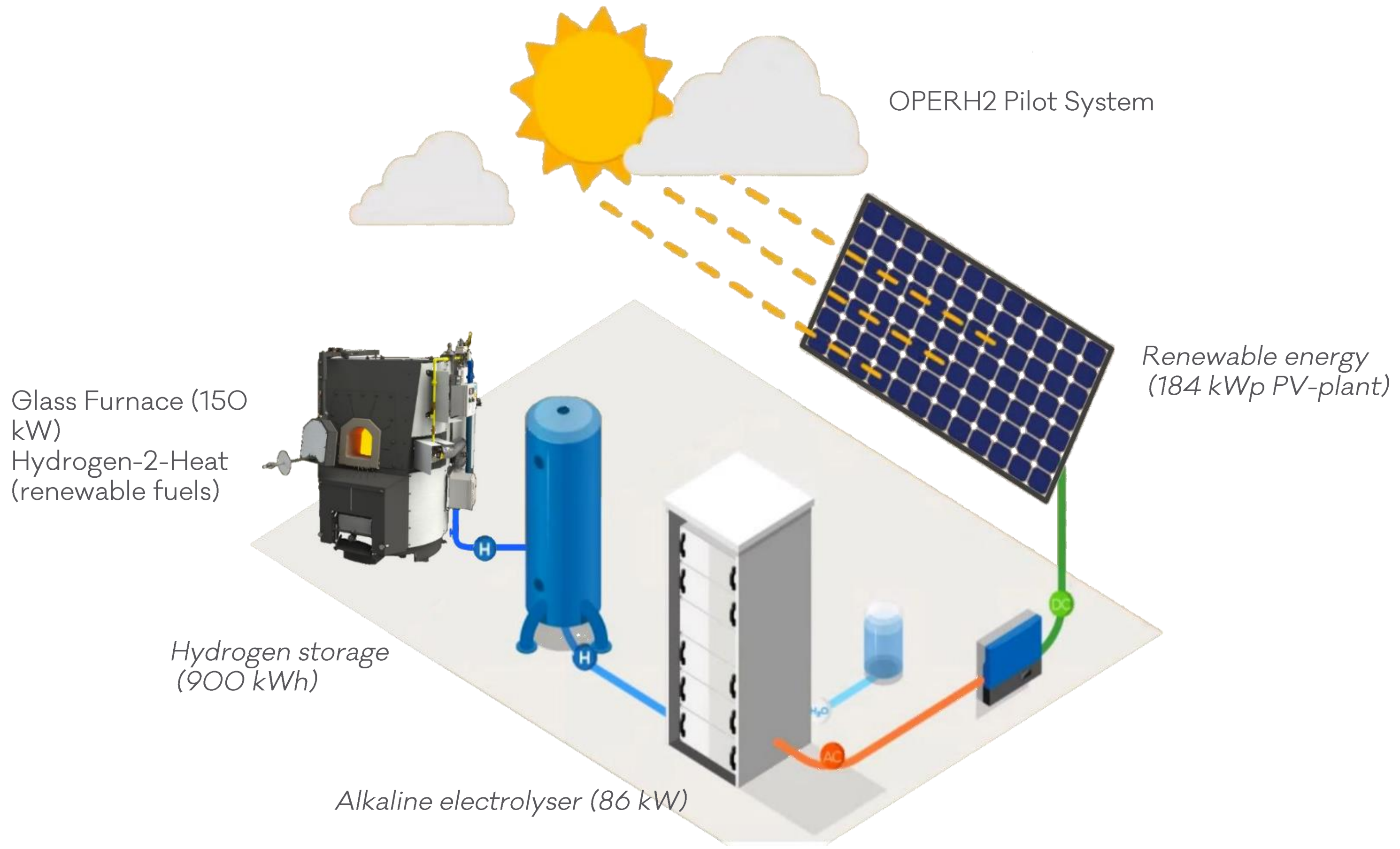


Source: etipbioenergy.eu

2 Hydrogen pilot system

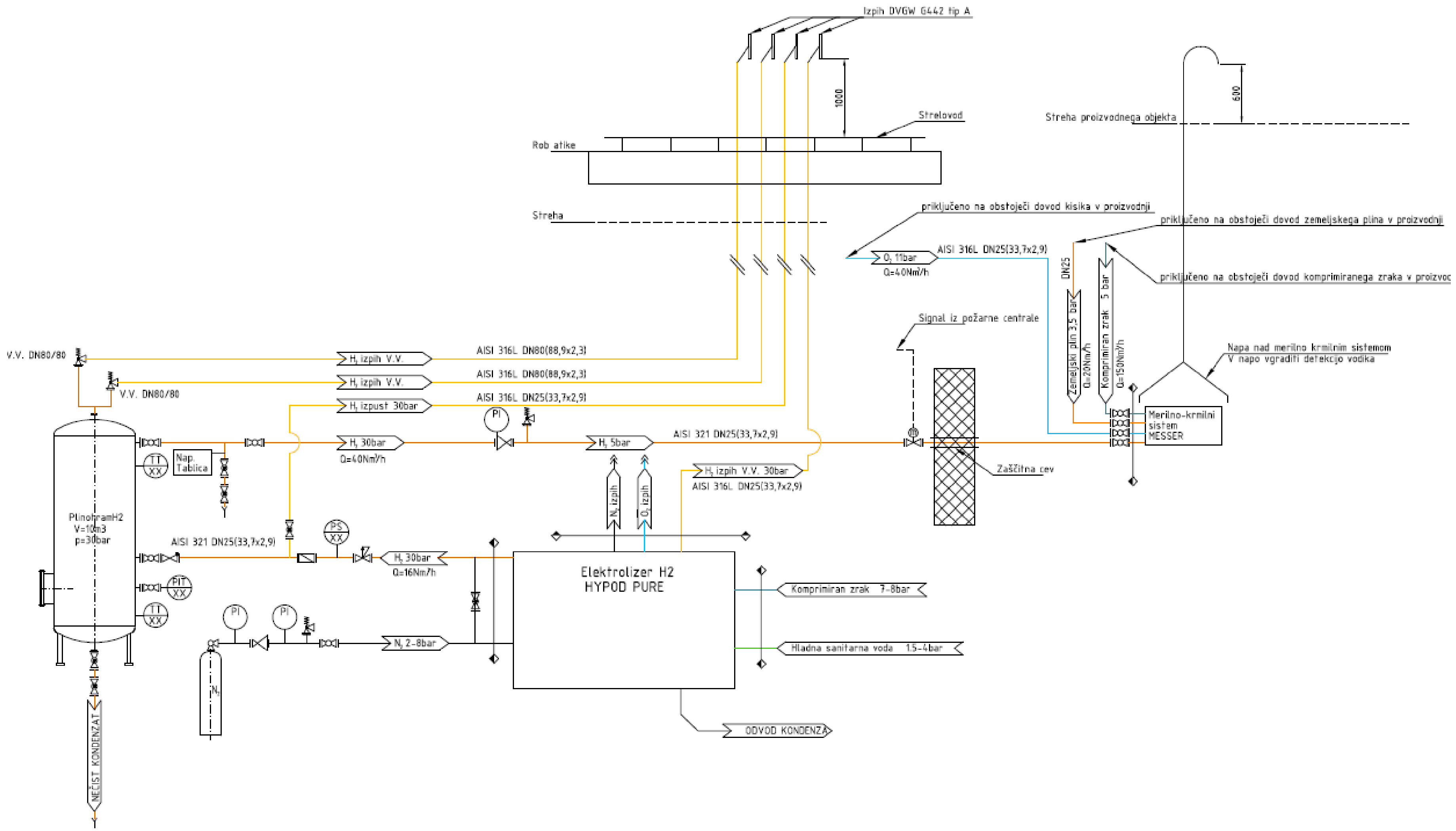
OPERH2 Project pilot

Optimization of energy conversion to replace the share of fossil fuels used for industrial glass melting with hydrogen.

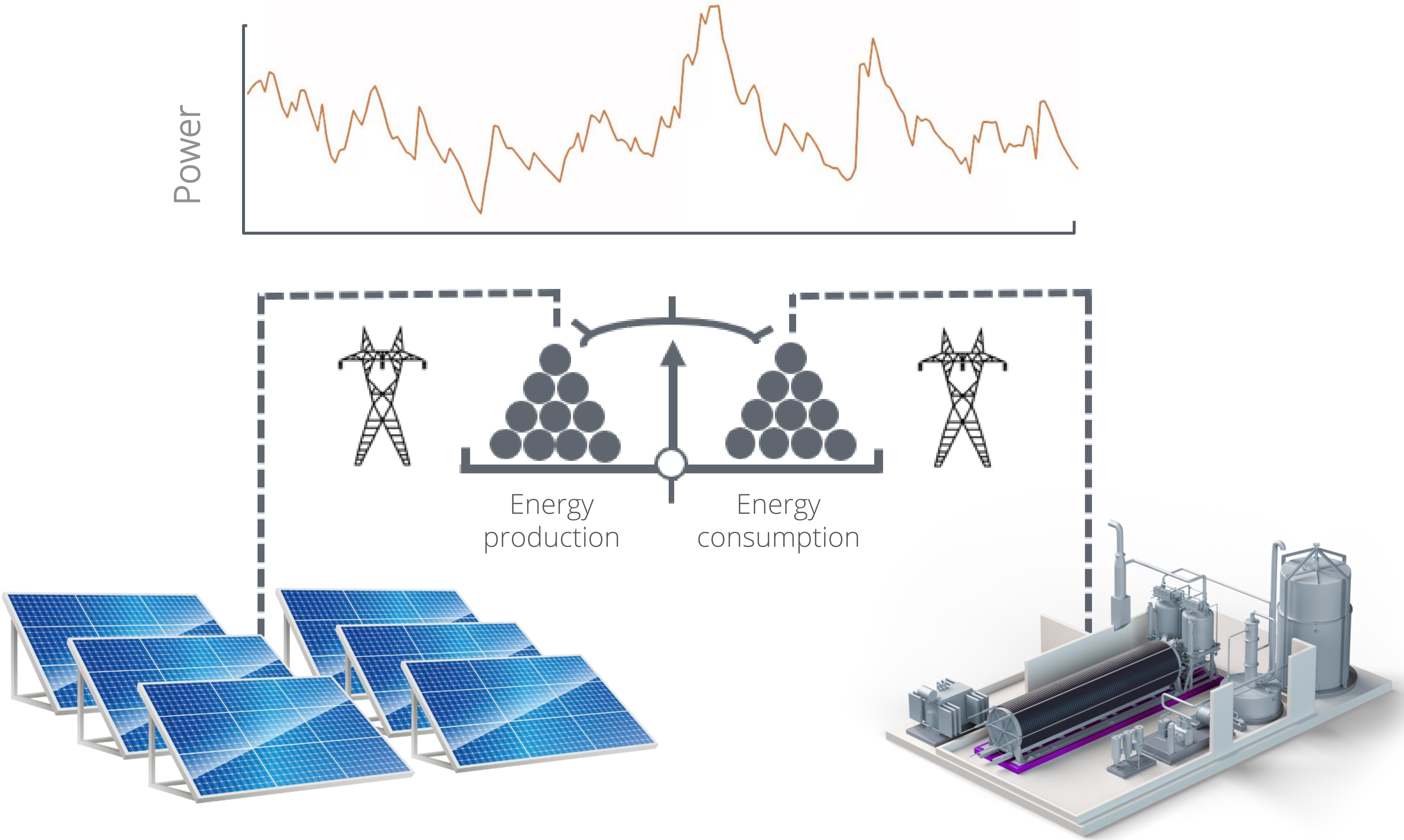


Design

Design


Izpih DVGW G442 tip A
1000
Strelovod
Rob atike
Streha
Streha proizvodnega objekta
600
priključeno na obstoječi dovod kisika v proizvodnji
priključeno na obstoječi dovod zemeljskega plina v proizvodnji
priključeno na obstoječi dovod komprimiranega zraka v proizvod
AISI 316L DN25(33,7x2,9)
Q=40Nm³/h
DN25
Zemeljski plin 3,5 bar
Q=20Nm³/h
Komprimiran zrak 5 bar
Q=150Nm³/h
Signal iz požarne centrale
Napa nad merilno krmilnim sistemom
V napo vgraditi detekcijo vodika
V.V. DN80/80
AISI 316L DN80(88,9x2,3)
AISI 316L DN25(33,7x2,9)
PI
AISI 321 DN25(33,7x2,9)
Merilno-krmilni sistem MESSER
Q=40Nm³/h
Zaščitna cev
Nap. Tablica
PlinohramH2
V=10m3
p=30bar
AISI 321 DN25(33,7x2,9)
PS XX
Q=16Nm³/h
Elektrolizer H2
HYPOD PURE
Komprimiran zrak 7-8bar
Hladna sanitarna voda 1.5-4bar
ODVOD KONDENZA
NEČIST KONDENZAT

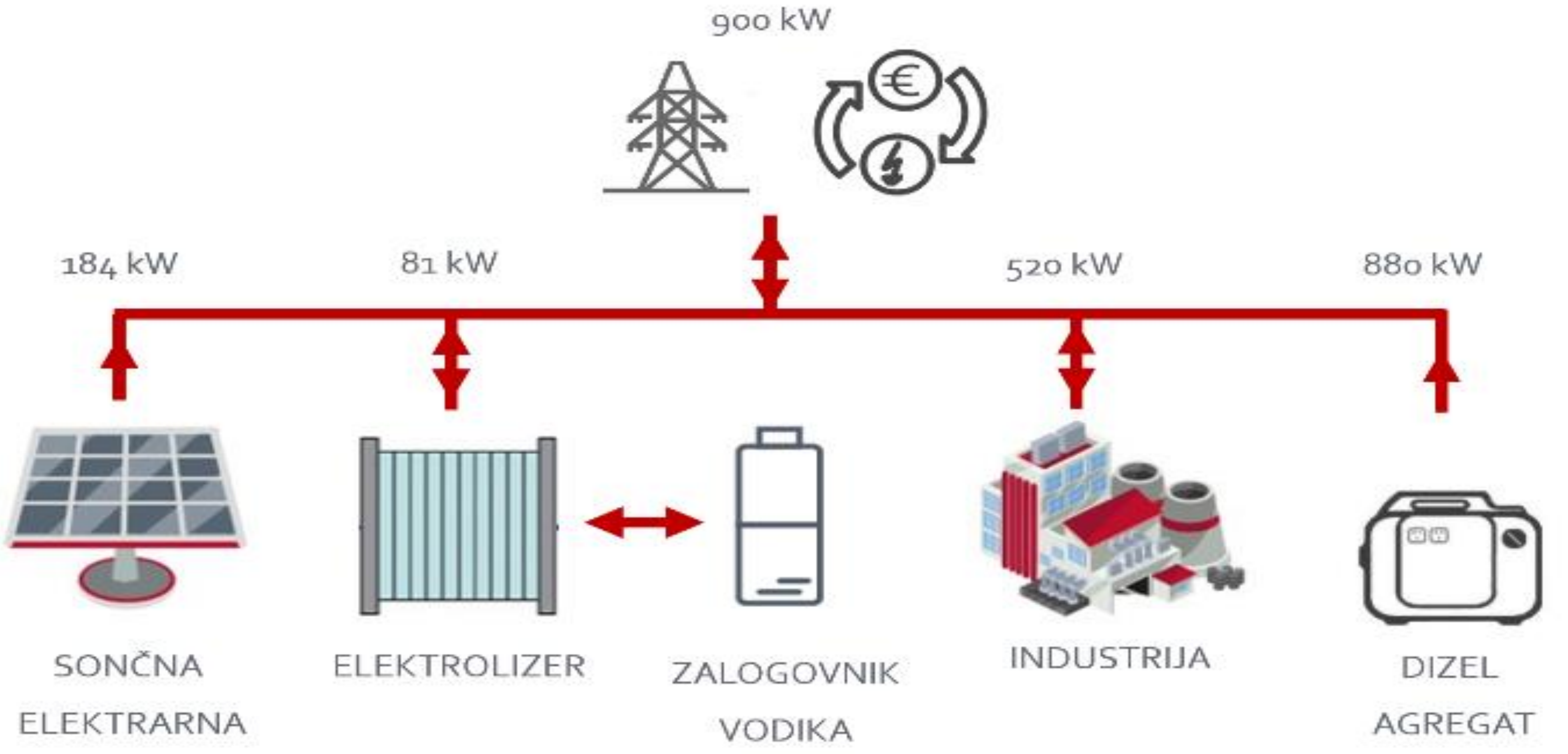
PV coupled with WE



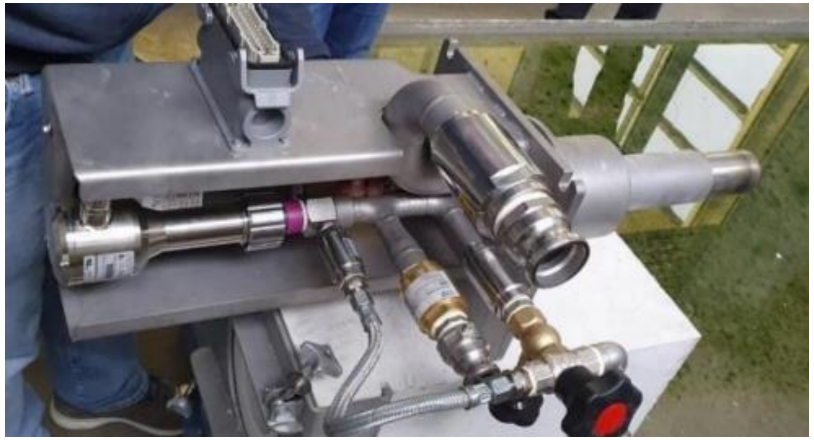
HRASTNIK1860

PV coupled with WE

Energy Management System



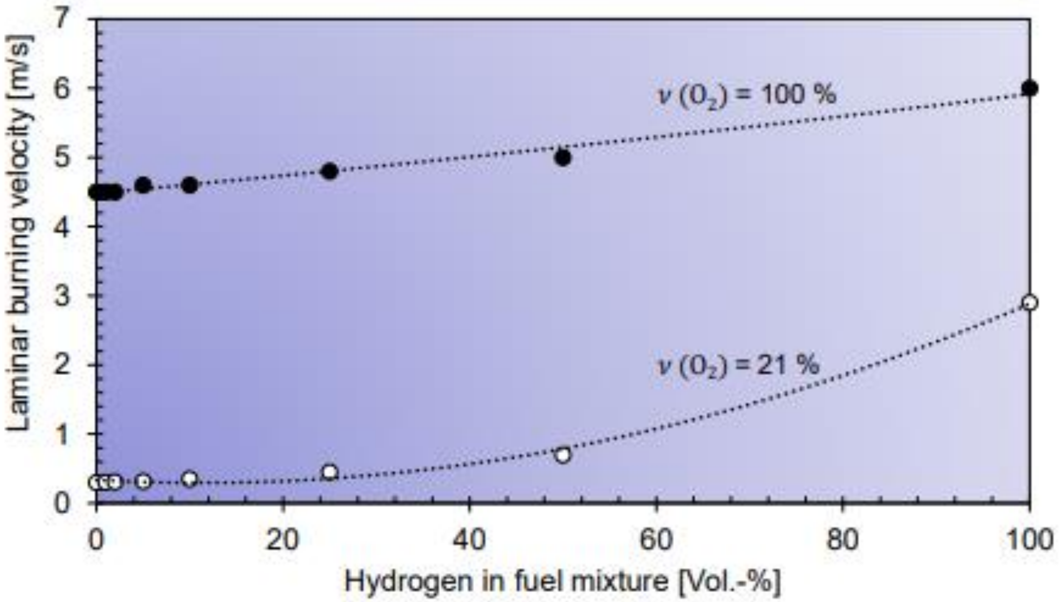


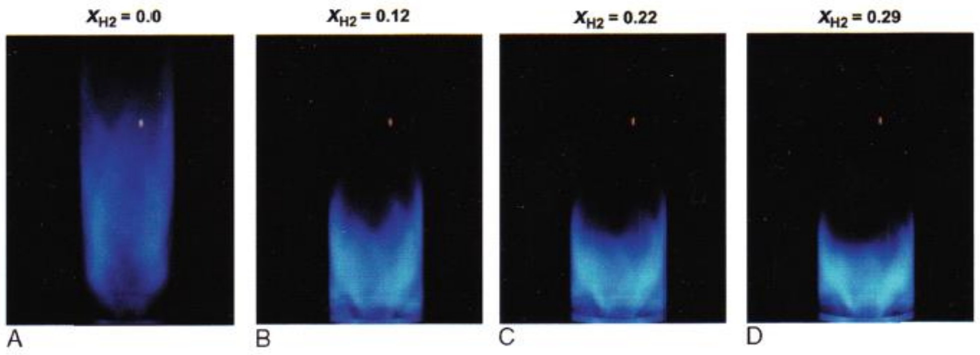


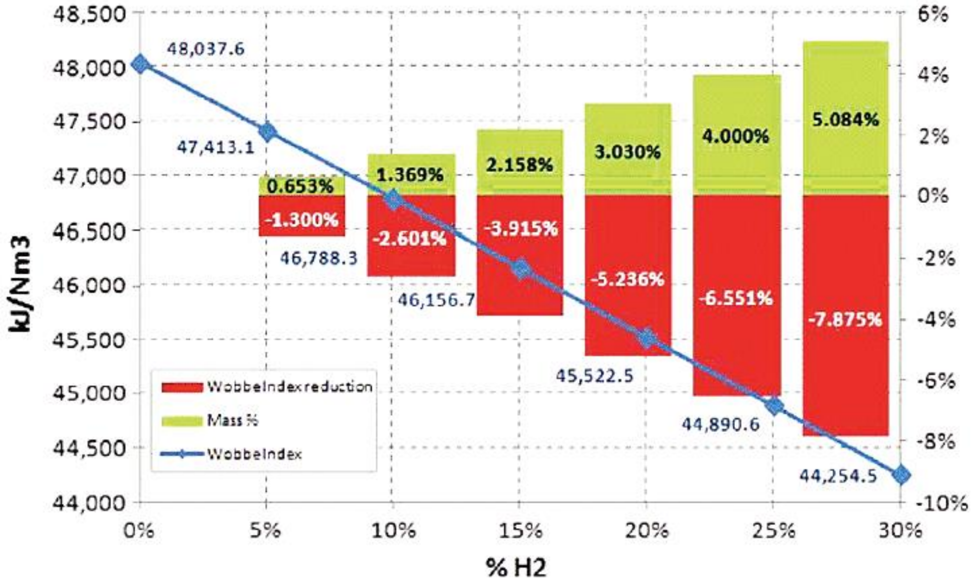
3 Hydrogen combustion

Hydrogen combustion

- Laminar burning velocity 10x higher with H2
- Lower Wobbe index





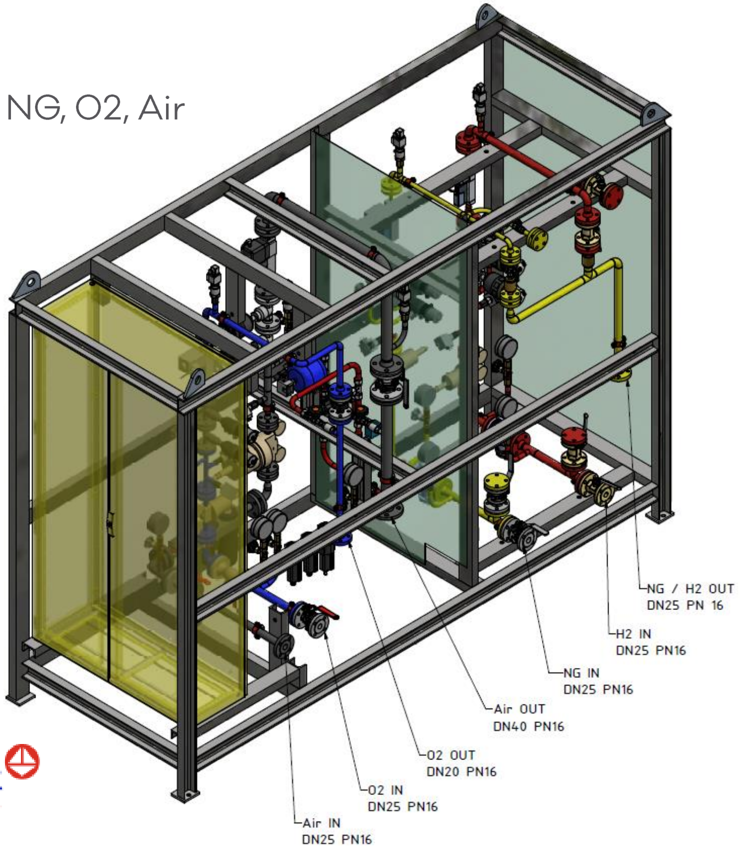


Source: L. Santoli et al.

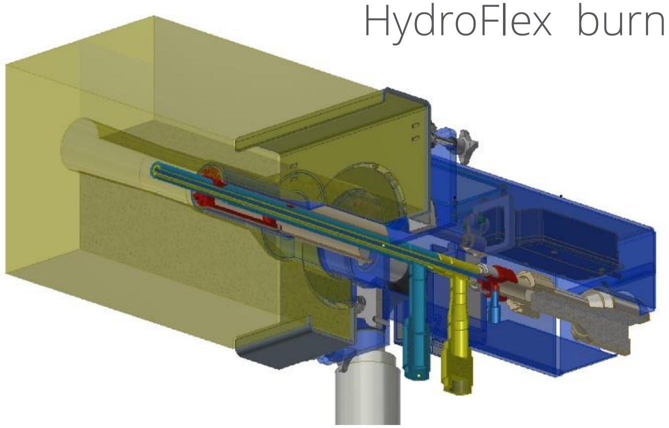
HydroFlex combustion system

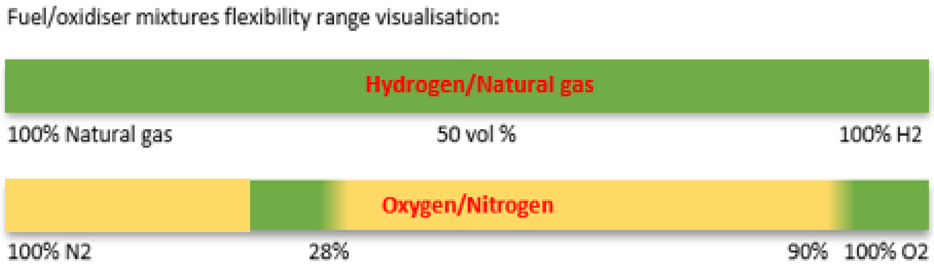
- High exit velocity burners
- Mixure of natural gas and hydrogen in every ratio possible, and mixture of air and oxygen in every ratio

Skid for H2, NG, O2, Air



HydroFlex burner





MESSER
Gases for Life

Open flame testing

- Similar flame length and temperature distribution for Air-hydrogen, Oxy-hydrogen and Oxy-gas combustion

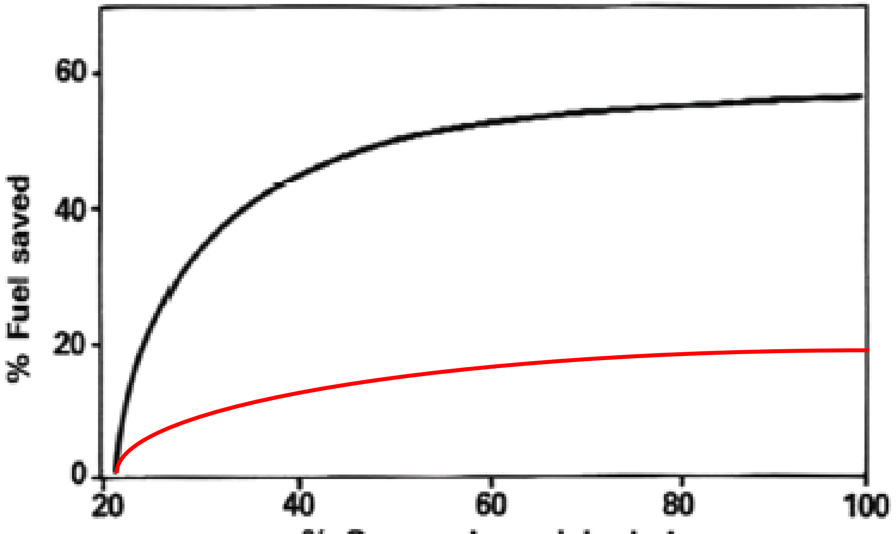
Air-H2 | Oxy-H2 | Oxy-gas

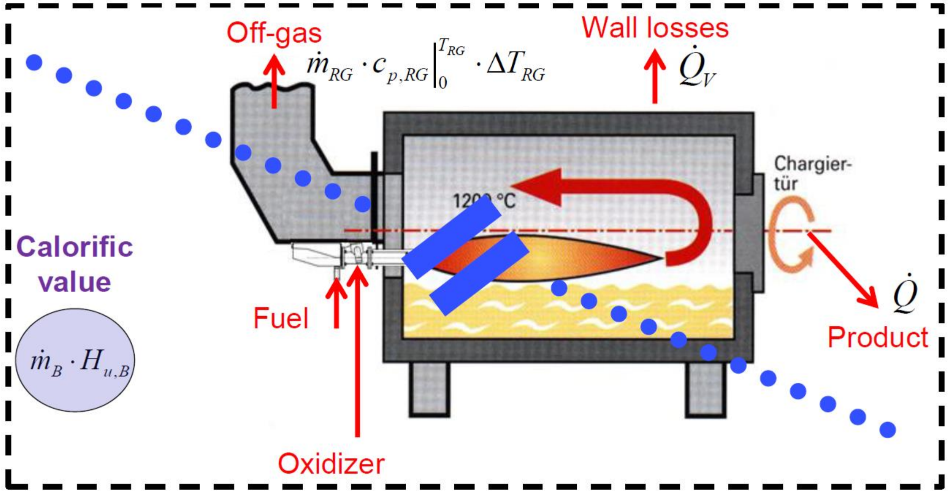
Combustion efficiency

CH_4 + 9.5 Air → CO_2 + $2H_2O$ + 7.52 N_2 (10.52)
CH_4 + $2O_2$ → CO_2 + $2H_2O$ (3) → 45-55% fuel savings

h(NG) = ~ 3 h(H_2)

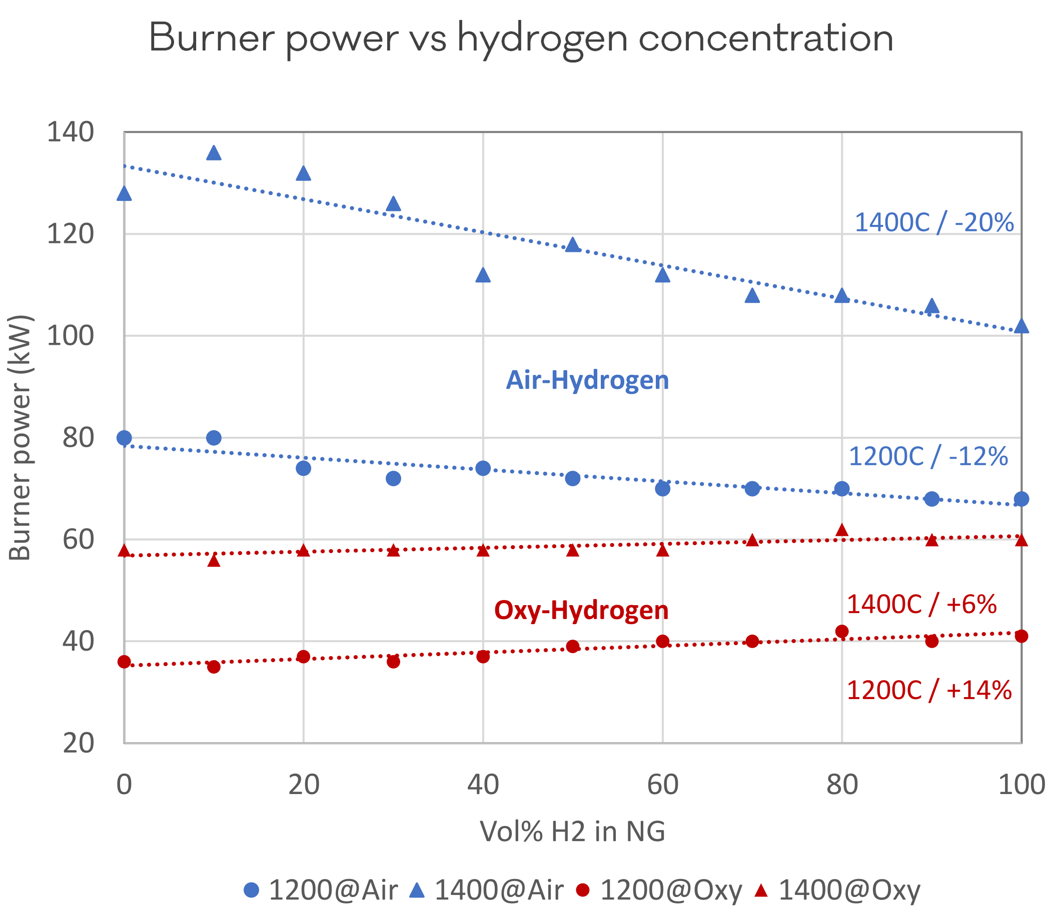
3 H_2 + 7.14 Air → 3 H_2O + 5.64 N_2 (8.64) → 15-20% fuel savings
3 H_2 + 1.5 O_2 → $3H_2O$ (3) → 43-53% fuel savings





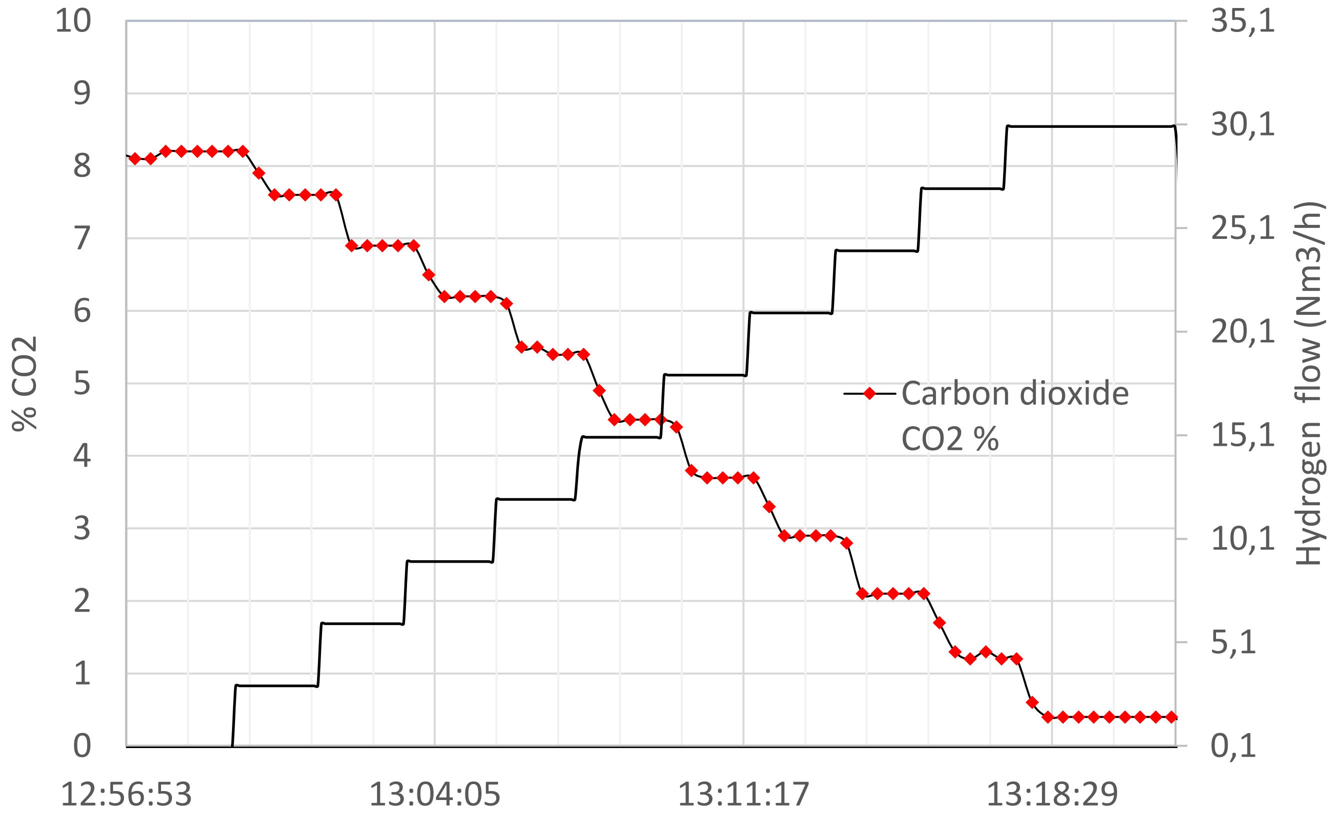
- Higher efficiency at higher temperatures

Combustion efficiency

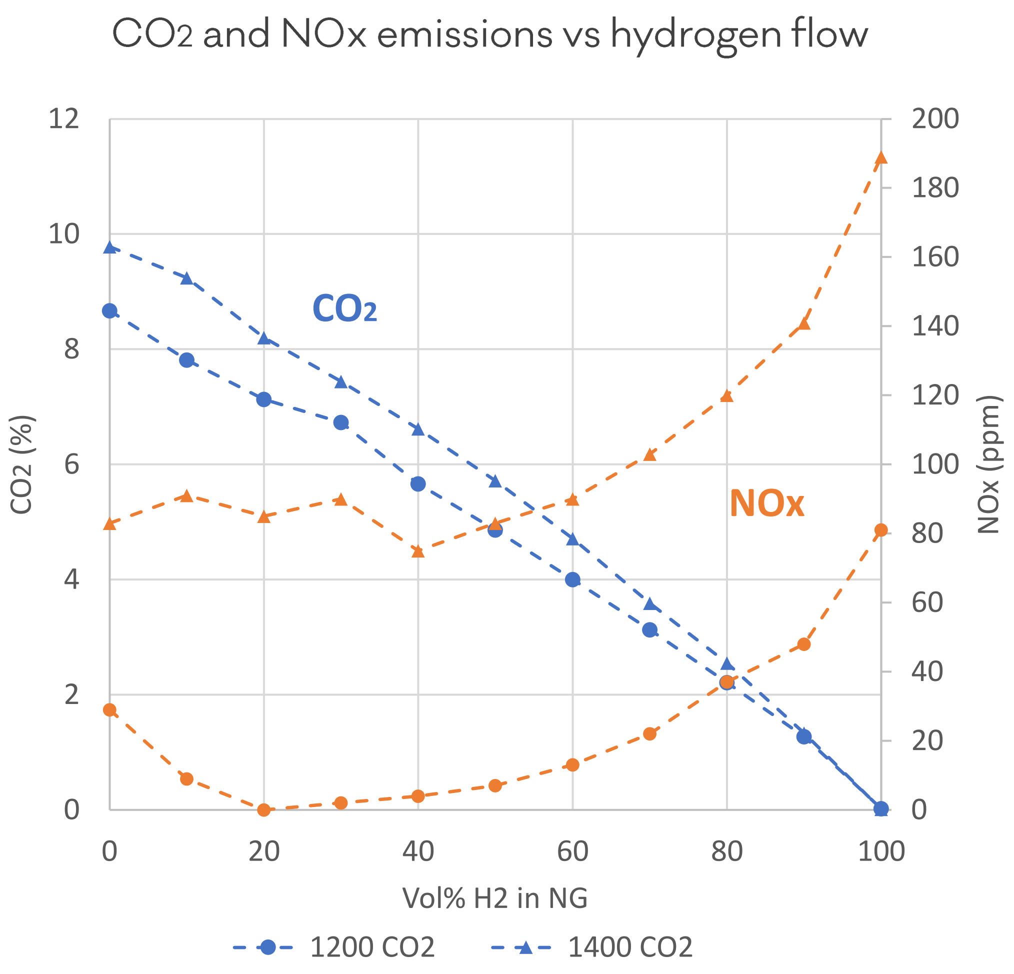


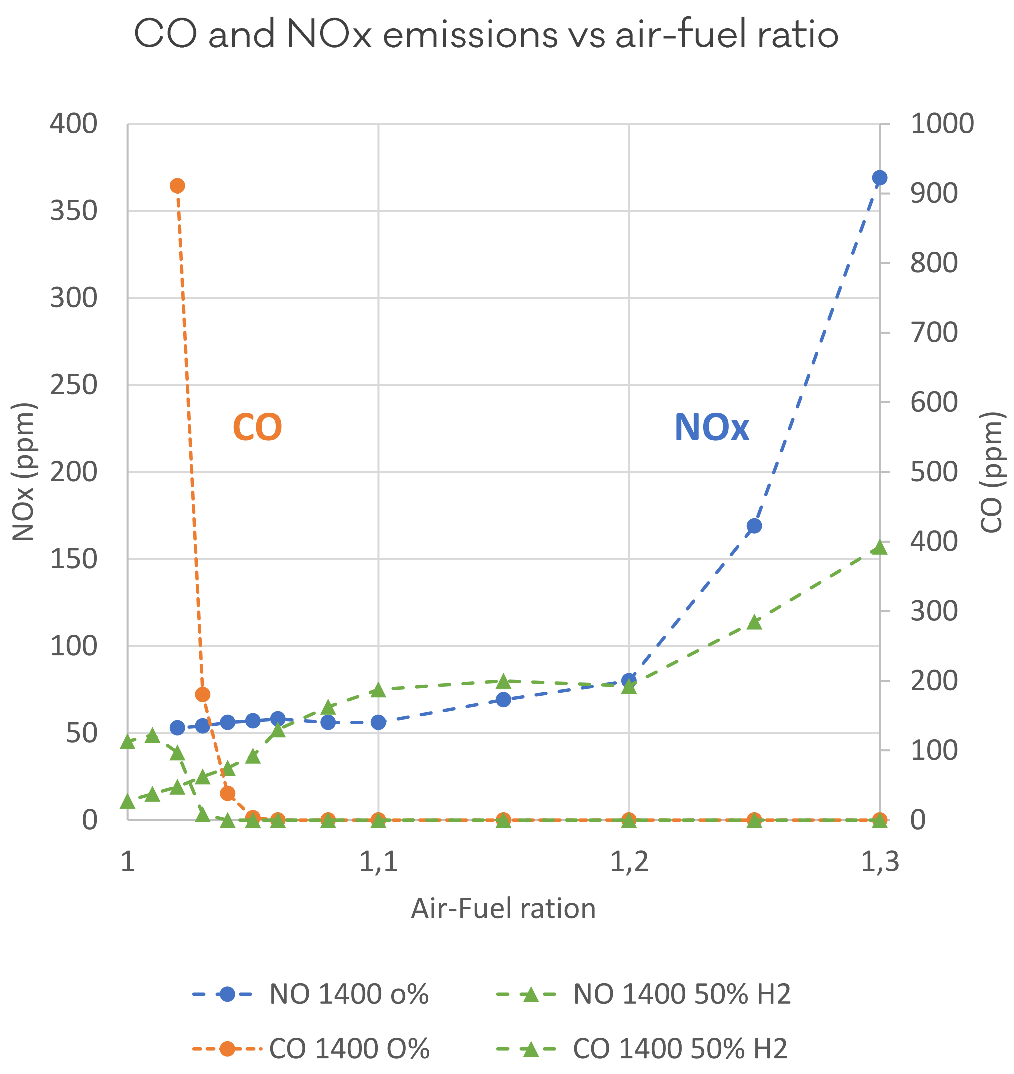
CO_2 emissions

CO2 emission vs hydrogen flow

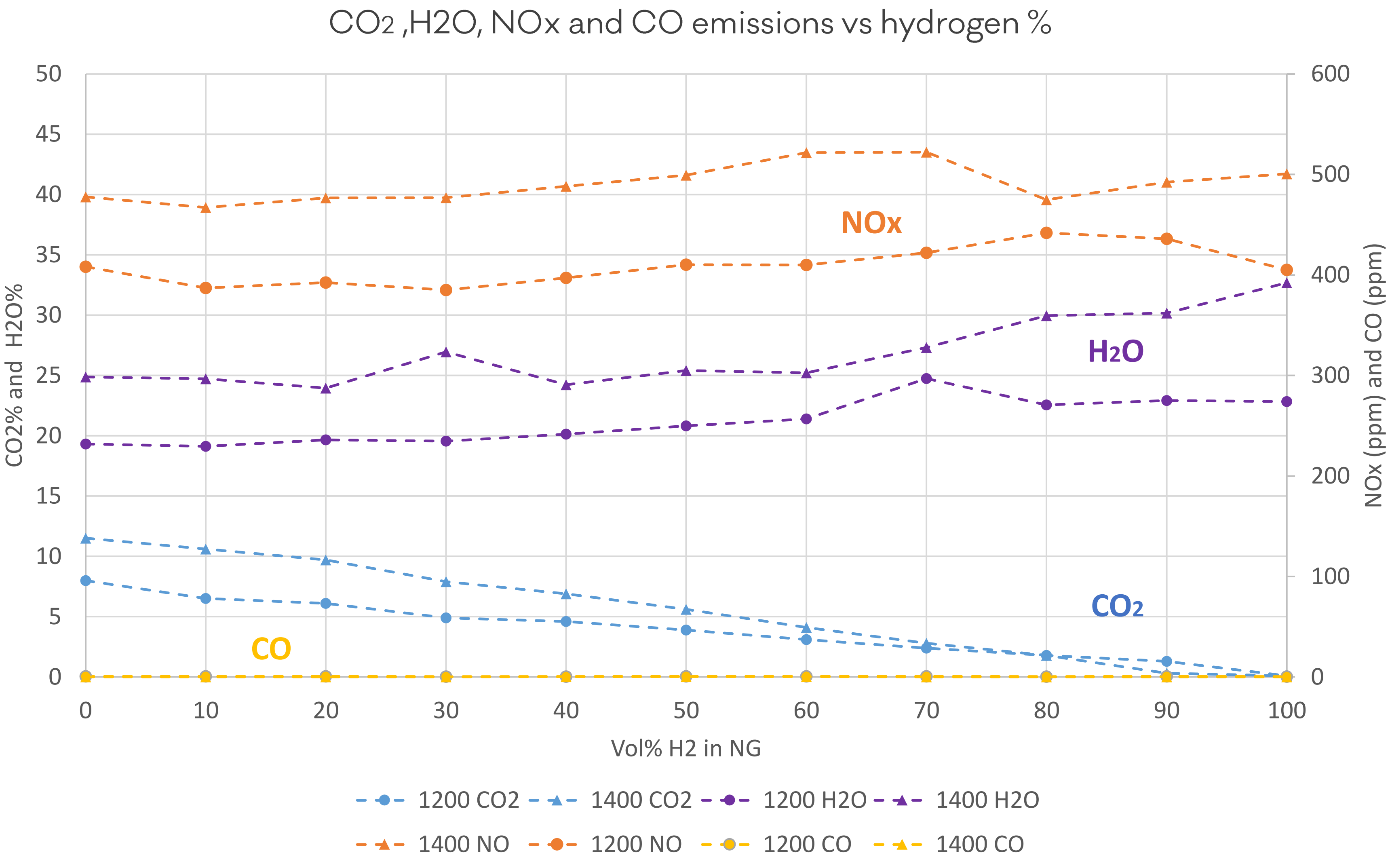


Air-Hydrogen combustion





Oxy-Hydrogen combustion



4 Carbon-free glass melting and LCA

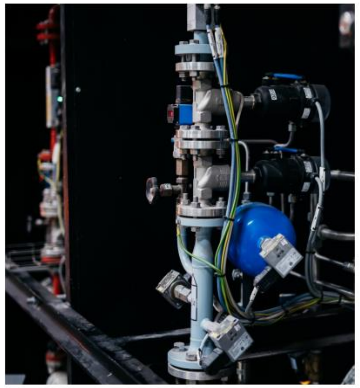
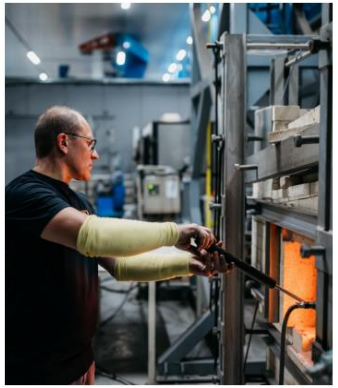
Pilot demonstration

- Melting of glass with 100% hydrogen and 100% PCR cullet







Our most sustainable glass bottle

Comparative LCA (ISO 14040/44)

Method: ReCiPe Endpoint (H) V1.13 / Europe ReCiPe H/A / Single score
Comparing 1 p 'S_Steklenica Jupiter (500ml) argegirano' with 1 p 'Z_Steklenica Jupiter (500ml) argegirano';

Project roadmap

TRL6

Pilot demonstration of hydrogen glass melting

1 PHASE

Industrial qualification of hydrogen glass melting glass at operational level

2 PHASE

Design and construction of the system

3 PHASE

Operation of the system

4 PHASE

TRL9

5 H2GLASS

H2GLASS

HRASTNIK1860

1 H2GLASS (Horizon)

2 Industrial qualification

3 Commercial aspect

4 Industiral demonstration

5 What‘s next... ?

6 Q & A

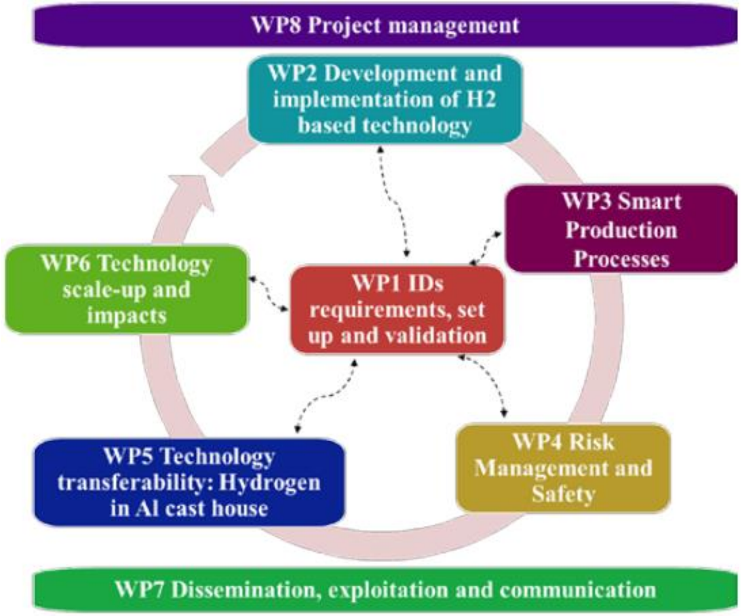
H2GLASS Consortium

- 23 partners
- 4 years
- 33 M€ budget
- 24 M€ EU fund
- Launch in Jan 23

List of participants

Participant no.	Participant organisation name	Country
1 (coordinator)	SINTEF ER AS	Norway
2	SINTEF AS	Norway
3	SINTEF MANUFACTURING AS	Norway
4	STAM	Italy
5	STEINBEIS INNOVATION GGMBH	Germany
6	WE PLUS SPA	Italy
7	NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET NTNU	Norway
8	THE UNIVERSITY OF NOTTINGHAM	United Kingdom
9	Stara Glass S.p.a.	Italy
10	Steklarna Hrastnik d.o.o.	Slovenia
11	KEMIJSKI INSTITUT	Slovenia
12	FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV	Germany
13	ASTON UNIVERSITY	United Kingdom
14	UNIVERSITAT POLITECNICA DE CATALUNYA	Spain
15	EUROPEAN ALUMINIUM	Belgium
16	STAZIONE SPERIMENTALE DEL VETRO S.c.p.A.	Italy
17	Vetrobalsamo S.p.A.	Italy
18	OCV CHAMBERY INTERNATIONAL	France
19	ZIGNAGO VETRO SPA	Italy
20	SENER INGENIERIA Y SISTEMAS SA	Spain
21	CIB UNIGAS	Italy
22	HYDRO HAVRAND	Norway
23	PTML PILKINGTON	UK

H2GLASS Concept



WP No	Work Package Title	Lead Participant No	Lead Participant Short Name	Person-months	Start month	End month
WP1	IDs requirements, set up and validation	3	SINTEF RM	241,0	1	47
WP2	Development and implementation of H2 based technology	10	SH	300,0	1	36
WP3	Smart Production Processes	4	STAM	290,0	6	42
WP4	Risk Management and Safety	1	SINTEF ER	124,0	1	48
WP5	Technology transferability: H2 in Aluminium cast house	22	HYDRO	95,0	1	47
WP6	Technology scale-up and impacts	2	SINTEF	168,0	1	48
WP7	Dissemination, exploitation and communication	5	SIG	185,0	1	48
WP8	Project Management	1	SINTEF ER	172,0	1	48
	Total			1575,0		

H2GLASS Concept

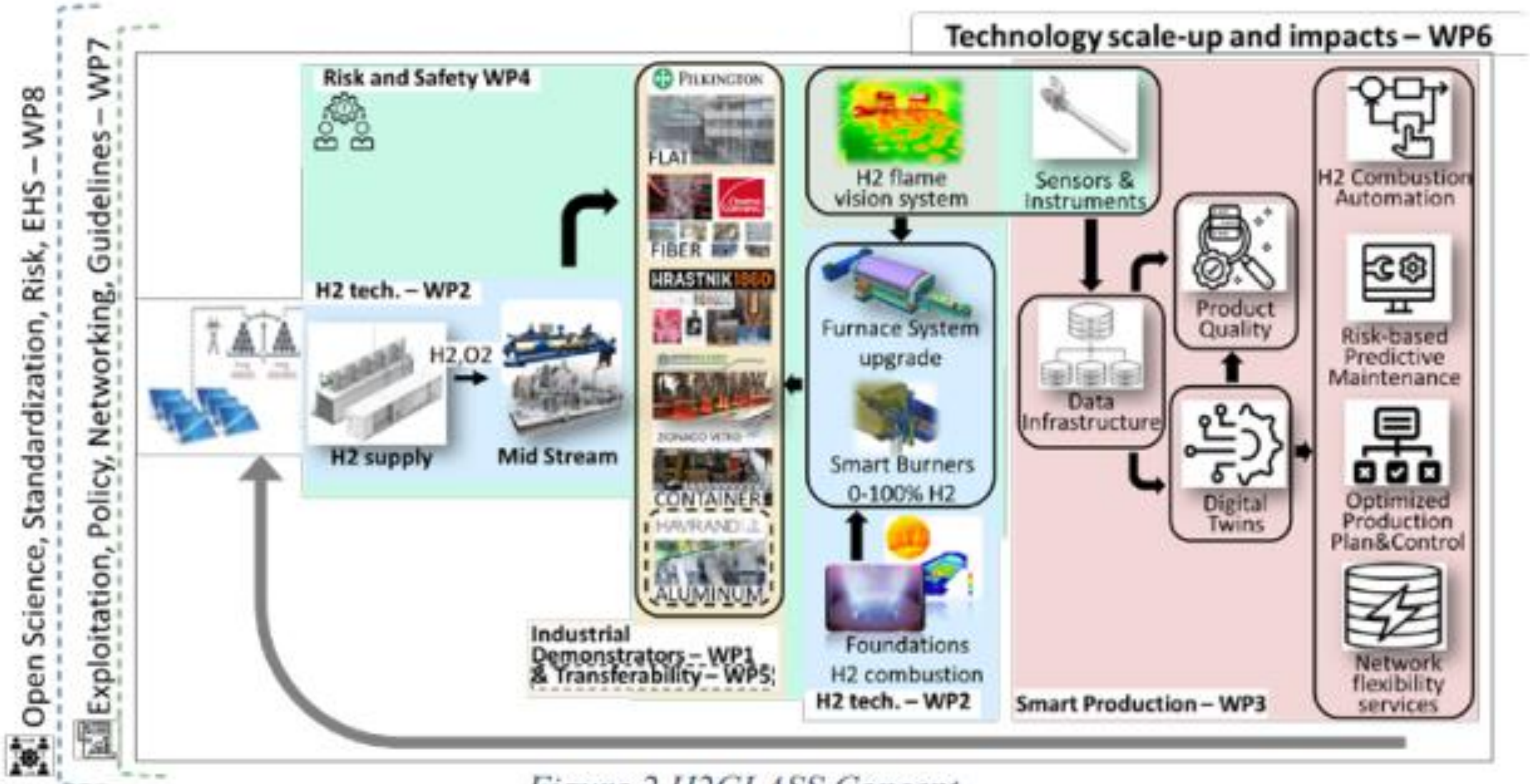
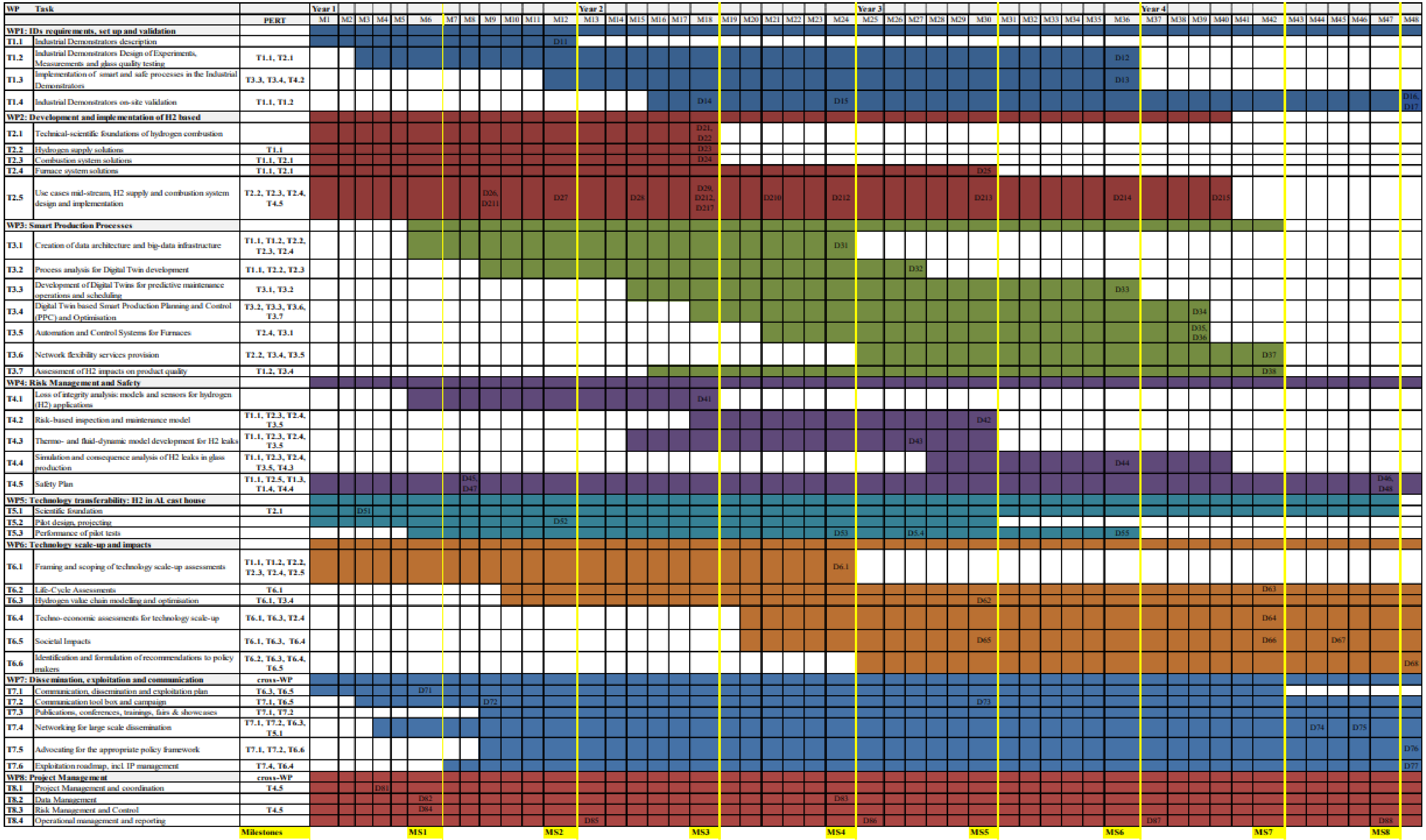


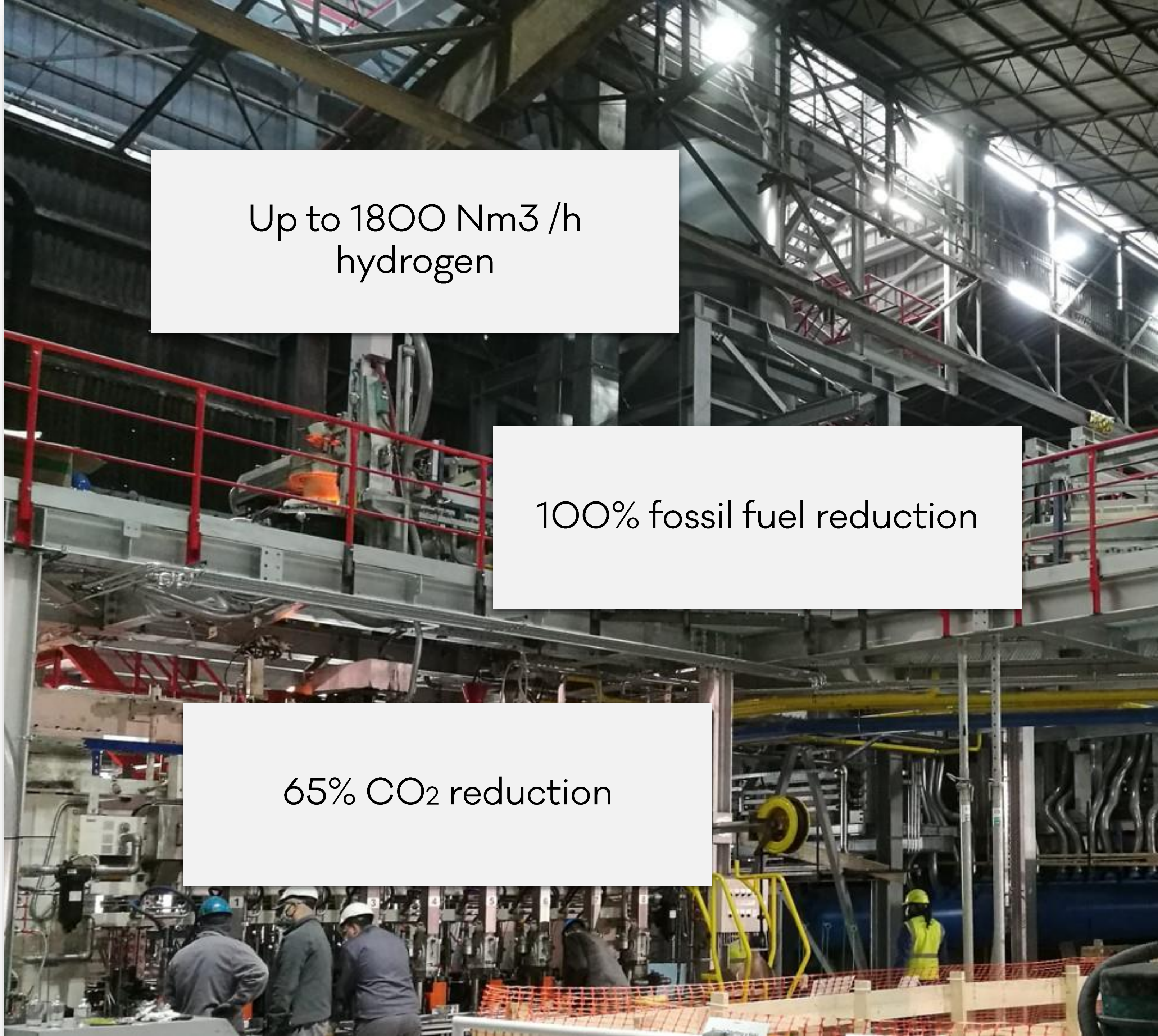
Figure 2 H2GLASS Concept

H2GLASS Gantt



Glass production decarbonisation utilizing Hydrogen

Large-scale
(120 t/day)



Up to 1800 Nm3 /h hydrogen

100% fossil fuel reduction

65% CO_2 reduction

HRASTNIK1860

Project roadmap

H2GLASS

TRL6

Pilot demonstration of hydrogen glass melting

1 PHASE

Industrial qualification of hydrogen glass melting glass at operational level

2 PHASE

Design and construction of the system

3 PHASE

Operation of the system

4 PHASE

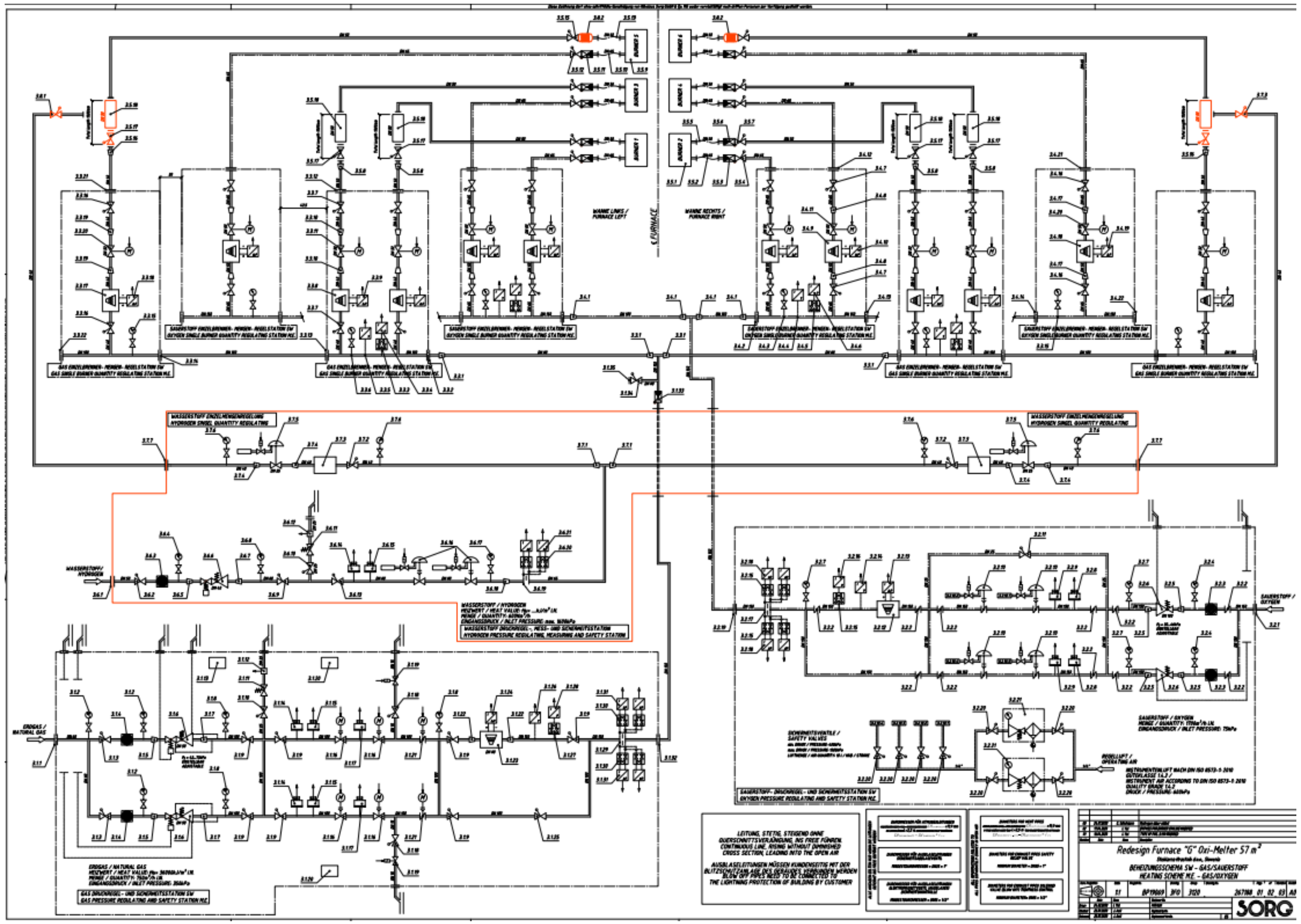
TRL9

Implementation

	2023	2023-2024	2024-2026
	Industrial qualification	Design and construction	Operation
Activity	• Engineering and construction of a gas station with hydrogen equipment directly from the hydrogen car tank • Supply and installation of gas hydrogen equipment for glass furnace • Supply and installation of measuring equipment • Testing of hydrogen at industry level under different technological conditions	• Engineering of a hydrogen production plant including construction, electrical and machinery design, fire safety and anti-explosion protection • Purchase of materials, services and equipment • Construction of a hydrogen production plant • Start-up of the hydrogen production plant and production of the work carried out	• Partial replacement of hydrogen with natural gas • Process parameter measurements and quality control • Multi-level digital twin system • Dynamic techno-economic analysis • Analysis of accelerated ageing of materials and equipment • Transition to glass production 5.0 (symbiosis with network, renewable sourcing, flexibility)
Goals	• Industrial qualification for the use of hydrogen on a glass furnace	• Construction of a system for the use of hydrogen at the economic level (oxygen coupling of glass furnace with PEM electrolysis)	• Realisation of decarbonisation targets – 20% lower fuel emissions
Period	• 1 month	• 18 months	• 5 years

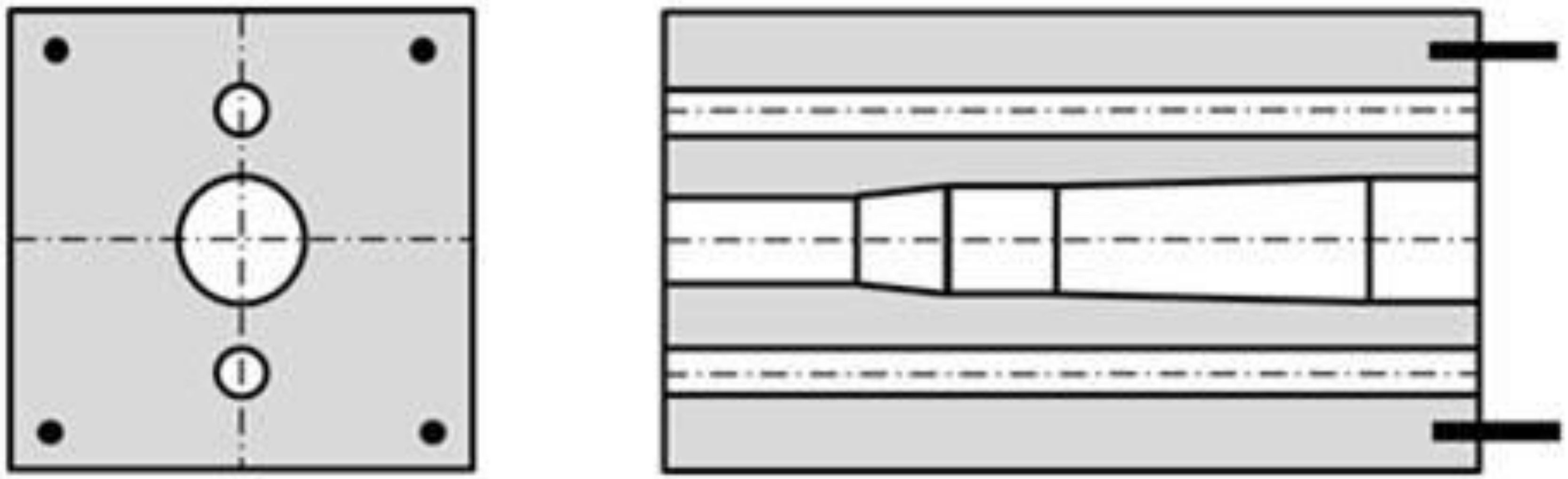
Industrial qualification

→ **Hydrogen gas skid , 600 Nm3/h**



Hydrogen burners

→ **Special burner to prevent foam formation**

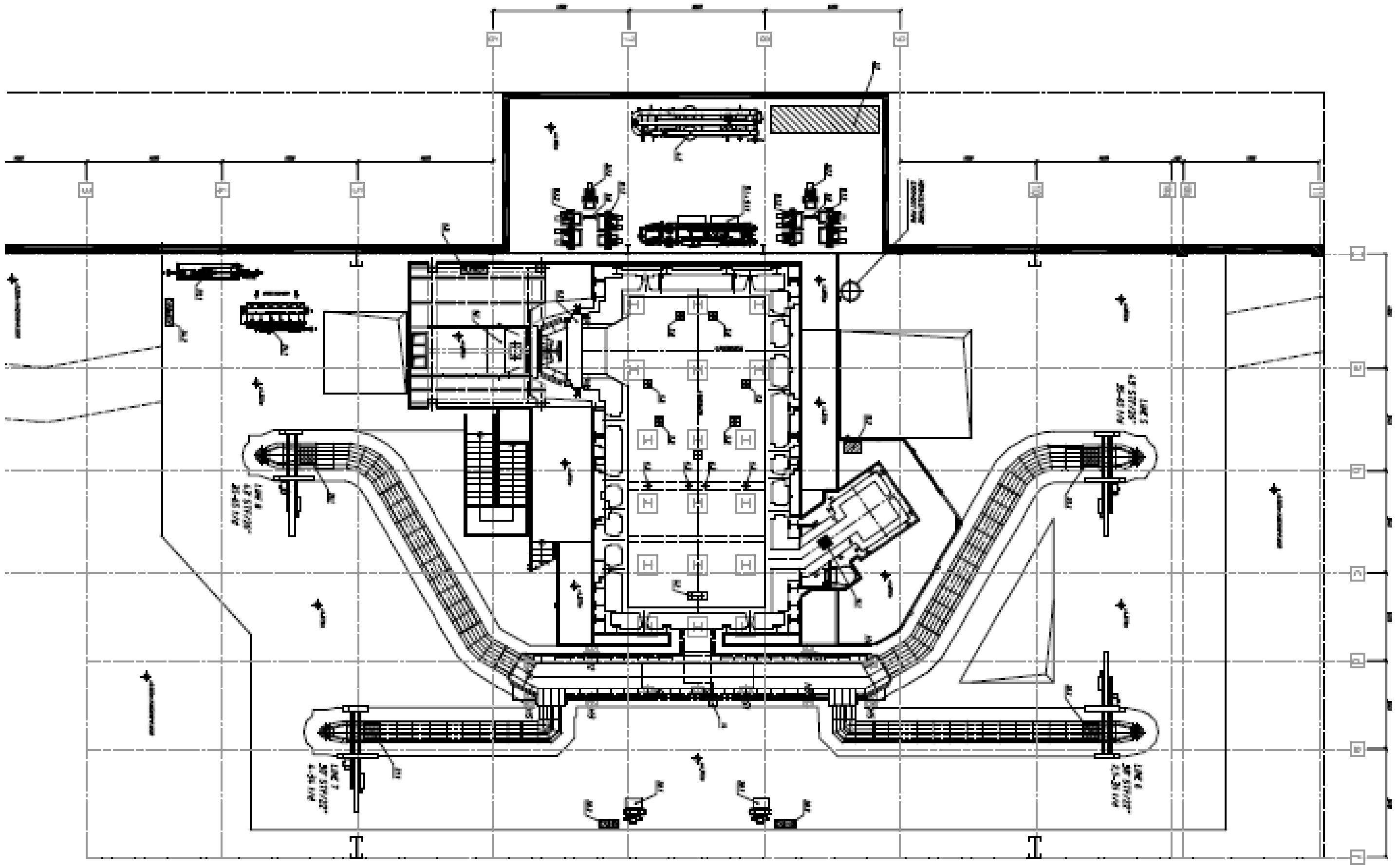


HRASTNIK1860

Industrial qualification

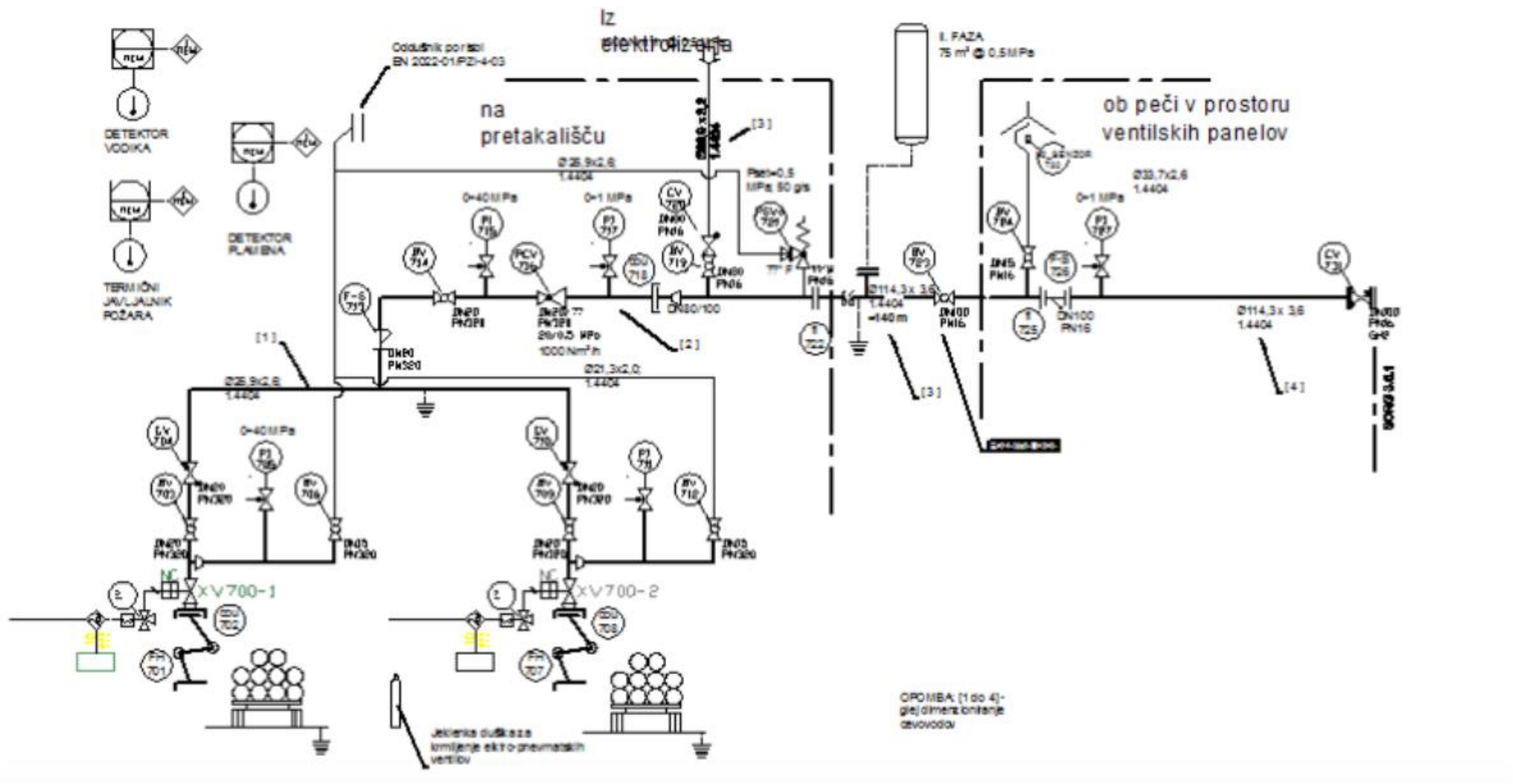
Industrial qualification

→ **Hydrogen gas skid, 600 Nm3/h – 2/6 bruners**



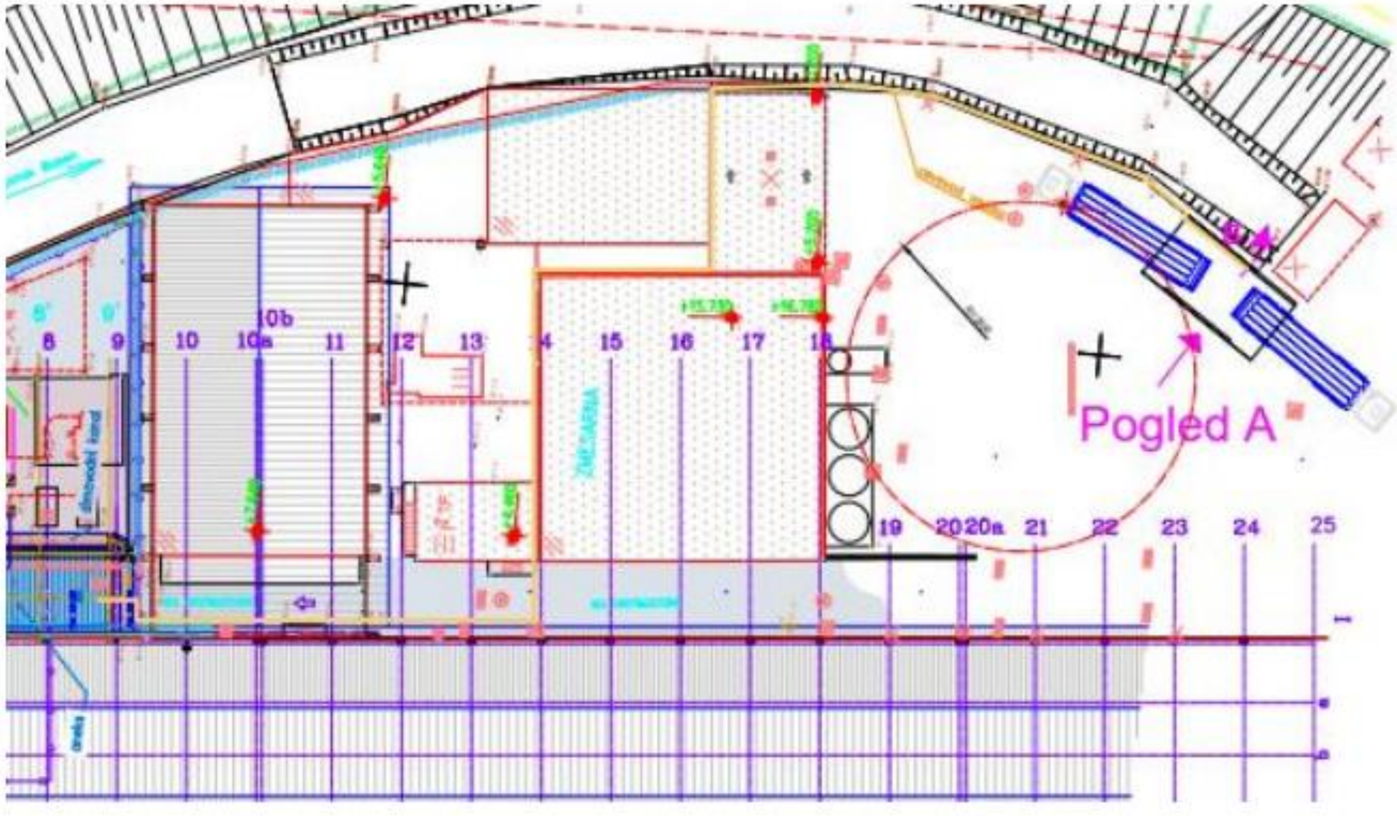
Industrial qualification

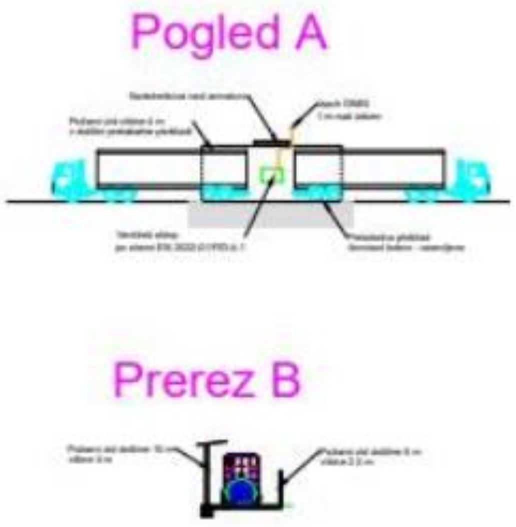
- → **Hydrogen from trailers**
- → **H2 piping (2000 Nm3/h)**



Industrial qualification

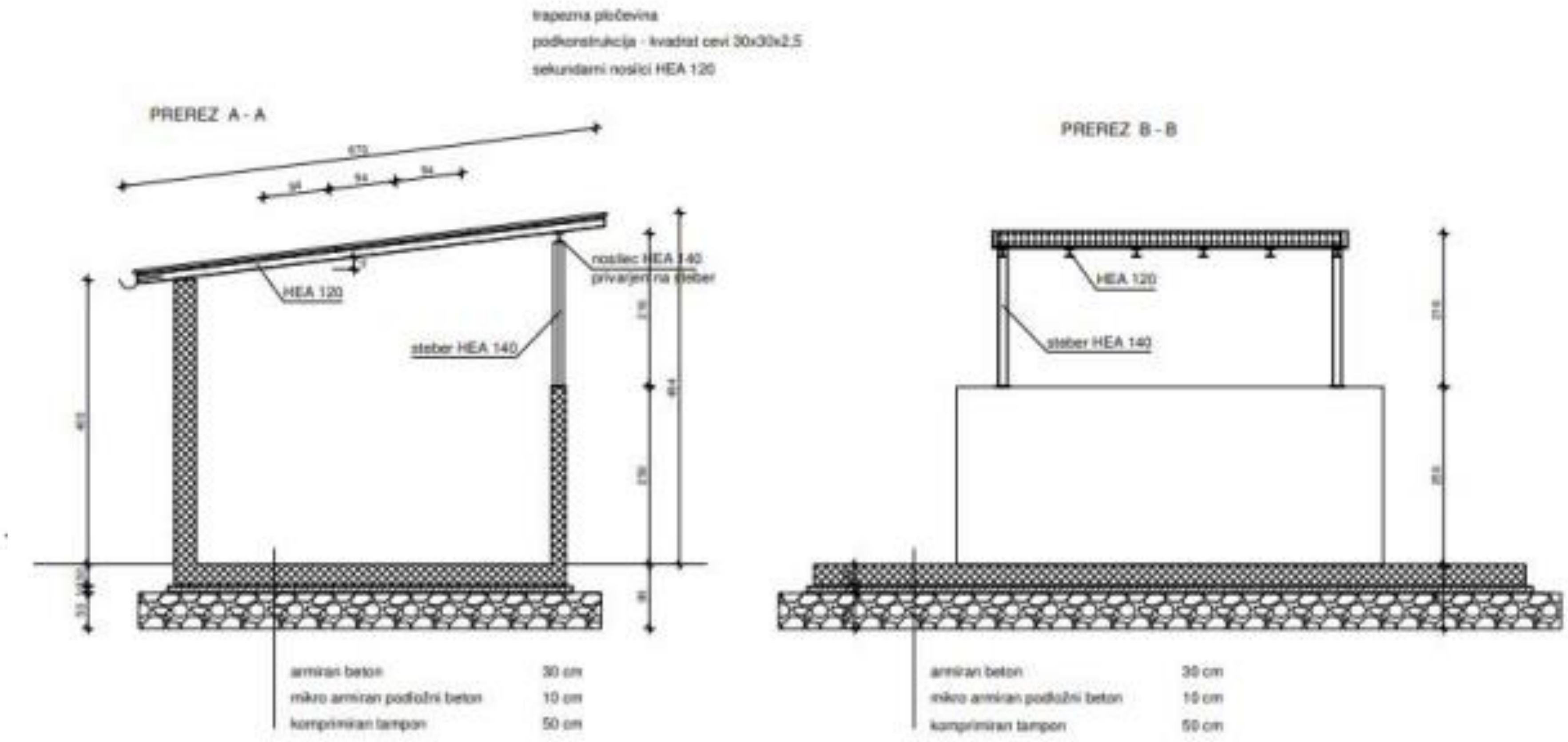
→ **H2 trailers supply station**





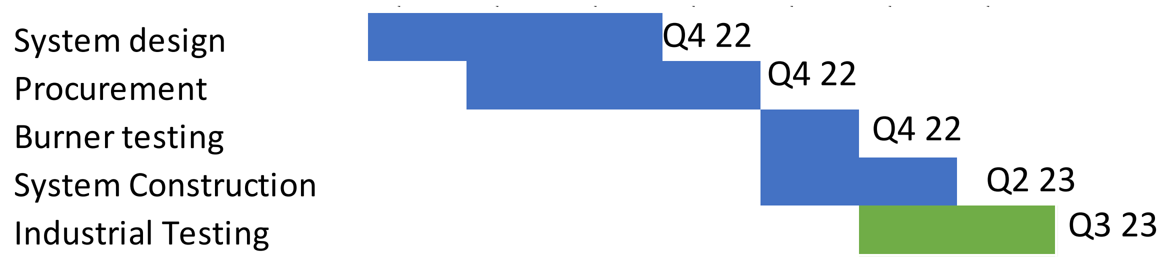
Industrial qualification

→ **H2 trailers corridor with a roof**



Industrial qualification

Industrial qualification timeline

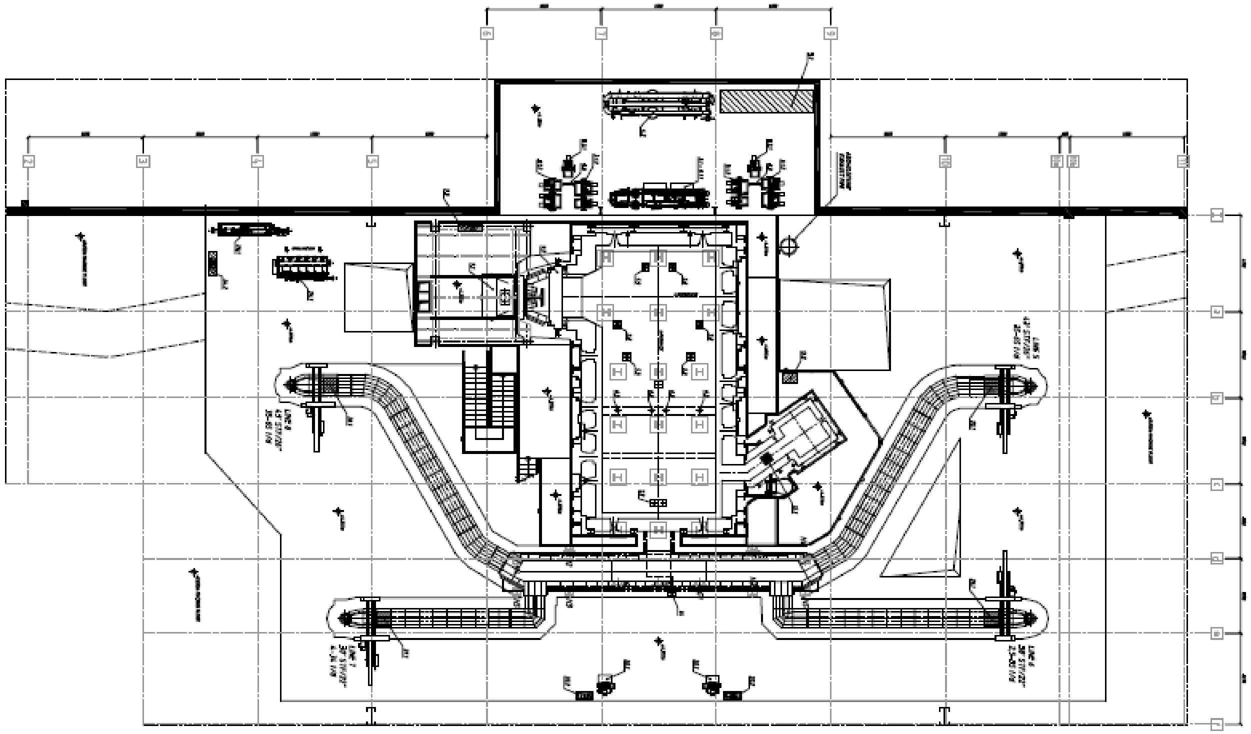


Industrial qualification experimental plan

Test type/week	Week 1	Week 2	Week 3	Week 4	Week 5	Week6	Average H2 % pair	Total H2%
Baseline measurements							0%	0%
1st burner pair							50%	18%
2nd burner pair							50%	18%
3rd burner pair							50%	18%
New burner 1st pair							70%	25%
High% H2 test /production							100%	36%

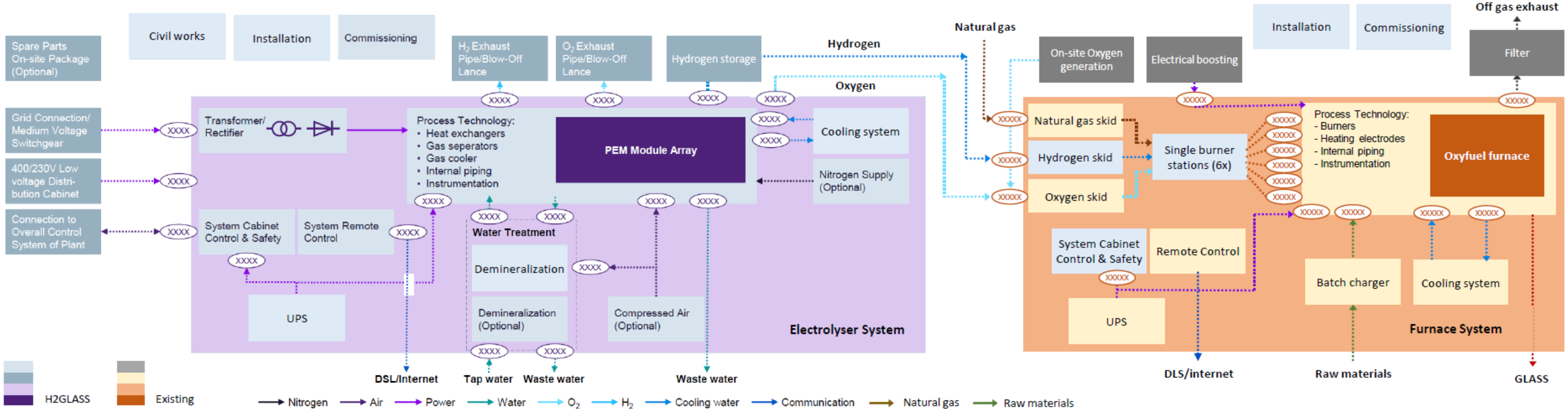
Industrial qualification

→ **Hydrogen new gas skid, 2000 Nm3/h**



Large-scale system design

→ **Portable PEM electrolyser (3MW, 20kV, 30 bar g)**



Process diagram: PEM Electrolyser system coupled with Oxyfuel glass furnace indicating H2GLASS project scope

H2GLASS Horizon Goals

Table 2 Overview of envisaged on-site tests with H2 at the Industrial Demonstrators' premises, with KPIs and Targets

SH					
Furnace type/capacity	**Fuel**	**Product type**	**H2 testing**	**Duration**	**H2 supply**
120 MTPD Oxyfuel furnace	Natural gas /Oxygen/ 10 % Electrical boosting	Extra-white flint container glass (10 < seed/100g glass)	(1) Successive testing of all three pairs of burners (2/6) with 100% H_2; (2) 100% H_2 ramping to all burners (6/6)	4-6 months	(1) 600 Nm3/h green H_2 from portable WE (2) 600 + 1000 Nm3/h Grey H_2 by vehicles
KPI_1: H2 Concentration in the total gas mix, target 100% **KPI_2: H2 in total Energy mix, target (1) 29% (2) 90%** **KPI_3 GHG reduction level, target (1) 21%, (2) 62%**					
170 MTPD Hybrid EP Regenerative furnace	Natural gas /Air/ 45% Electrical Super boosting	Extra-white flint container glass (10 < seed/100g glass)	(1) Testing pairs of burners (2/4) with 100% H2; (2) 100% H2 ramping to all burners (4/4)	4-6 months	(1) 600 Nm3/h green H_2 from portable WE (2) 600 + 1200 Nm3/h Grey H_2 by vehicles
KPI_1: II2 Concentration in the total gas mix, target 100% **KPI_2: H2 in total Energy mix, target (1) 27% (2) 55%** **KPI_3 GHG reduction level, target (1) 45%, (2) 62%**					

HRASTNIK1860

What‘s next?

Q & A