Industrial-Scale Hydrogen Utilization in Glass production

HRASTNIK1860

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

HRASTNIK1860

VISION

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

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GREEN TRANSFORMATION

Use of renewable energy sources

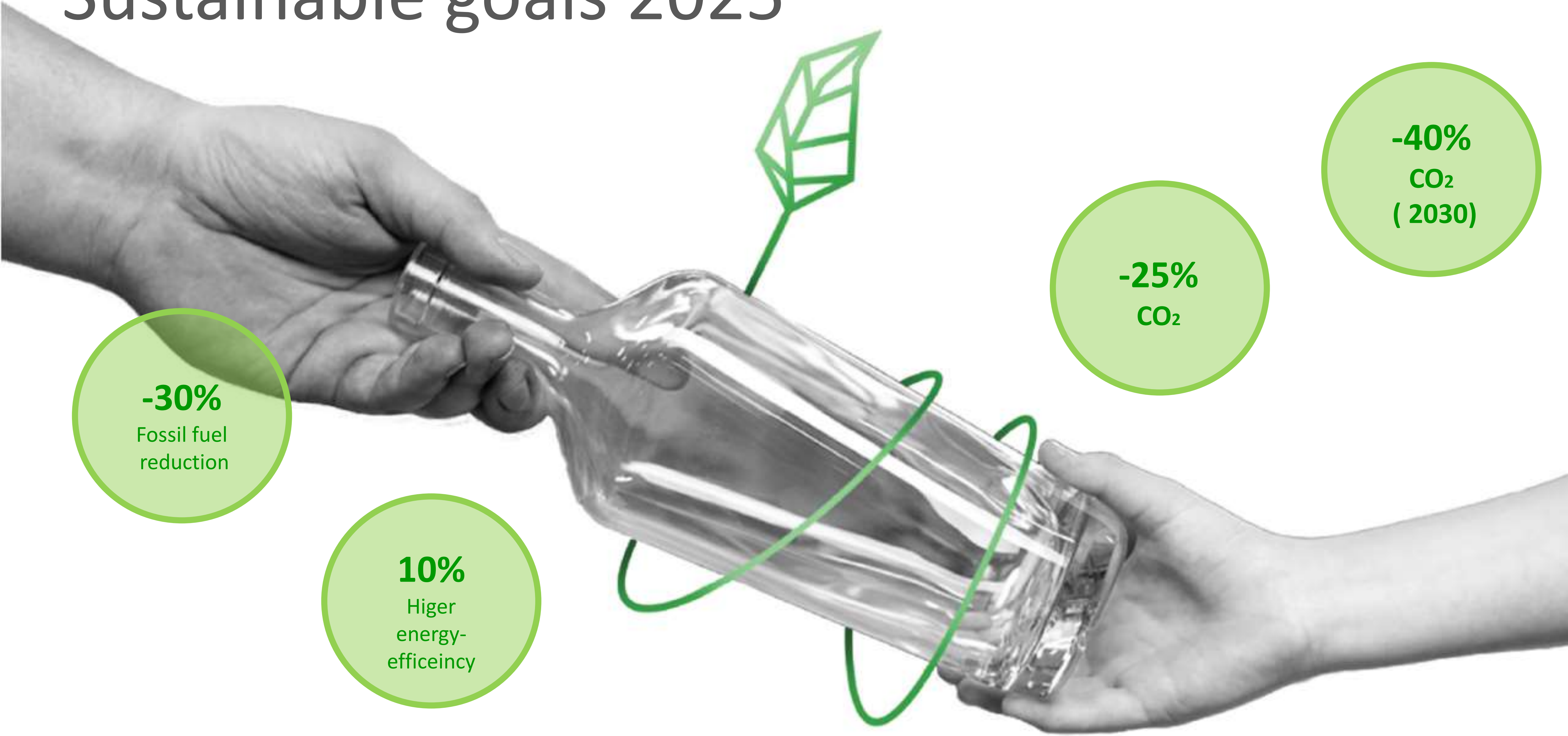
Improving energy efficiency

Electrification

Renewable fuels

Green innovation

Sustainable goals 2025



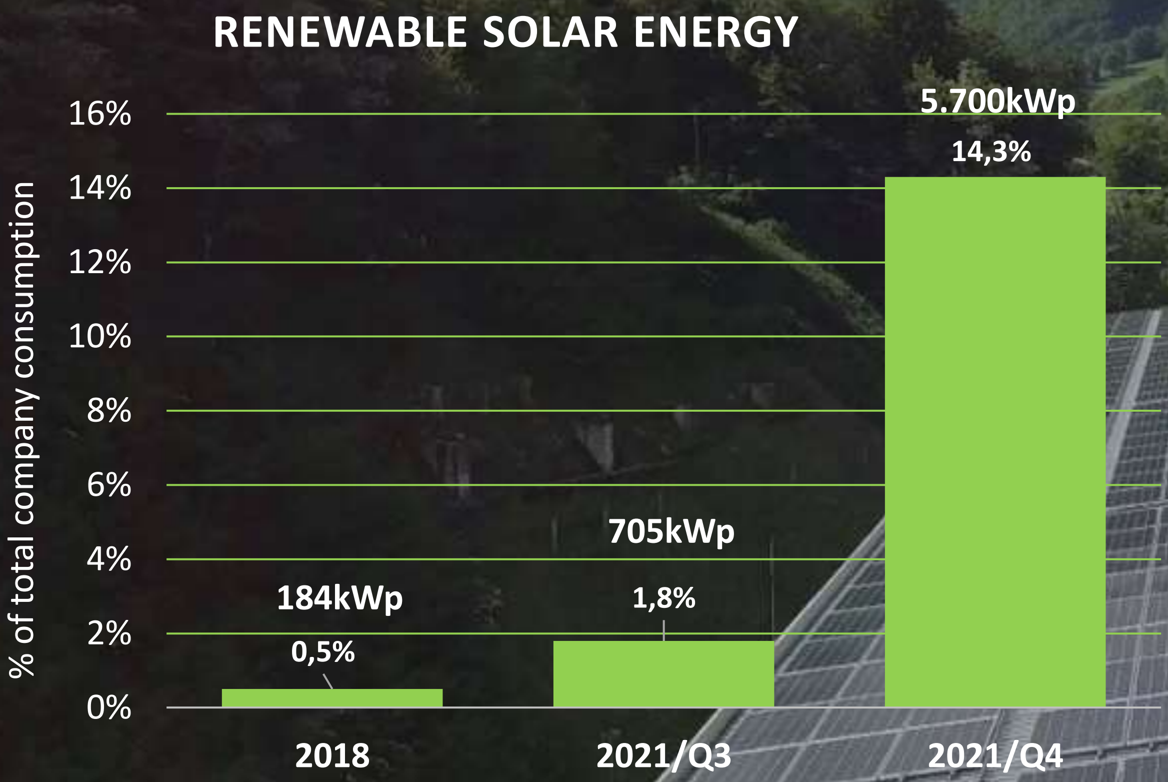
-30%
Fossil fuel reduction

10%
Higer energy-efficeincy

-25%
CO_2

-40%
CO_2
(2030)

Use of Renewable energy



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

2018 – 184kW First B2B solar power plant in Slovenia

14,3% self energy supply

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PV Plant – Steklarna Hrastnik 1

Date: 2018

Power: 184,2 kWp

Energy production: 176 MWh/ year

Renewable energy

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PV Plant – Steklarna Hrastnik 2

Date: 2021

Power: 521,4 kWp

Energy production: 488 MWh/ year

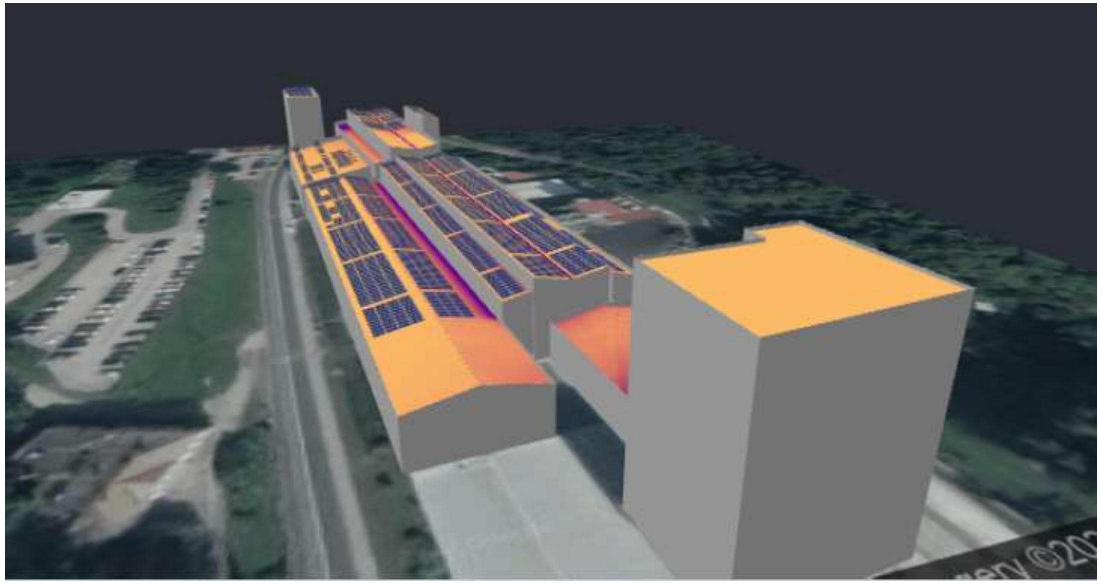
Renewable energy

PV Plant – Steklarna Hrastnik 3

Date: 2023

Power: 773,96 kWp

Energy production: 782 MWh/ year



Hydrogen 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.

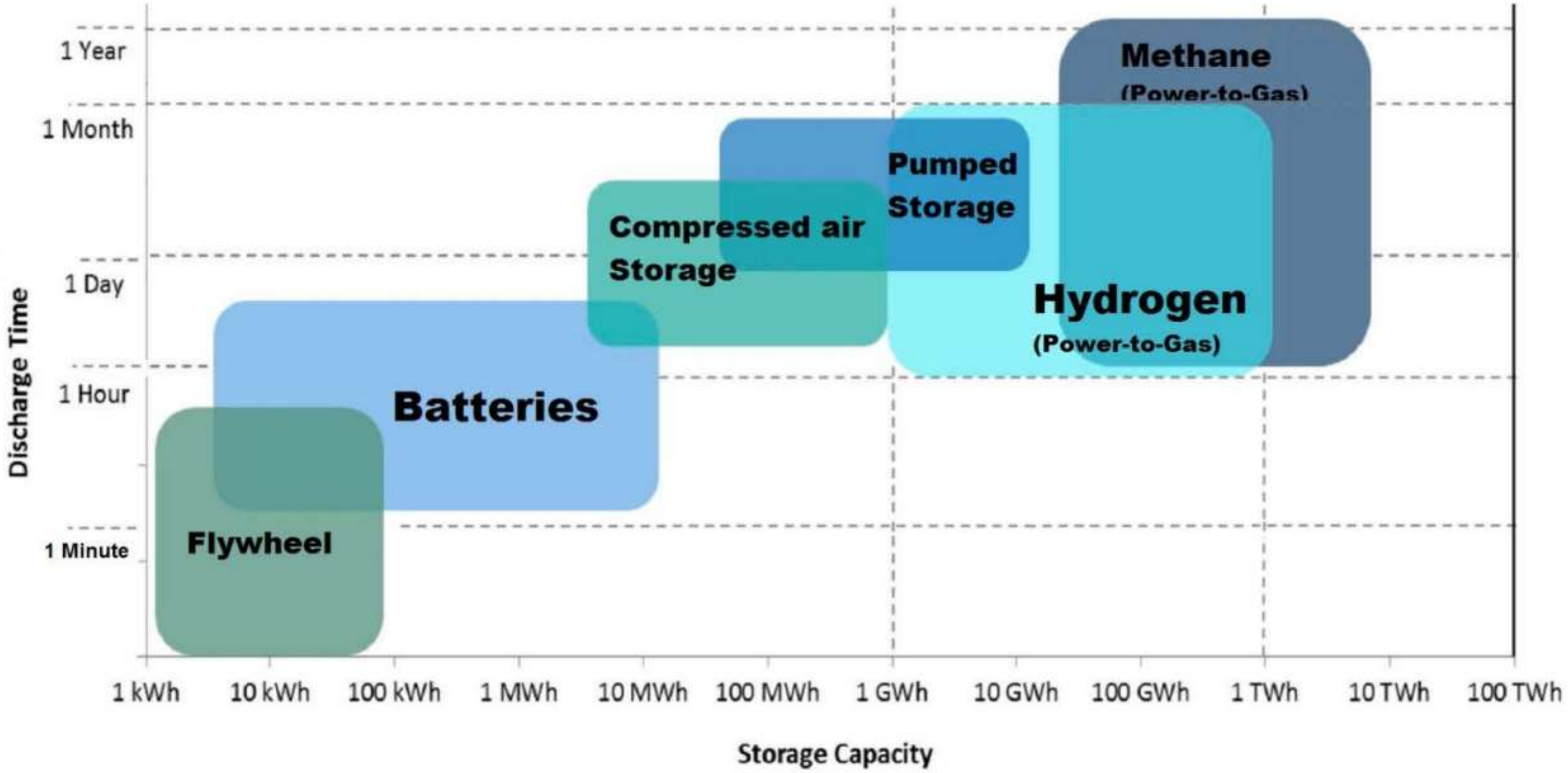
- ✓ IN ORDER TO ACHIEVE THESE REDUCTION LEVELS, CURRENT PRODUCTION TECHNOLOGIES NEED TO BE **DRAMATICALLY IMPROVED**, AND NEW TECHNOLOGIES NEED TO BE DEVELOPED AT THE **INDUSTRIAL LEVEL**.

- ✓ 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.

Hydrogen as renewable energy nexus

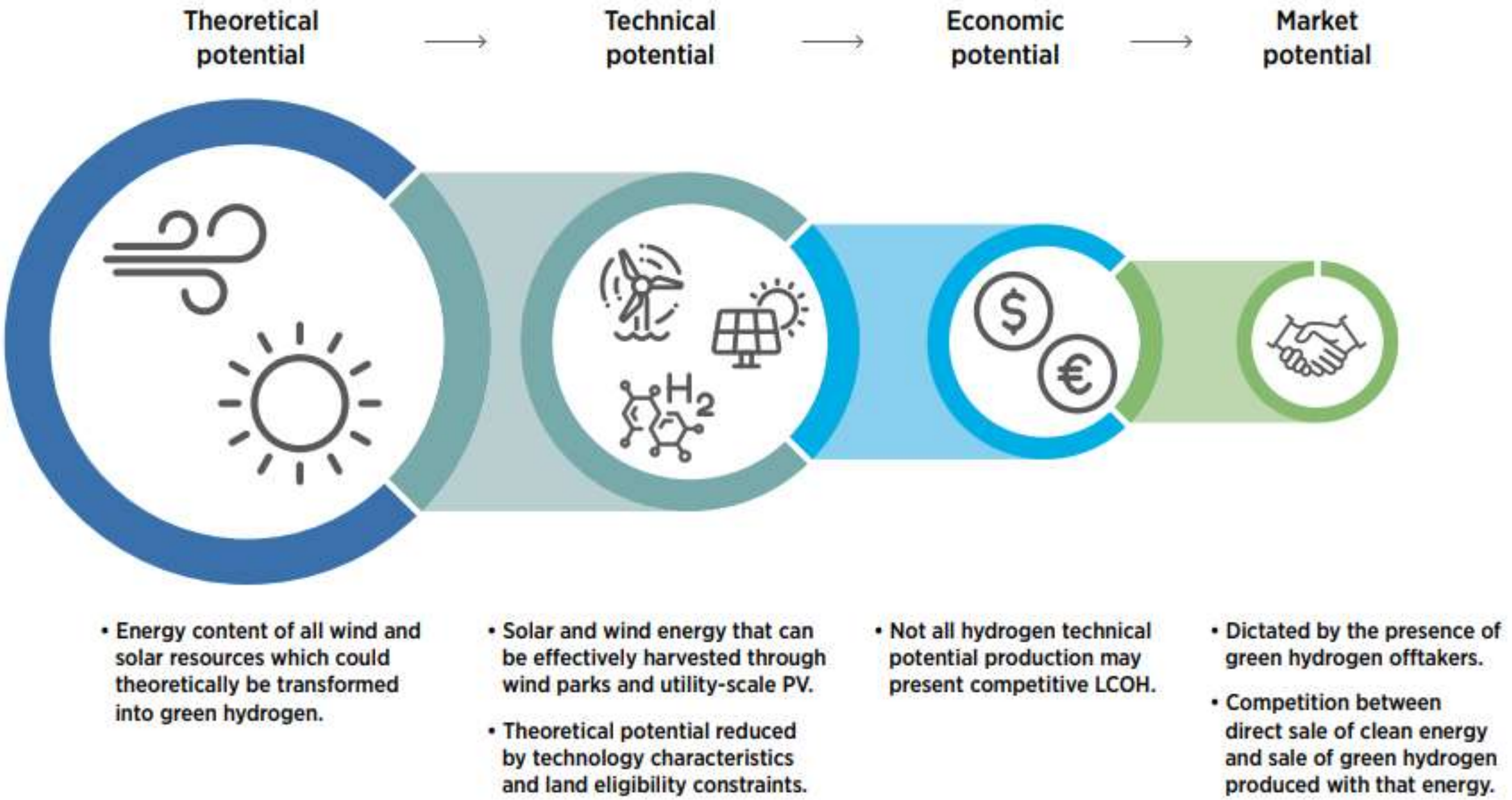
- ✓ **HYDROGEN CAN INCREASE RENEWABLE ELECTRICITY MARKET GROWTH POTENTIALS SUBSTANTIALLY** AND BROADEN THE REACH OF RENEWABLE SOLUTIONS
- ✓ ELECTROLYSERS CAN HELP TO INCREASE **POWER SYSTEM FLEXIBILITY** THROUGH HYDROGEN PRODUCTION IN GRIDS WITH HIGH SHARE OF VARIABLE RENEWABLE ELECTRICITY
- ✓ HYDROGEN CAN PLAY A KEY ROLE FOR **SEASONAL STORAGE** IN POWER SYSTEMS WITH A HIGH SHARE OF VARIABLE RENEWABLE ENERGY.
- ✓ **POWER-2-X** AND **CCUS**, WHERE HYDROGEN FROM ELECTROLYSIS AND CO2 ARE CONVERTED INTO LIQUID **E-FUELS**
- ✓ **ENERGY - INTENSIVE COMMODITIES PRODUCED WITH HYDROGEN** (AMMONIA PRODUCTION, IRON, STEEL AND GLASSMAKING, LIQUIDS FOR AVIATION, OR FEEDSTOCK FOR SYNTHETIC ORGANIC MATERIALS PRODUCTION)
- ✓ HYDROGEN TO **DECARBONISE ROAD TRANSPORT OF GOODS** (FCEVS FOR A LONG-DISTANCE, HEAVY-DUTY TRANSPORT)
- ✓ HYDROGEN TO **LEVERAGE THE ROLE OF NATURAL GAS** AS A LOW-CARBON TRANSITION FUEL IN THE CONTEXT OF JOINT USE OF THE NATURAL GAS INFRASTRUCTURE FOR HYDROGEN AND NATURAL GAS MIXTURES.

Hydrogen for RE storage



Source: School of Engineering, RMIT University (2015)

But?



Source: IRENA Global Hydrogen Trade Costs 2022

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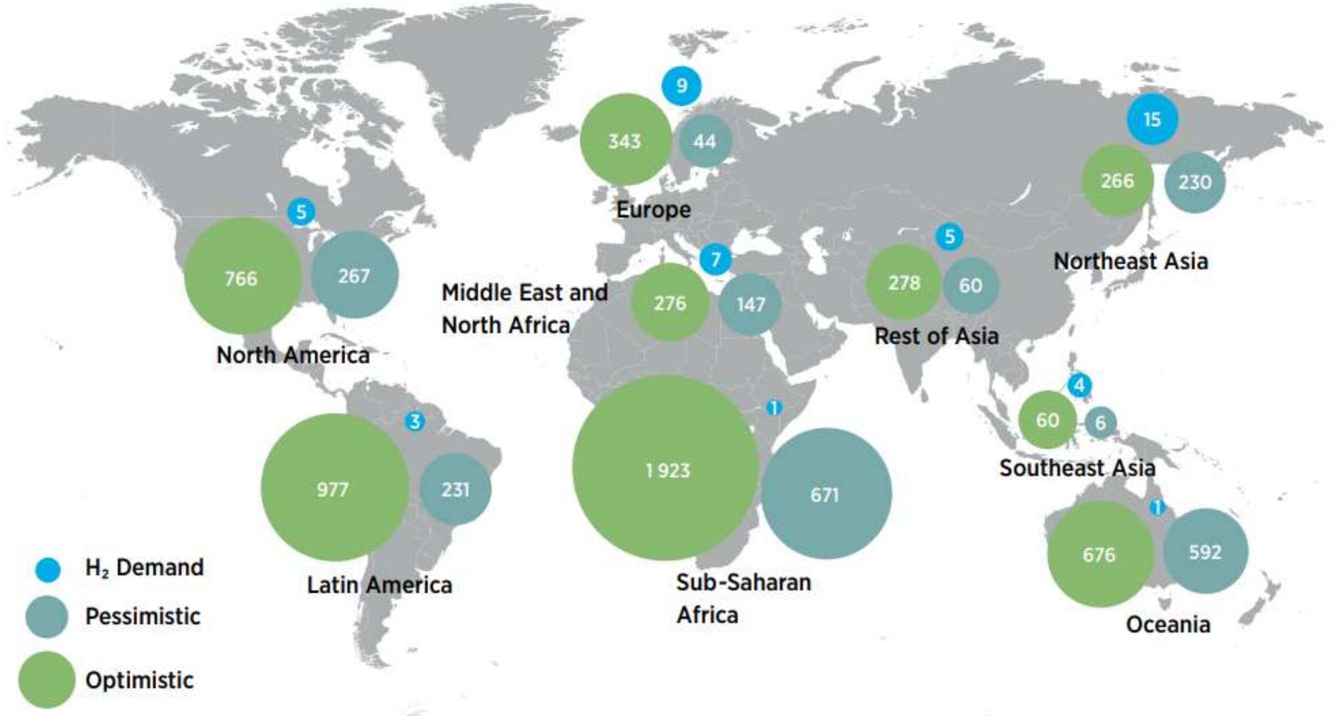
Potential of green hydrogen supply below and forecasted hydrogen demand



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

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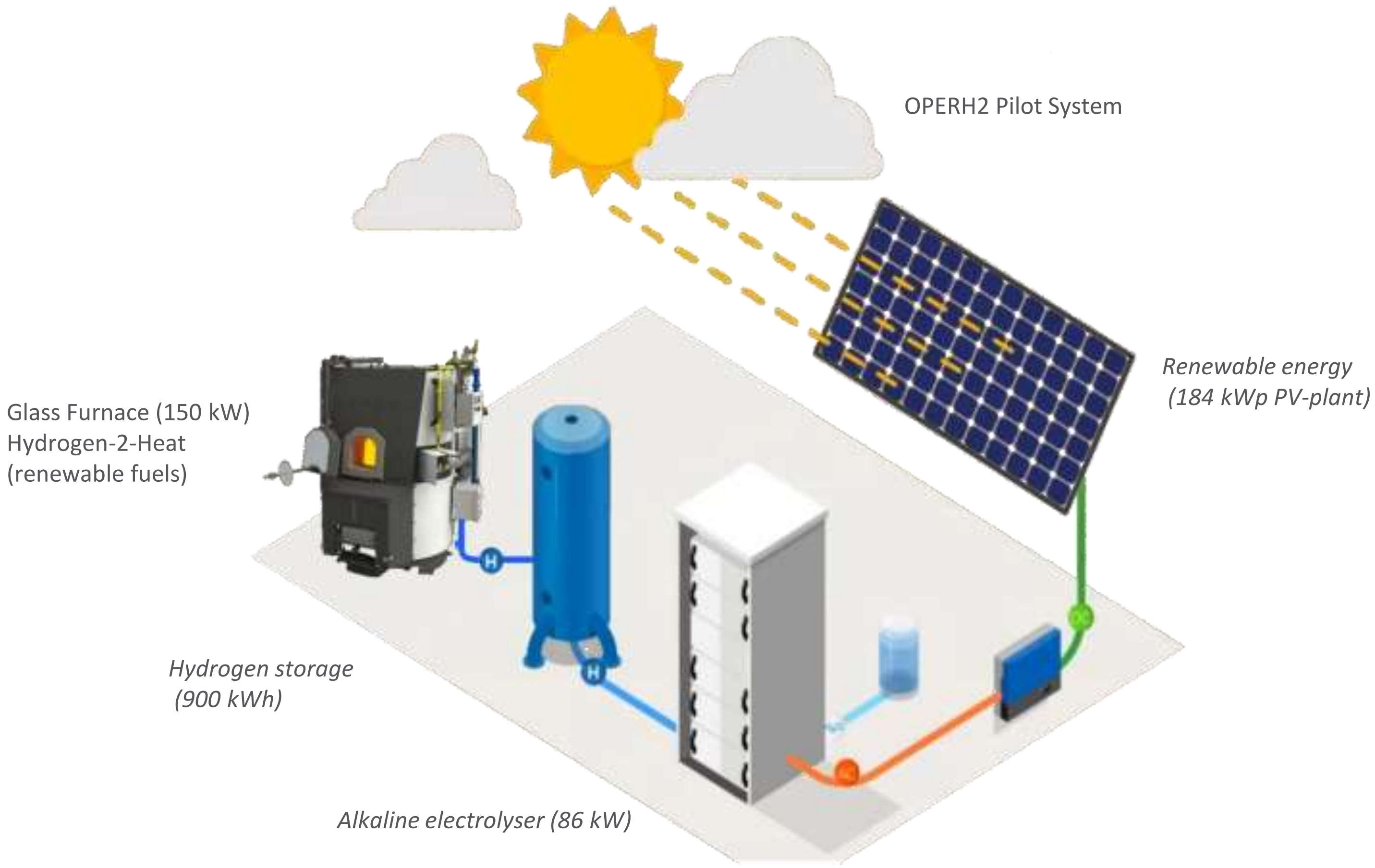
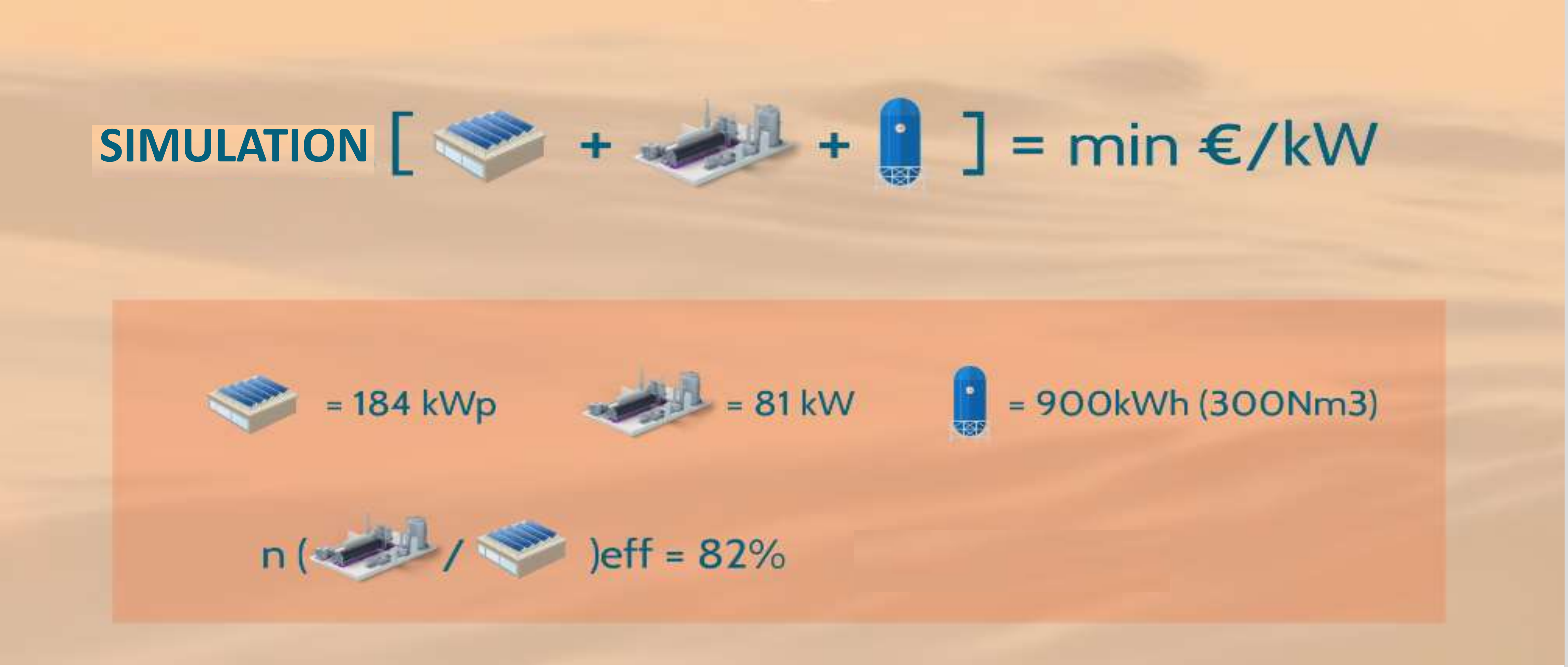
2 Hydrogen pilot system

OPERH2 Project pilot

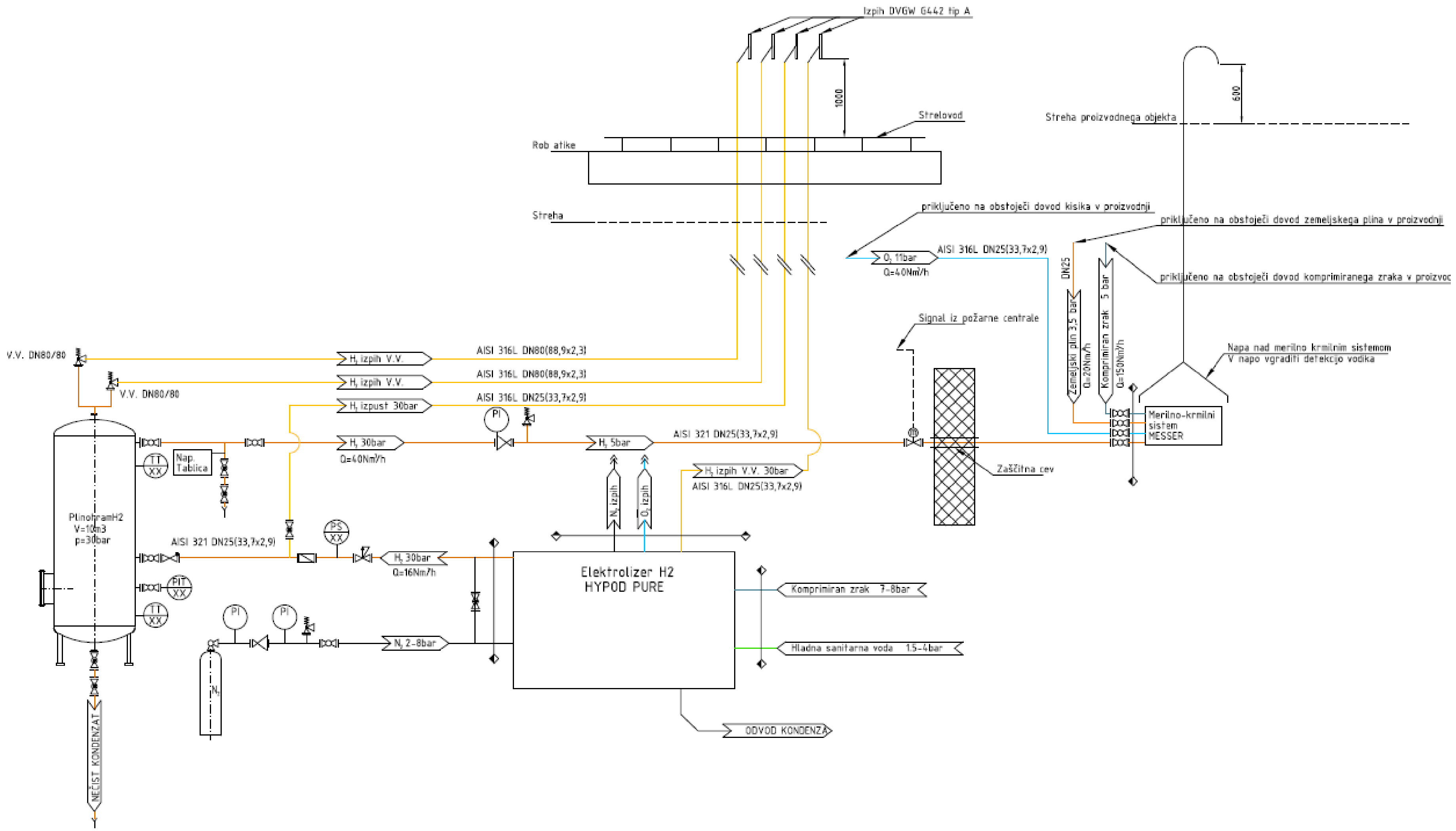
Optimization of energy conversion to replace the share of fossil fuels used for industrial glass melting with hydrogen.



Design

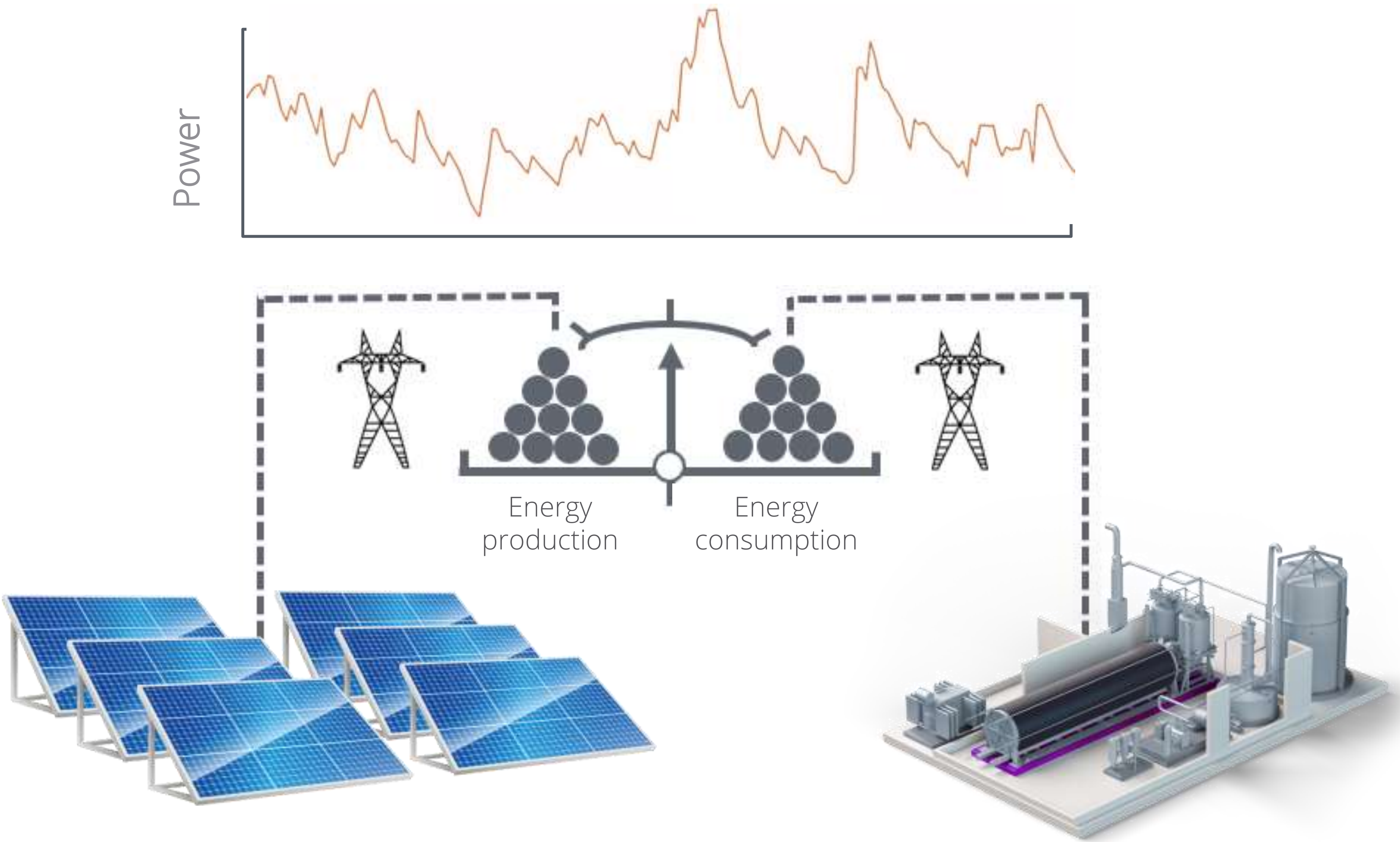


Design

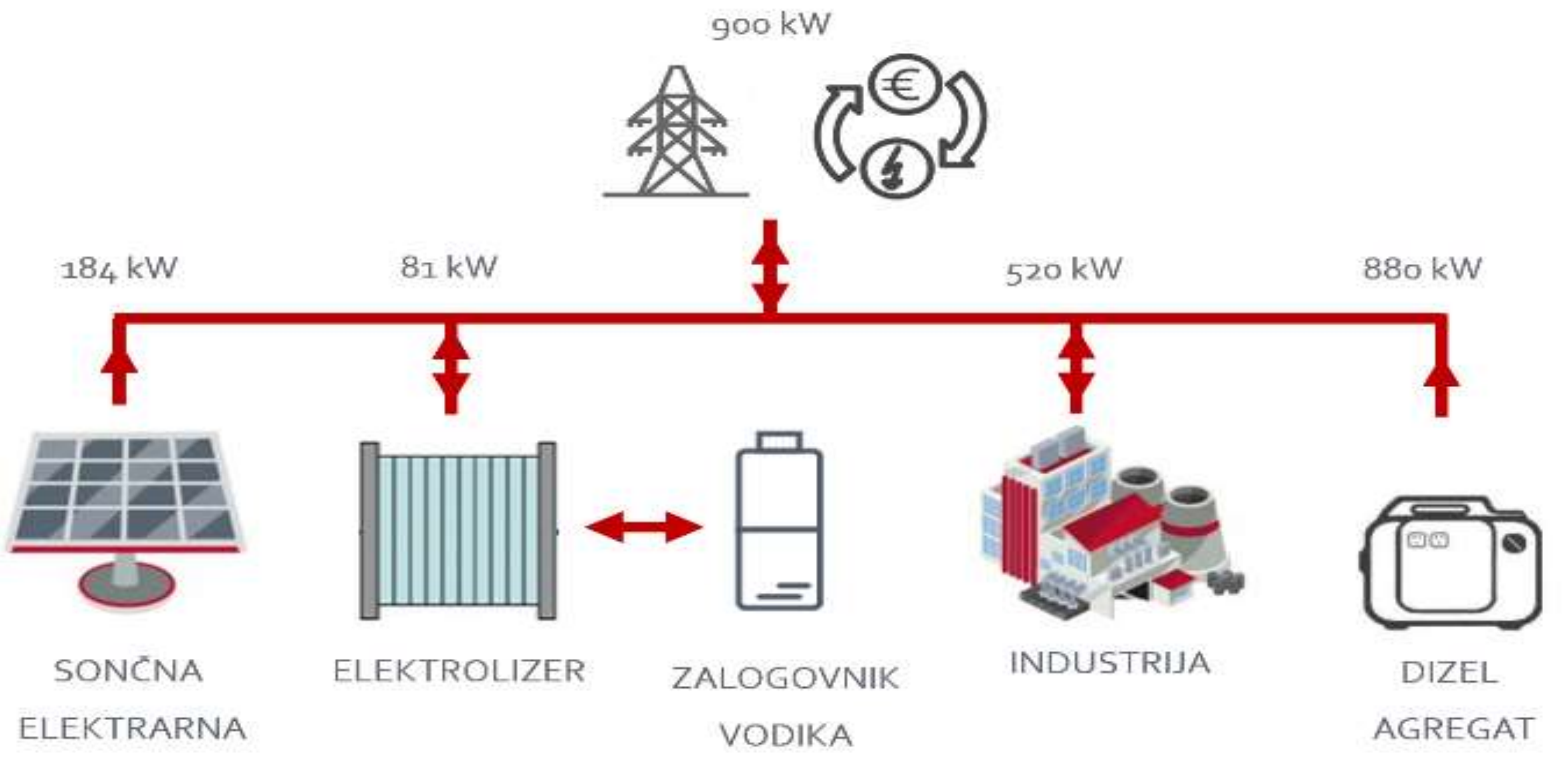


Izpih DVGW G442 tip A
1000
Strelovod
Rob atike
Streha
600
Streha proizvodnega objekta
priključeno na obstoječi dovod kisika v proizvodnji
priključeno na obstoječi dovod zemeljskega plina v proizvodnji
priključeno na obstoječi dovod komprimiranega zraka v proizvoc
O₂ 11bar
Q=40Nm³/h
AISI 316L DN25(33,7x2,9)
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
Merilno-krmilni sistem MESSER
V.V. DN80/80
H₂ izpih V.V.
AISI 316L DN80(88,9x2,3)
V.V. DN80/80
H₂ izpih V.V.
AISI 316L DN80(88,9x2,3)
H₂ izpust 30bar
AISI 316L DN25(33,7x2,9)
H₂ 30bar
Q=40Nm³/h
PI
H₂ 5bar
AISI 321 DN25(33,7x2,9)
Zaščitna cev
Nap. Tablica
TT XX
H₂ izpih V.V. 30bar
AISI 316L DN25(33,7x2,9)
N₂ izpih
O₂ izpih
PlinohramH2
V=10m3
p=30bar
AISI 321 DN25(33,7x2,9)
PS XX
H₂ 30bar
Q=16Nm³/h
Elektrolizer H2
HYPOD PURE
Komprimiran zrak 7-8bar
Hladna sanitarna voda 1.5-4bar
PIT XX
TT XX
PI
PI
N₂ 2-8bar
N₂
NEČIST KONDENZAT
ODVOD KONDENZA

PV coupled with WE



Energy Management System



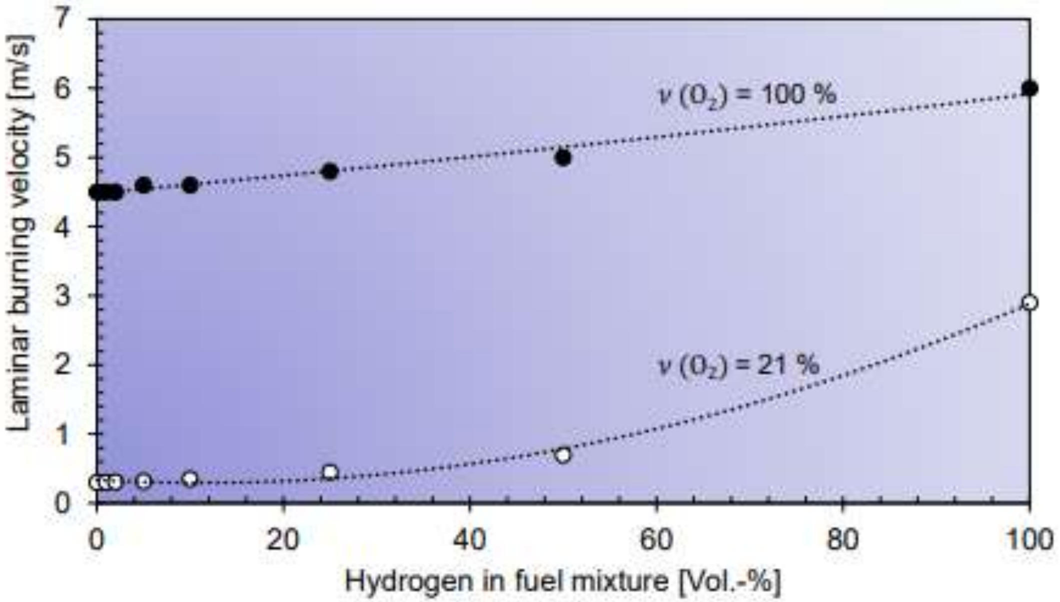


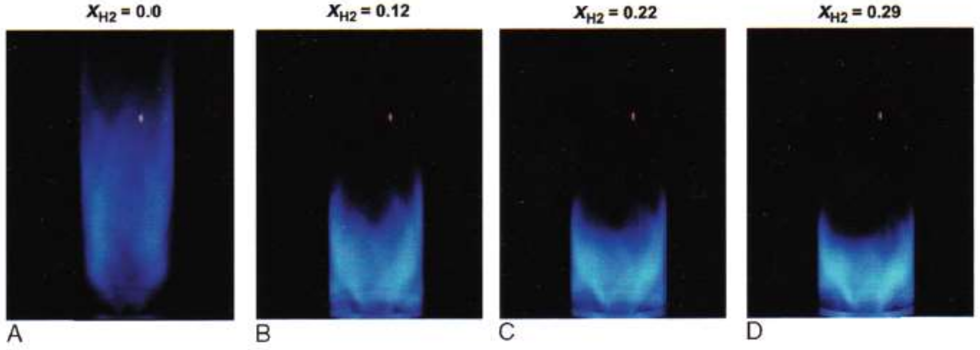


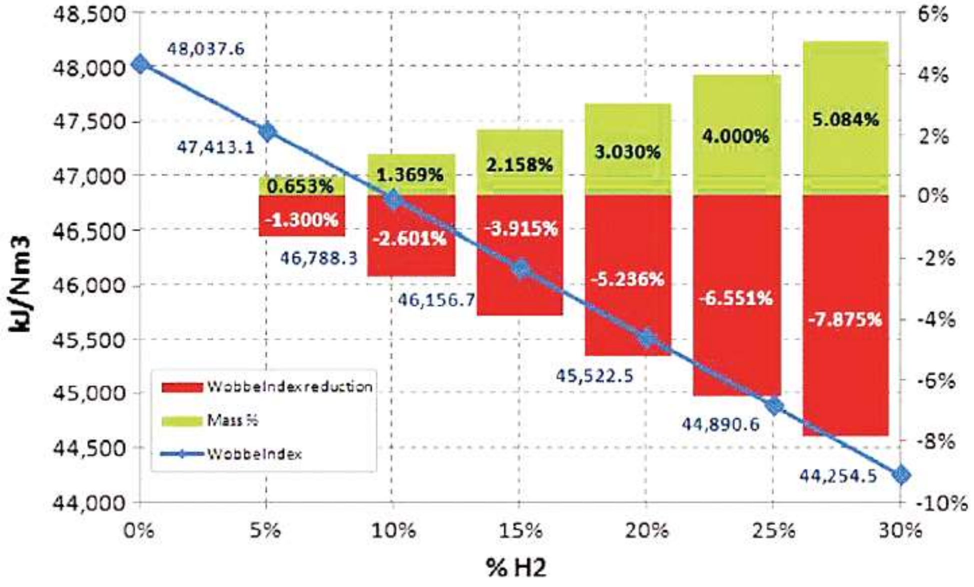
3 Hydrogen combustion

Hydrogen combustion

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





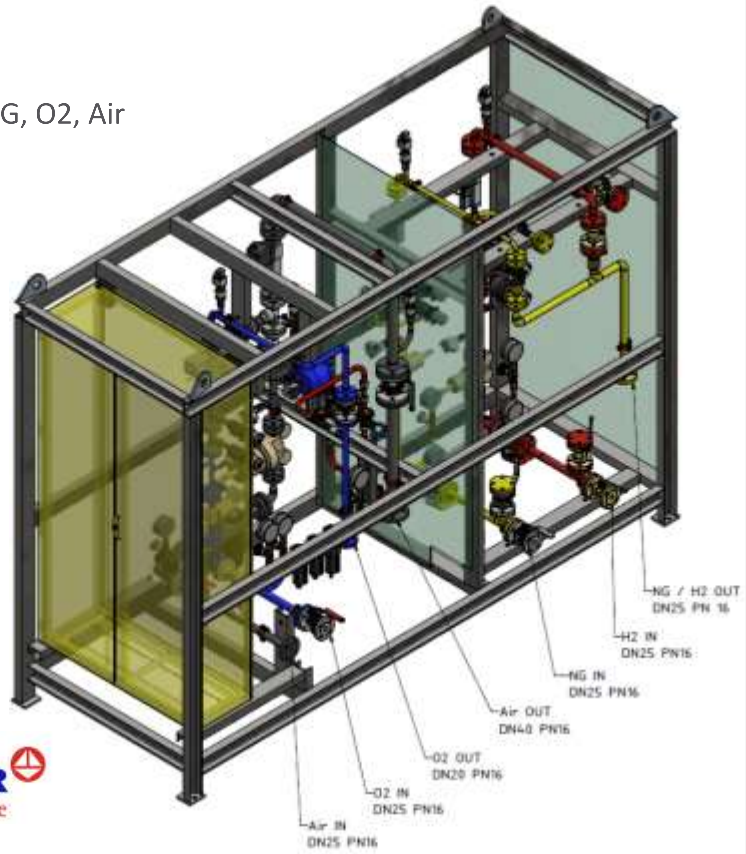


Source: L. Santoli et al.

HydroFlex combustion system

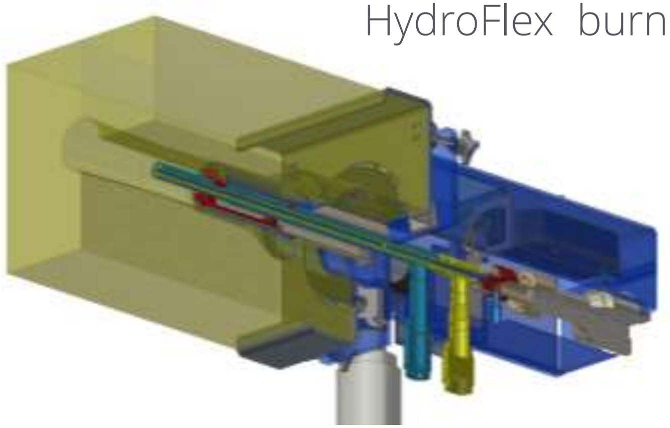
- High exit velocity burners
- Mixure of natural gas and hydrogen in every ratio possible, and mixture of air and oxygen in every ratio

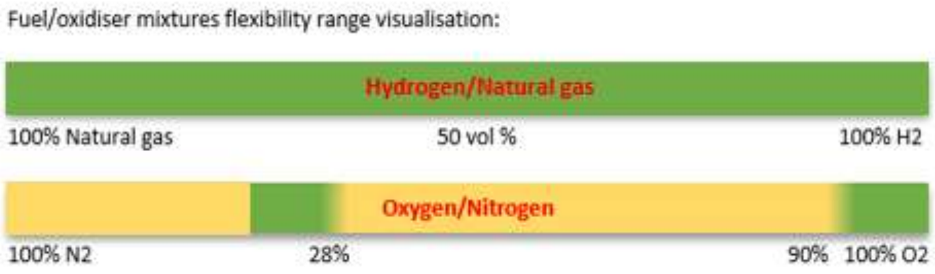
Skid for H2, NG, O2, Air



MESSER
Gases for Life

HydroFlex burner





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Open flame testing

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

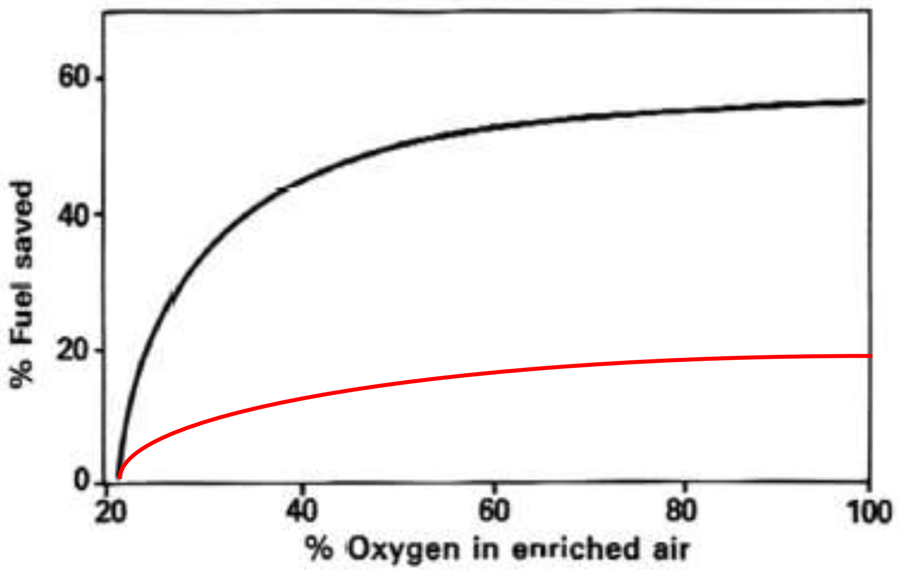
Air-H2 | Oxy-H2 | Oxy-gas

Combustion efficiency

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

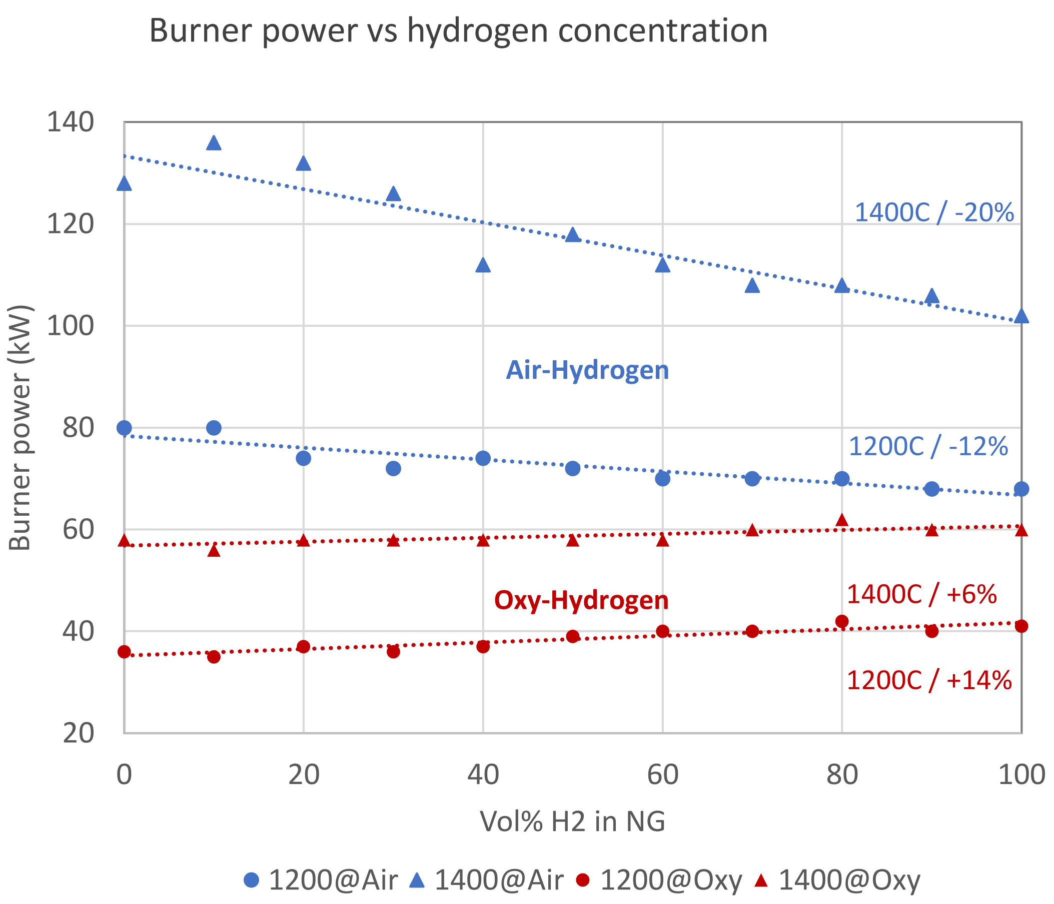
h(NG) = ~ 3 h(H2)

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

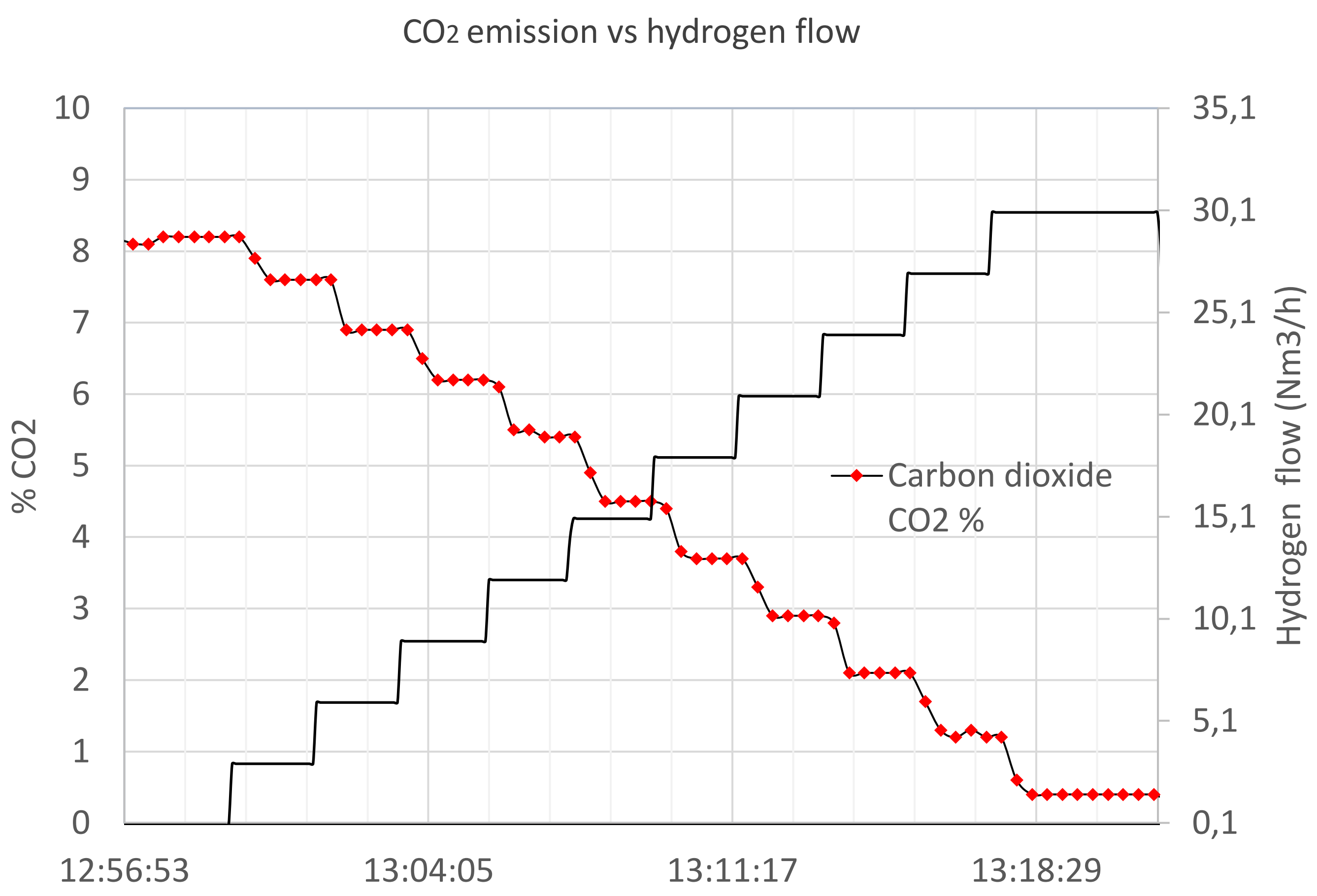


- Higher efficiency at higher temperatures

Combustion efficiency



CO_2 emissions



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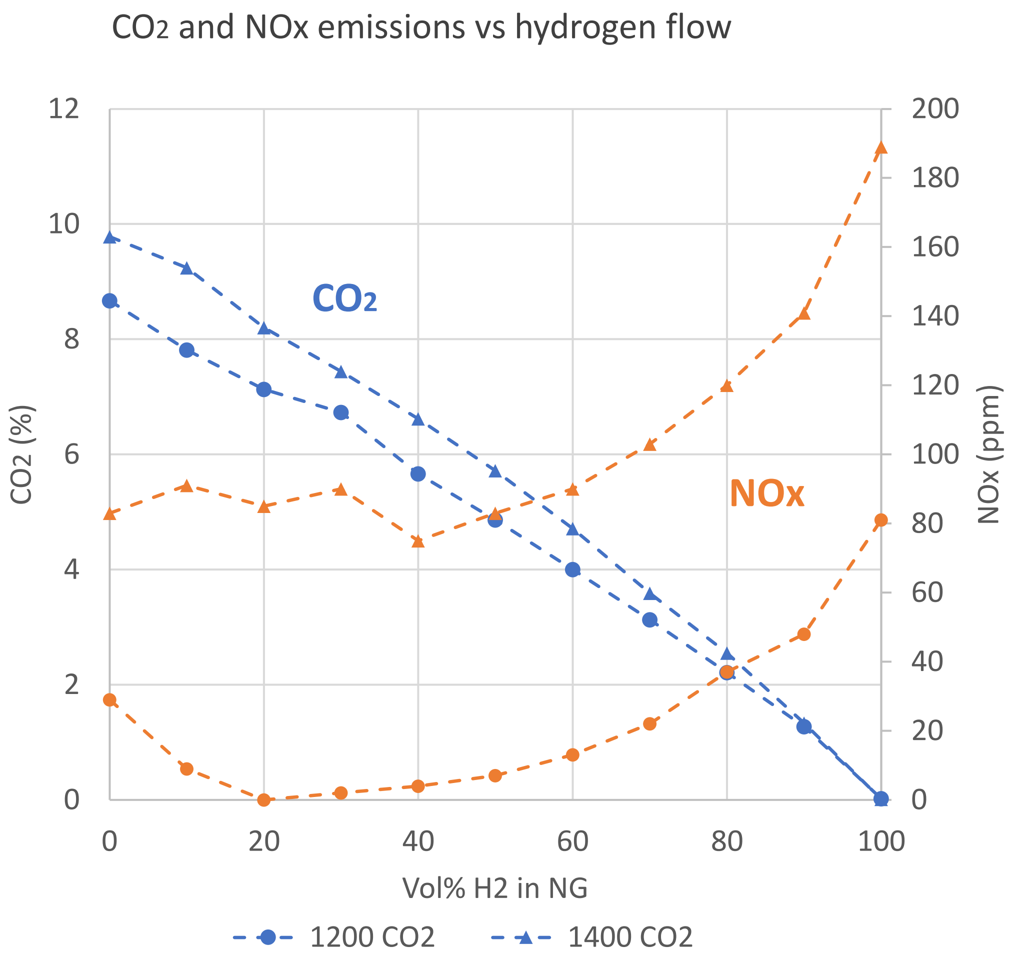
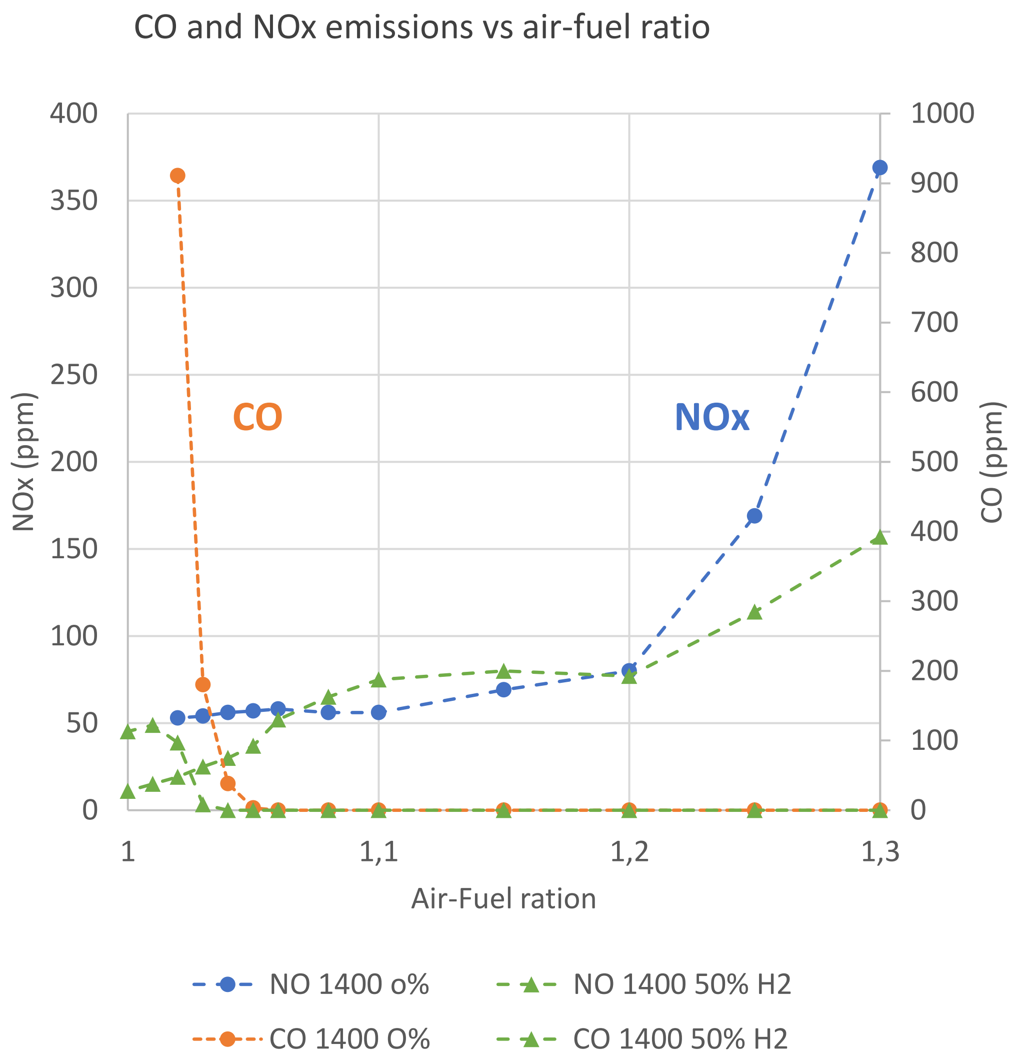
Emissons

Air-Hydrogen combustion





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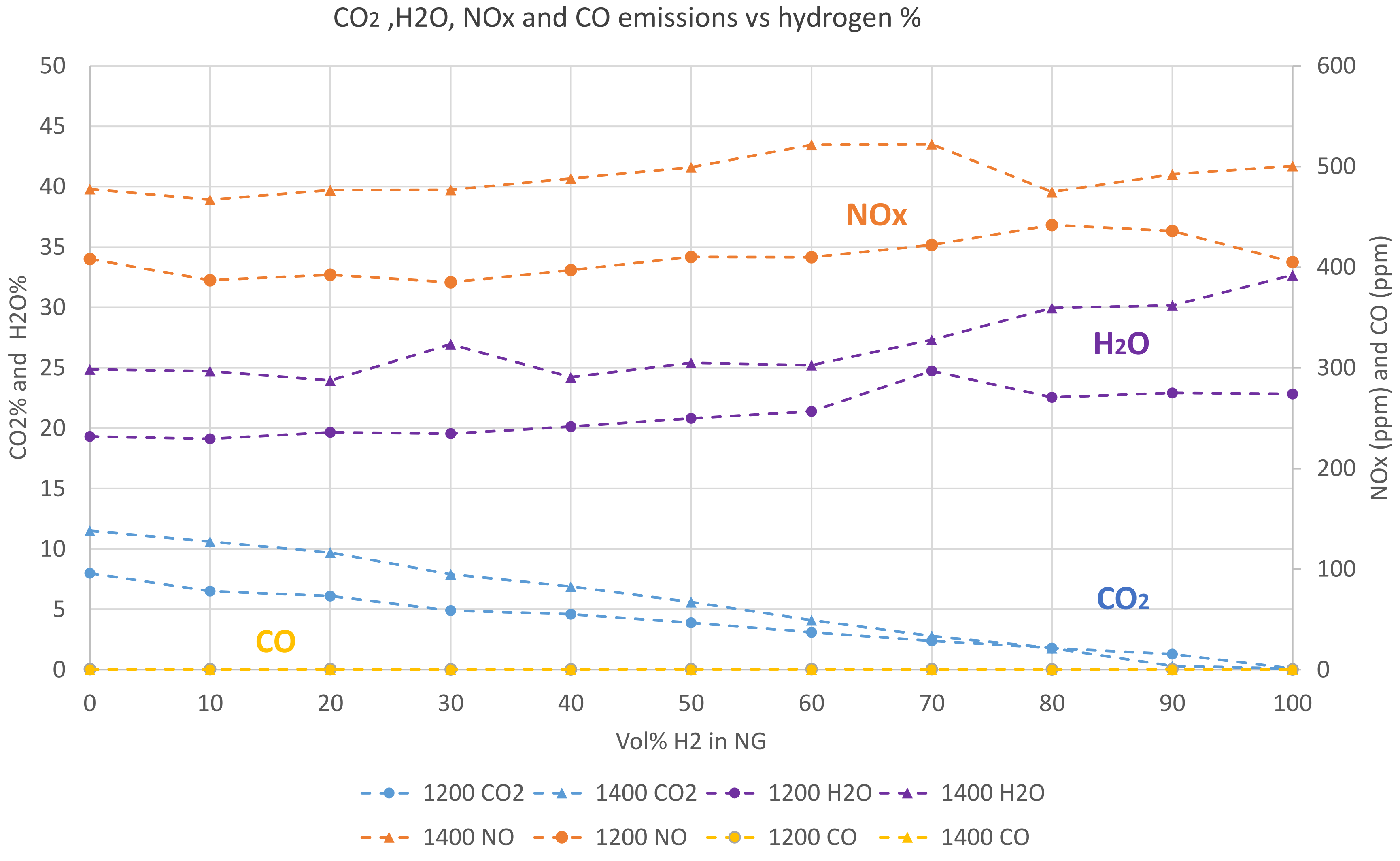
Emissons

Oxy-Hydrogen combustion



4 Carbon-free glass melting and LCA

Pilot demonstration

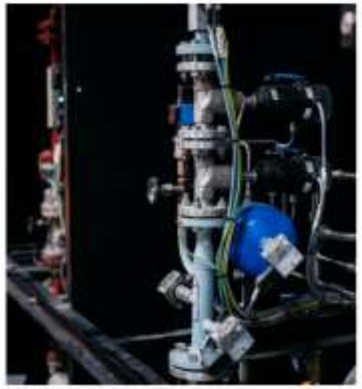
- Melting of glass with 100% hydrogen and 100% PCR cullet











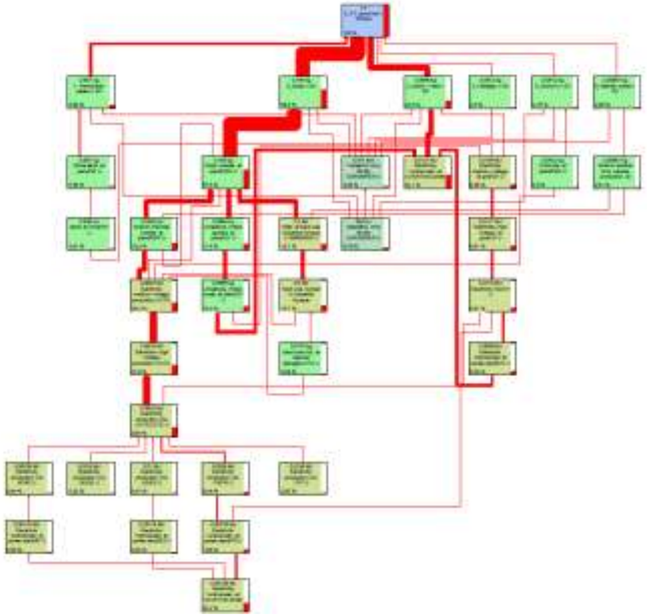

Our most sustainable glass bottle

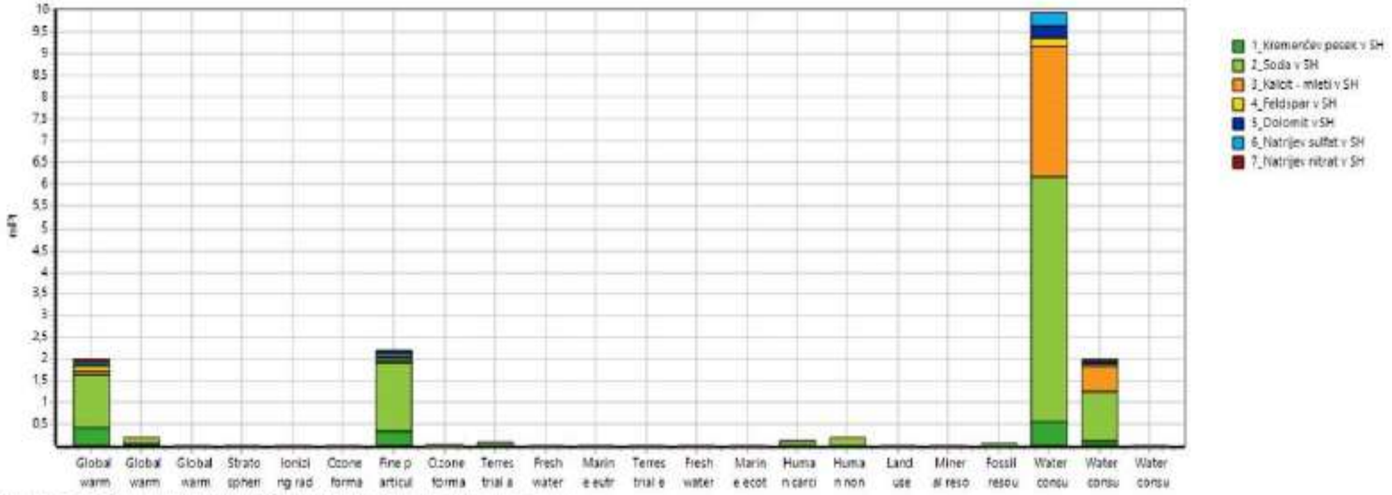
Comparative LCA (ISO 14040/44)

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';

GHG emission reduction – the other side of the story

- → Using more (renewable) electricity will decrease carbon footprint but will most probably also increase water footprint.
- → Hydrogen from WE will also significantly and additionlay increase water footprint
- → Cradle-to-Grave LCA can give us more holistic data on environmental impacts
- → Hratsnik1860 strategy is to decrease GHG emission while maintaining total environmental impact (mPt) as low as possible.





Method: ReCiPe 2016 Endpoint (H) V1.04 / World (2010) H/A / Weighting / Excluding infrastructure processes
Analyzing 1 p 'S_PI_surovine v SH/kos';

5 H2GLASS

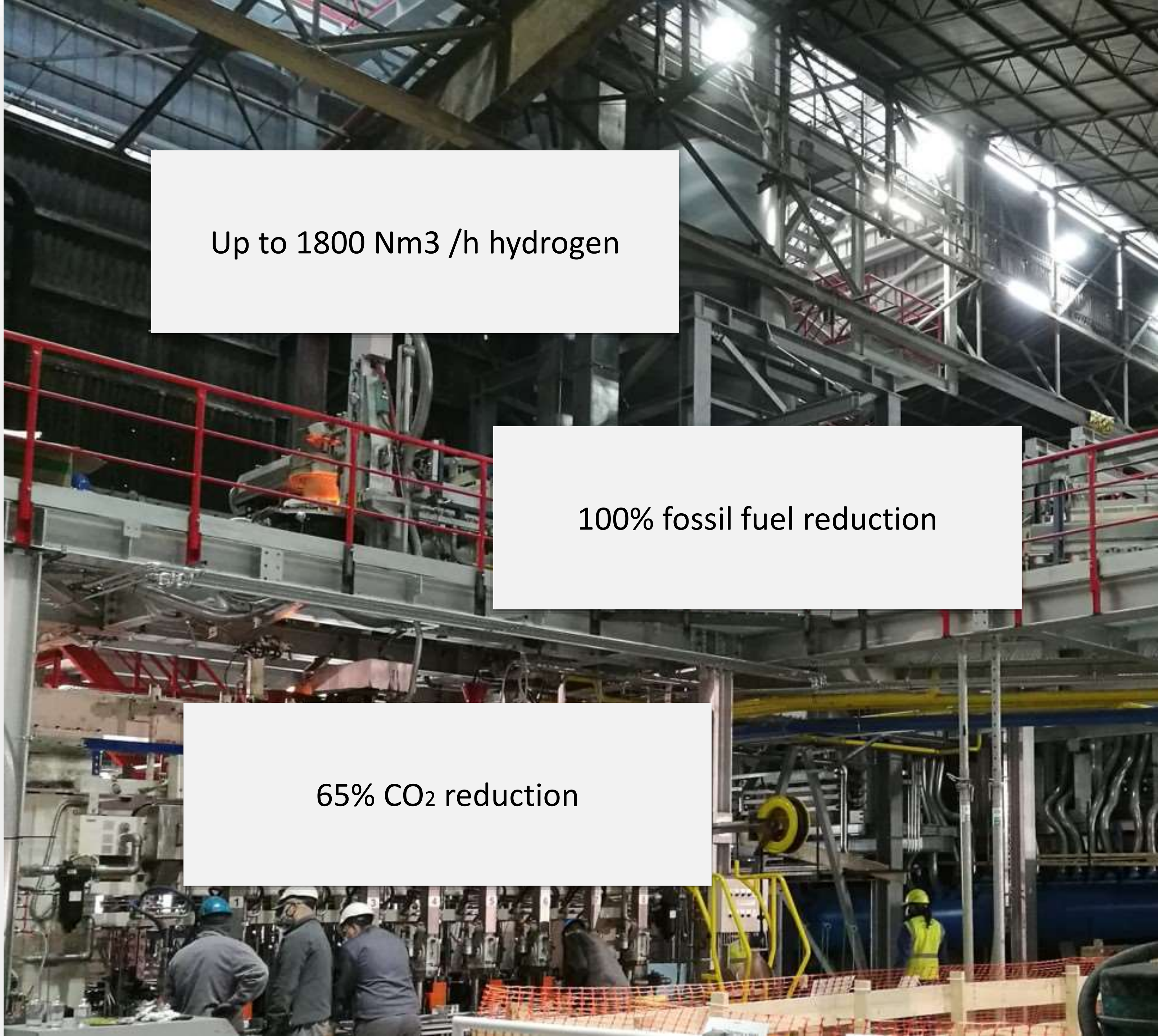
Project roadmap

OPERH2	H2GLASS		NAHV
Pilot demonstration of hydrogen glass melting	Industrial qualification of hydrogen glass melting glass at operational level	Design and construction of the system	Operation of the system
1 PHASE	2 PHASE	3 PHASE	4 PHASE

TRL6 → TRL9

Glass production decarbonisation utilizing Hydrogen

Large-scale
(120 t/day)



Up to 1800 Nm3 /h hydrogen

100% fossil fuel reduction

65% CO_2 reduction

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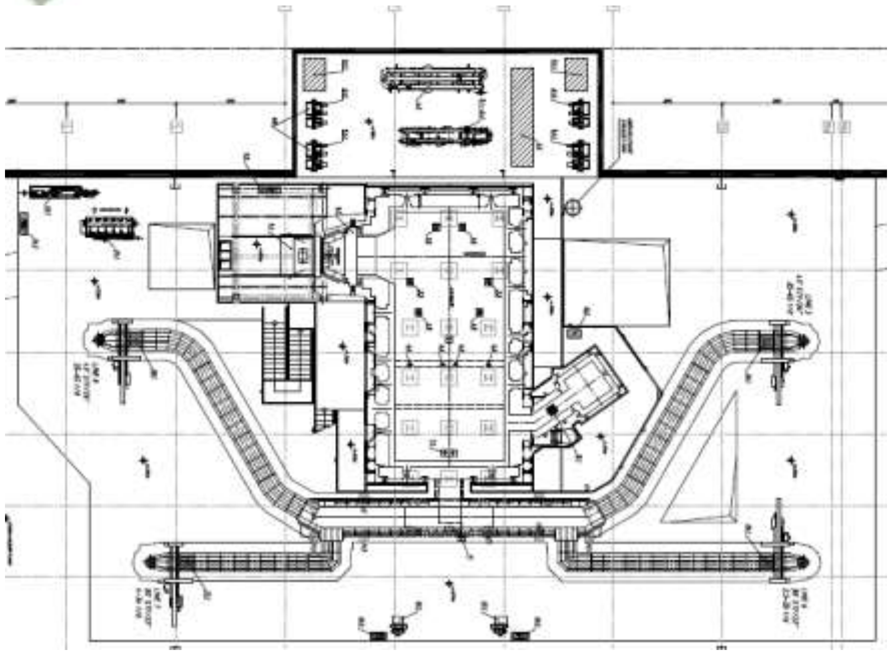
SH Demo 1 – Oxyfuel furnace



Furnace Type: Oxyfuel furnace (SORG)

Year of constrution: Q4 2020

Energy consumption

Natural gas = 600 Nm3/h (6 burners)

Oxygen form on site Cryo plant = 1200 Nm3/h

Boosting = 10%

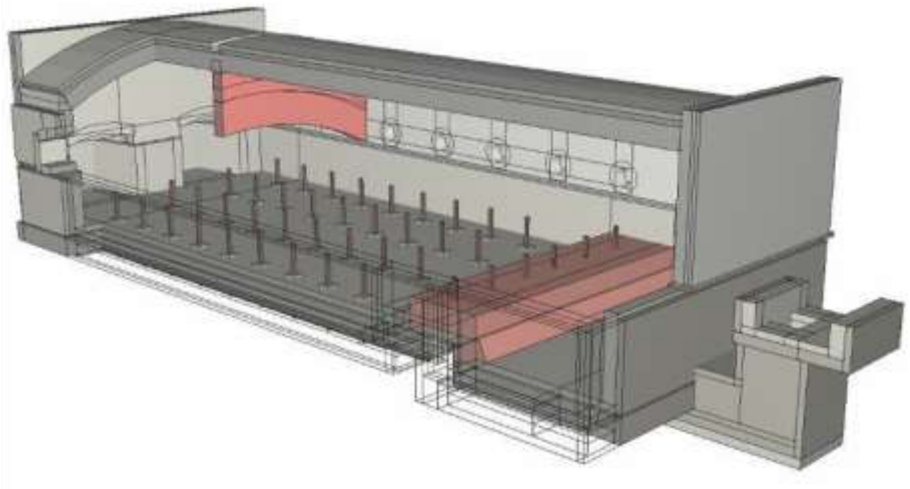
Type of burner: Eclipse PF300 (existing), SplitOX (mixed gas up to 100% H2)

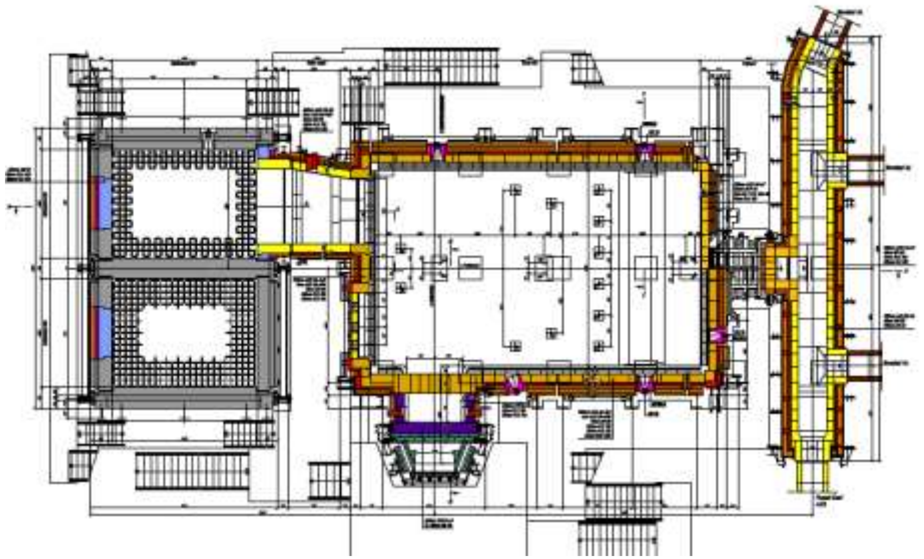
Type of glass: Extra white flint

Monitoring & control: Temperature metering, flows, pressure, glass level, O2 metering, Camera System (+ ES3, NIR, batch monitoring, AMS for Emissions)

H2 readiness : Preprepared for the installation of hydrogen combustion system

SH Demo 2 - EP Hybrid furnace





Furnace Type: EP Hybrid furnace

Year of constrution: Q2 2023

Energy consumption

Natural gas = 1200 Nm3/h (2 burners)

Boosting = 4.500 kW (up to 43%)

Type of burner: SDB 231 (up to 60% H2 ready)

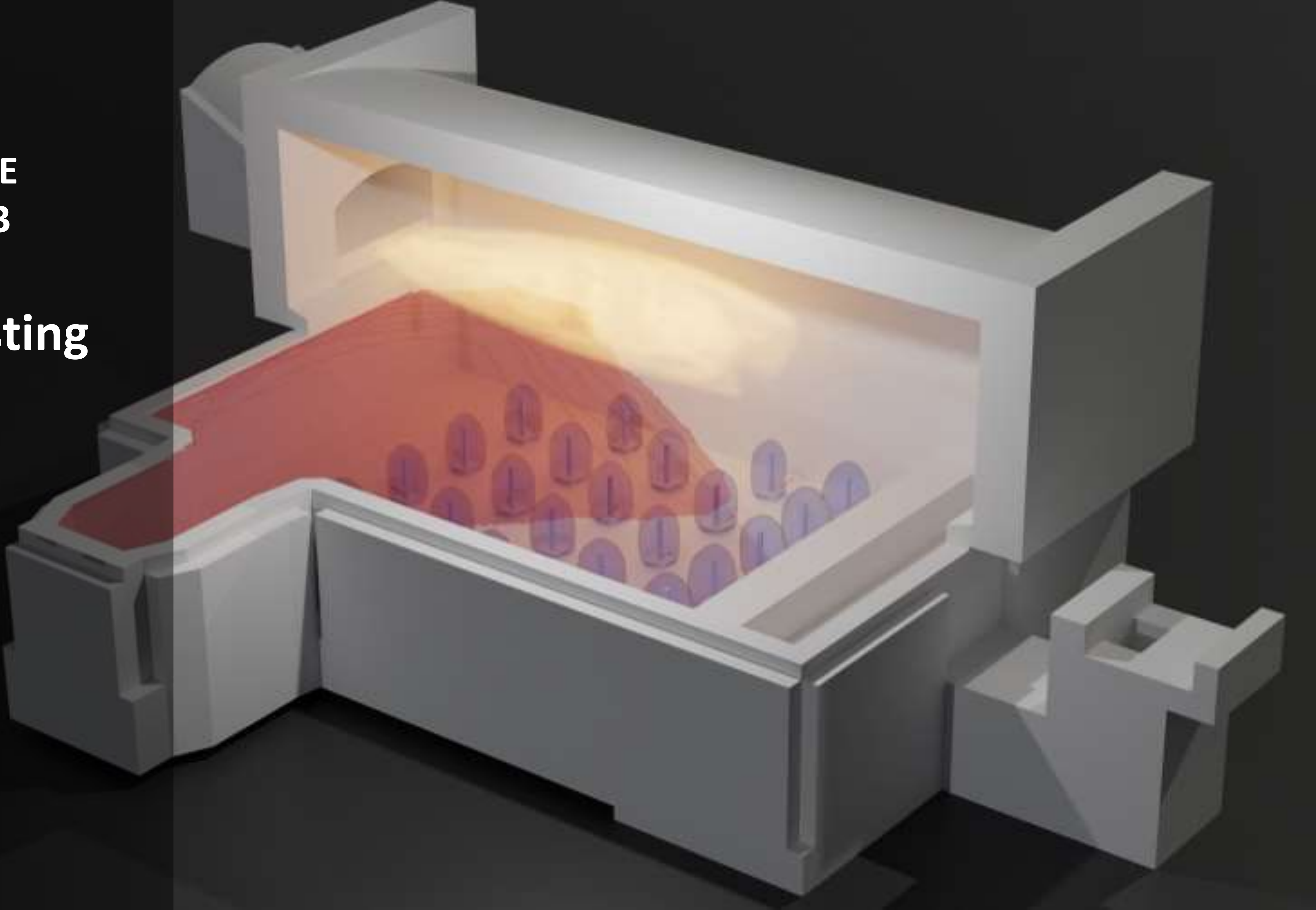
Type of glass: Extra white flint

Monitoring & control: Temperature metering, flows, pressure, glass level, O2 metering, NIR Camera System (+ ES3, batch monitoring, AMS for Emissions)

H2 readiness : Preprepared for the installation of hydrogen combustion system

HYBRID
REGENARATIVE
FURNACE 2023

>40% boosting
-35% CO_2
-50% NG



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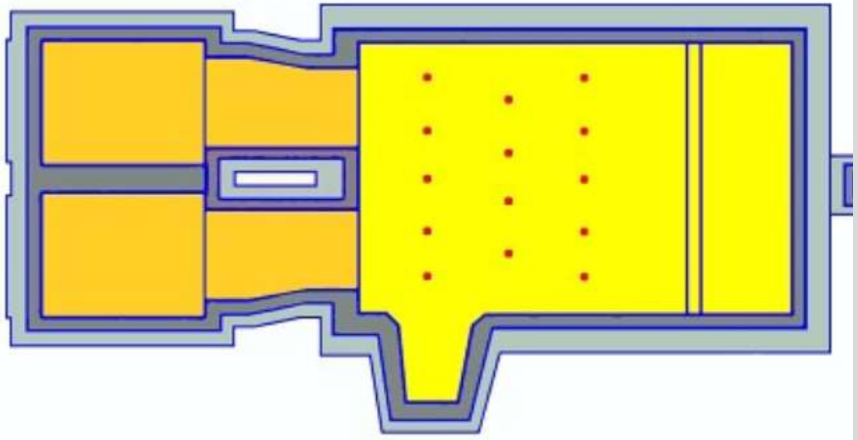
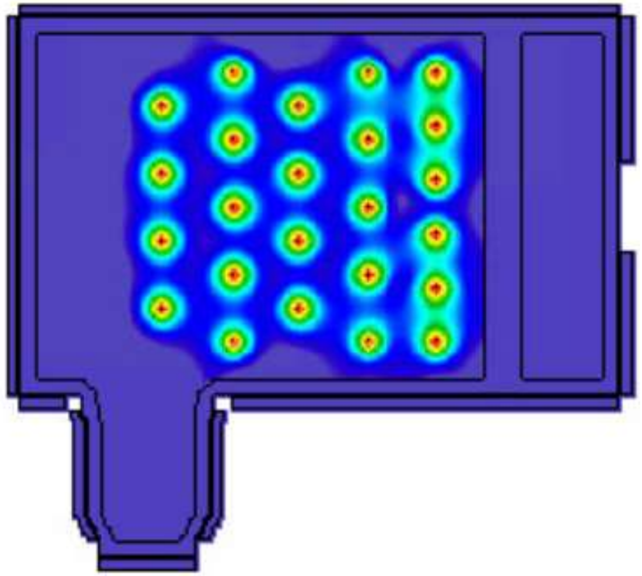
Innovation

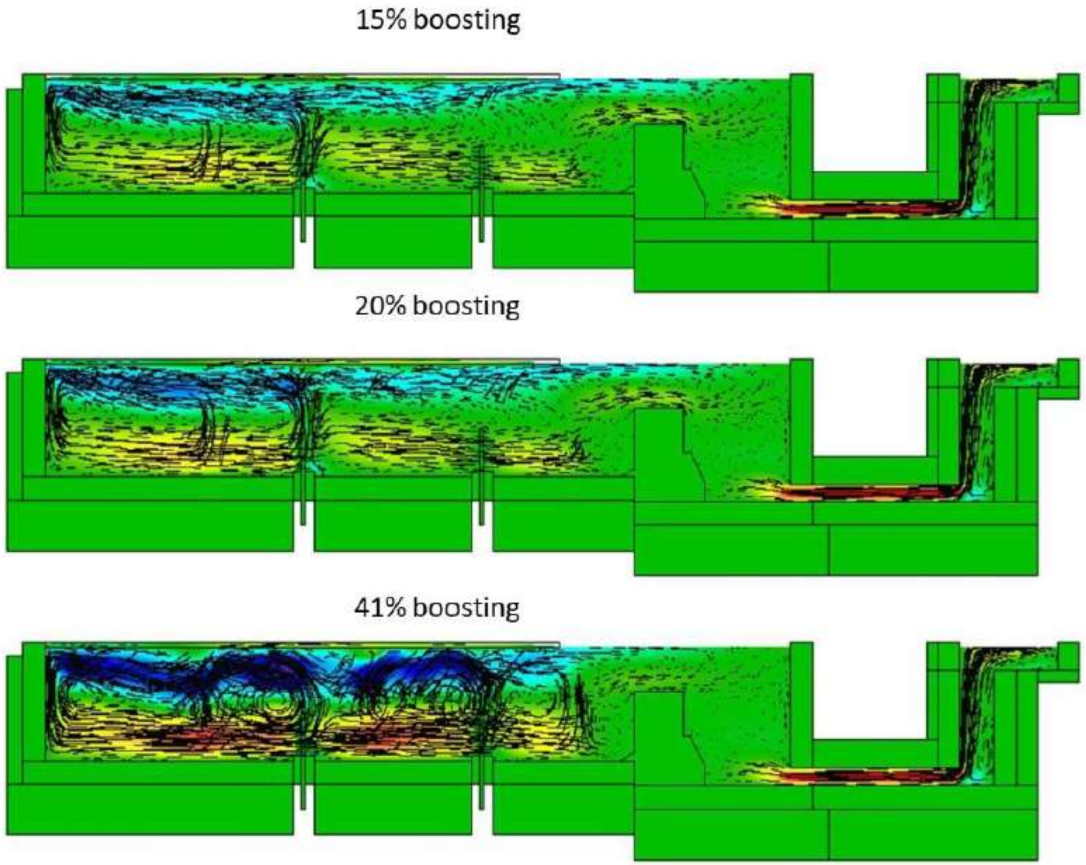
<10% boosting



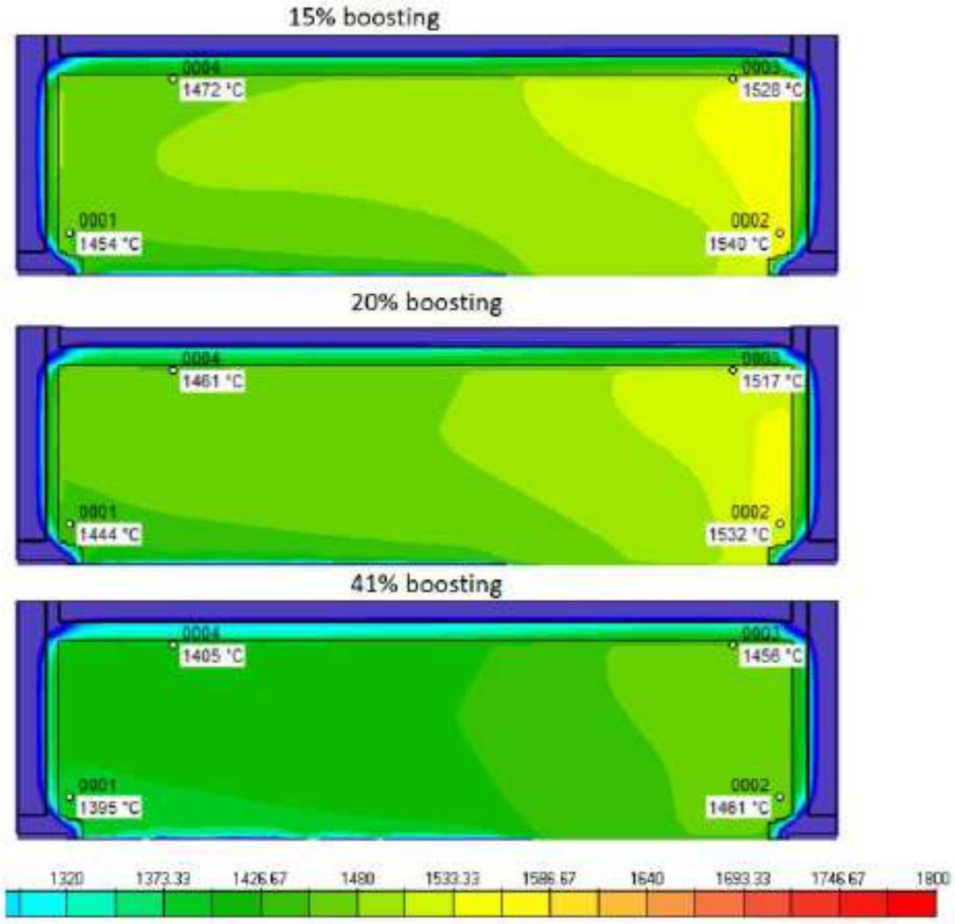
>40% boosting



Innovation



15% boosting
20% boosting
41% boosting



15% boosting
0004
1472 °C
0003
1528 °C
0001
1454 °C
0002
1540 °C
20% boosting
0004
1461 °C
0003
1517 °C
0001
1444 °C
0002
1532 °C
41% boosting
0004
1405 °C
0003
1456 °C
0001
1395 °C
0002
1461 °C
1320
1373.33
1426.67
1480
1533.33
1586.67
1640
1693.33
1746.67
1800

Roadmap for SH DEMO sites

	2023-2024 1.Phase (partial Hydrogen replacement)	2024-2025 2.Phase (100% Hydrogen replacement)	2025-2026 3.Phase - Validation
	• Suppy from hydrogen trailers • Up to 1000 Nm3/h	• Suppy from hydrogen trailers + electrolyser • Up to 1600-1800 Nm3/h	• Suppy from hydrogen trailers + electrolyser • Up to 1600-1800 Nm3/h
Oxyfuel furnace	• Q3/ 2023 • Hydrogen gas skid up to 600 Nm3/h • 2/6 burners – 600 Nm3/h • 29% energy / 60% vol Hydrogen	• Q4/ 2024 • Hydrogen gas skid up to 2000 Nm3/h • 6/6 burners – 600 Nm3/h • 90% energy / 100% vol Hydrogen	• Performance testing • 6/6 burners – 600 Nm3/h • 90% energy / 100% vol Hydrogen
EP Hybrid furnace	• Q1/2024 • Hydrogen gas skid up to 2000 Nm3/h • 1/2 burners – 900 Nm3/h • 27% Energy / 75 % vol Hydrogen • 40% boosting	• Q1/2025 • Hydrogen gas skid up to 2000 Nm3/h • 1/2 burners – 900 Nm3/h • 55% Energy / 100 % vol Hydrogen • 40% boosting	• Performance testing • 1/2 burners – 900 Nm3/h • 55% Energy / 100 % vol Hydrogen • 40% boosting
Period	• 1 month	• 2-3 moths	• 1 moths

Considerations

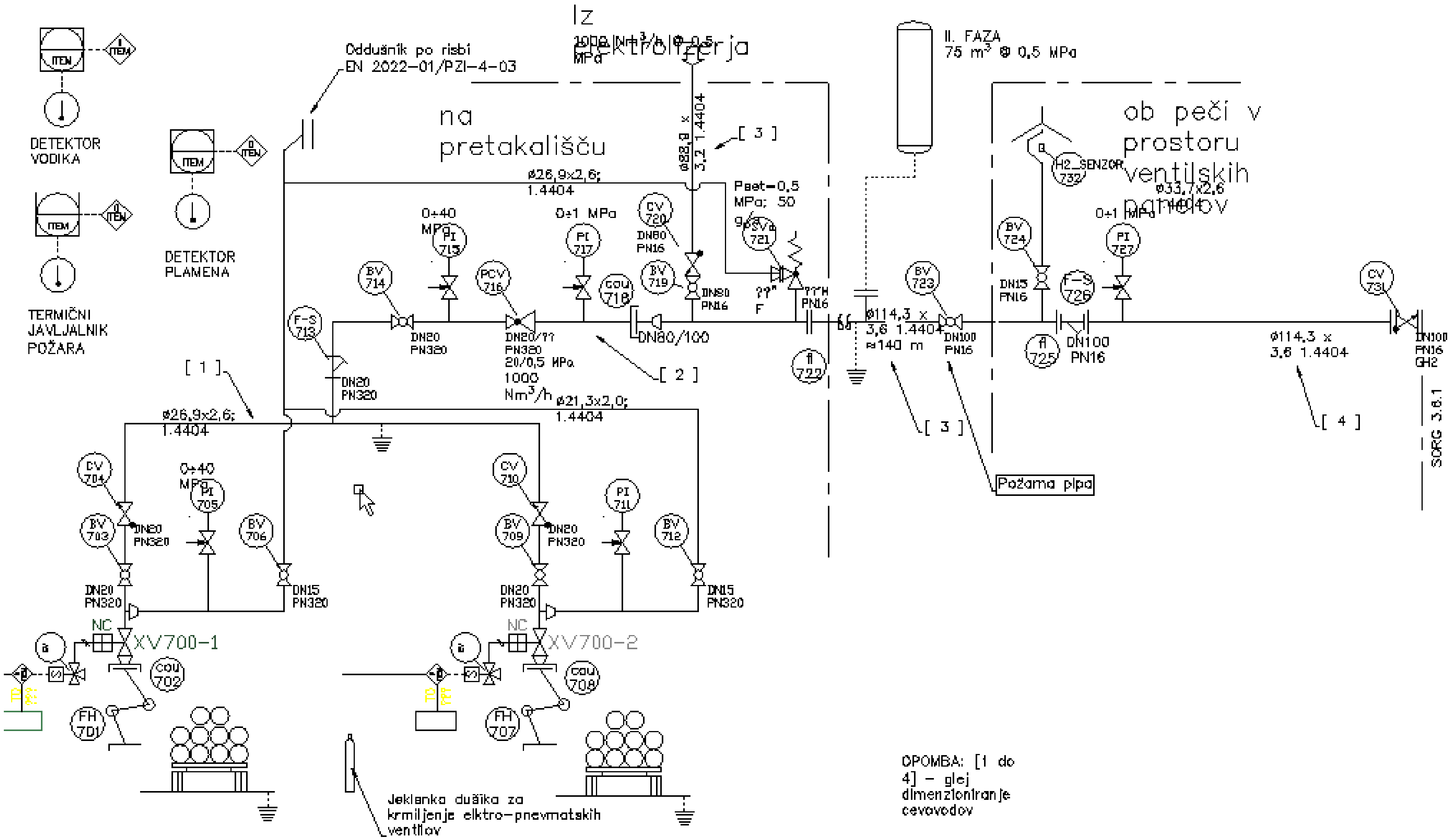
- **Quality considerations**
  - Seeds (impact on glass refinement - foaming, radiative heat transferee)
  - Glass colour (impact on RedOx, Se-oxidation state)

- **Technological limits**
  - Maximal Hydrogen concentration
  - Furnace/Combustion control
  - Combustion efficiency

- **Risks & mitigation measures**
  - Quality deviation → lower sustainability performance (% hydrogen)
  - Lower combustions efficiency → lower overall sustainability performance
  - Unexpected impact on process → lower quantity or lower overall sustainability performance

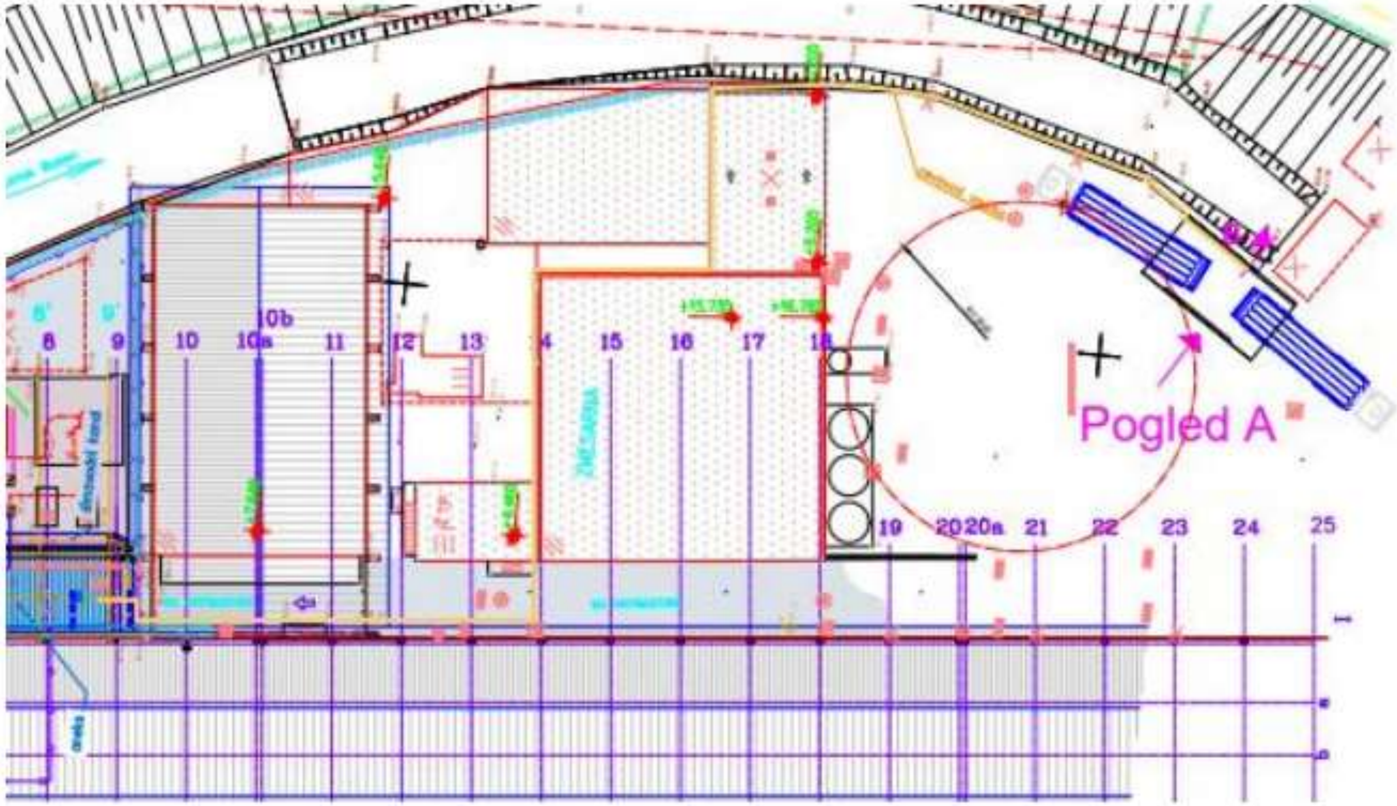
Phase 2 – 2023/24

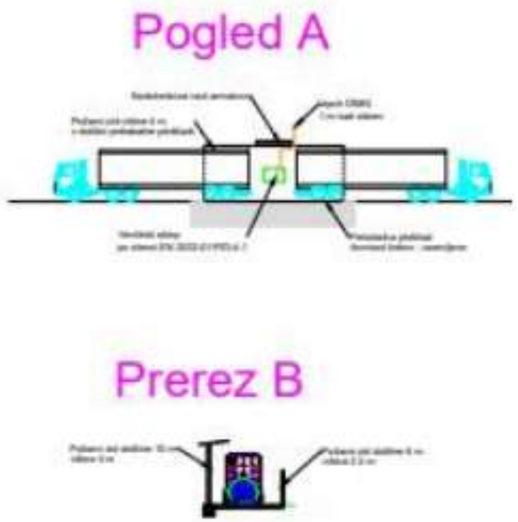
Shematic design



Industrial qualification

→ **H2 trailers supply station**

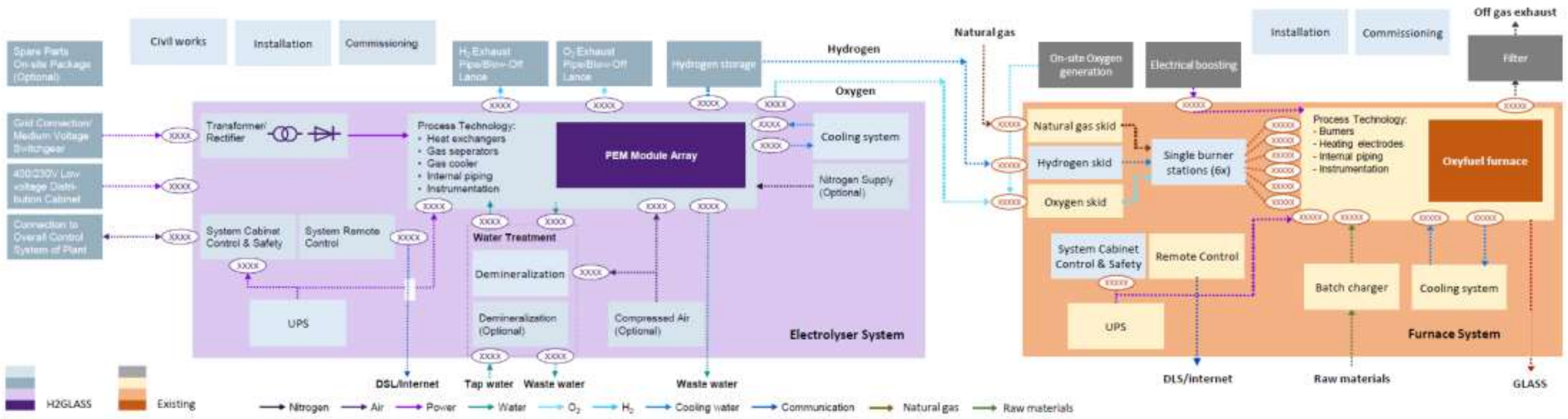




Phase 3 – 2024/25

Large-scale system design

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

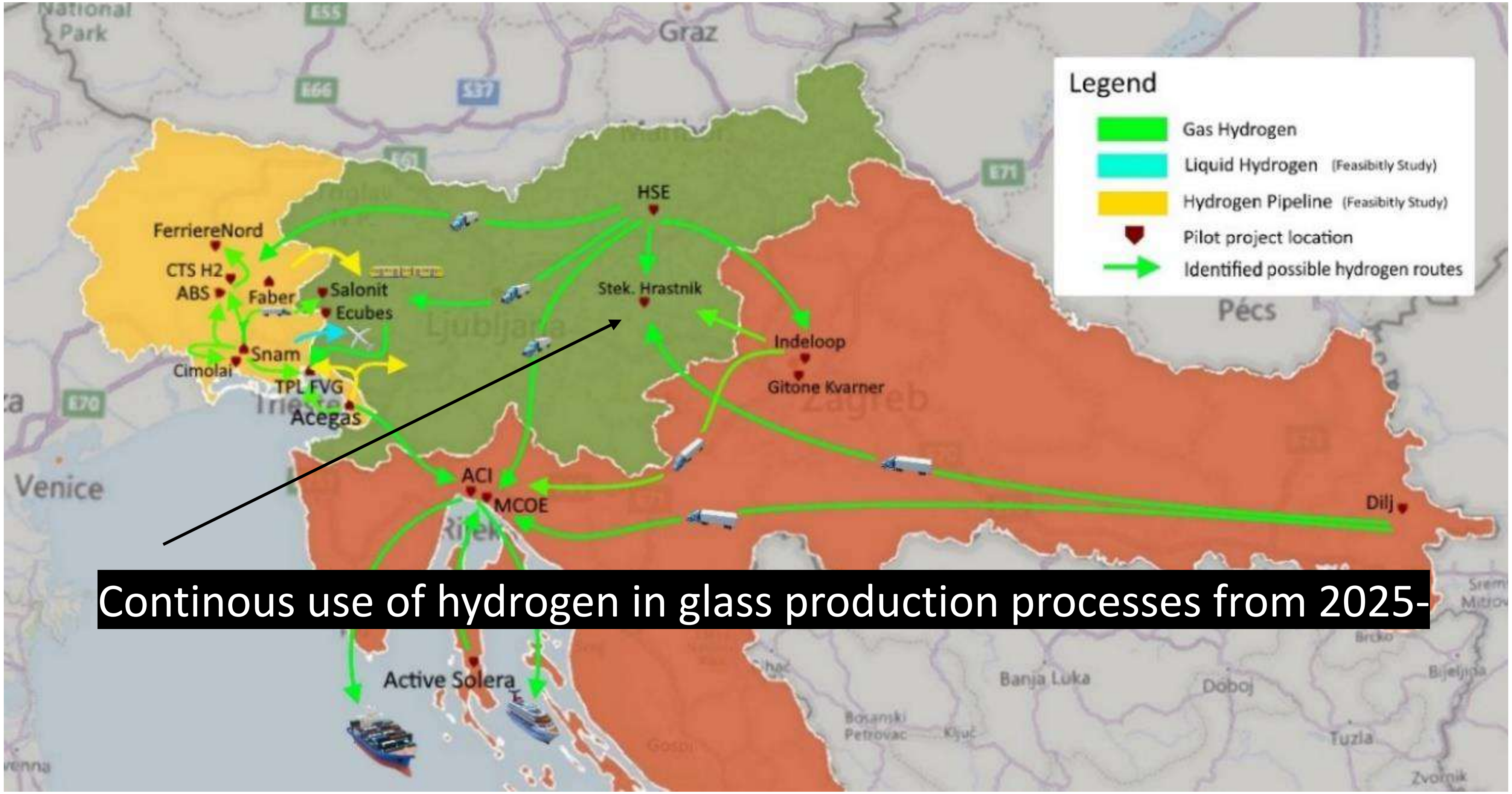


PEM Electrolyser system coupled with Oxyfuel glass furnace indicating H2GLASS project scope

Phase 4 – 2025/6

NAHV Project

North Adriatic hydrogen valley is one of the first EU transnational hydrogen valleys



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Q & A