

Pilot-Scale Demonstration of Green Hydrogen Production via 25 kW SOEC System

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INTRODUCTION

Solid Oxide Electrolyzer Cells (SOECs) are among the most promising technologies for efficient green hydrogen production due to their **high thermodynamic efficiency** and the possibility of exploiting waste heat or renewable thermal energy sources.

PLANT OVERVIEW

The PROMETEO prototype is a **25 kW SOEC system** for flexible green hydrogen production, integrating **PV, grid electricity, and CSP with Thermal Energy Storage (TES)** to decouple hydrogen production from renewable intermittency.

CSP heat (thermal oil HTF, 310 °C) is stored in TES and used to generate superheated steam for high-temperature electrolysis, ensuring stable SOEC operation.

OPERATIONAL MODES

- **Full load:** PV-grid + CSP-TES, continuous Hydrogen production
- **Partial load:** adaptive operation to renewable variability
- **Hot standby:** SOEC kept > 650 °C for fast restart
- **Night mode:** thermal maintenance via forming gas.

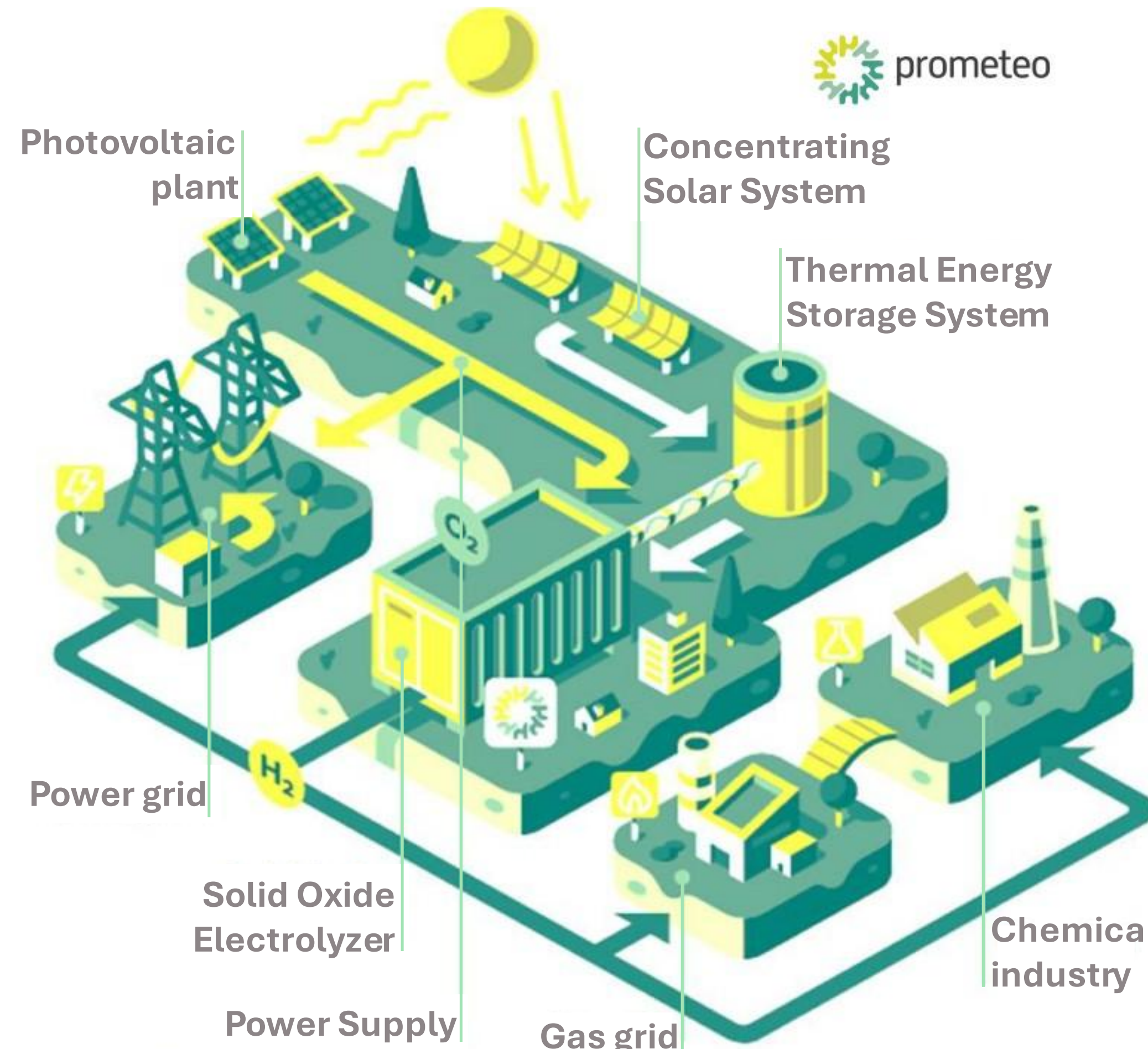


Figure 1 PROMETEO Concept plant

OBJECTIVES & EXPECTED IMPACTS

PROMETEO demonstrates a **high-efficiency SOEC system** for green hydrogen production, integrated with PV, CSP and TES to enable **flexible** and **continuous operation** under renewable conditions.

KEY OBJECTIVES

- SOEC validation (>1000 h)
- **15 kg H₂/day production**
- ≥85% electrical efficiency
- **<39 kWh/kgH₂ consumption**
- PV + CSP + TES integration
- ≥85% thermal storage efficiency

EXPECTED IMPACTS

- ≥10% solar-to-hydrogen efficiency
- **~2 €/kgH₂ cost target**
- Multi-MW scalability
- Industrial decarbonization
- Power-to-Hydrogen sector coupling

BALANCE OF PLANT (BoP)

The BoP represents the process and **functional core** of the PROMETEO SOEC system, enabling integration between **thermal management, fluid handling, and electrochemical operation**. The system is based on a modular skid layout and ensures coupling between renewable-driven thermal energy and high-temperature electrolysis.

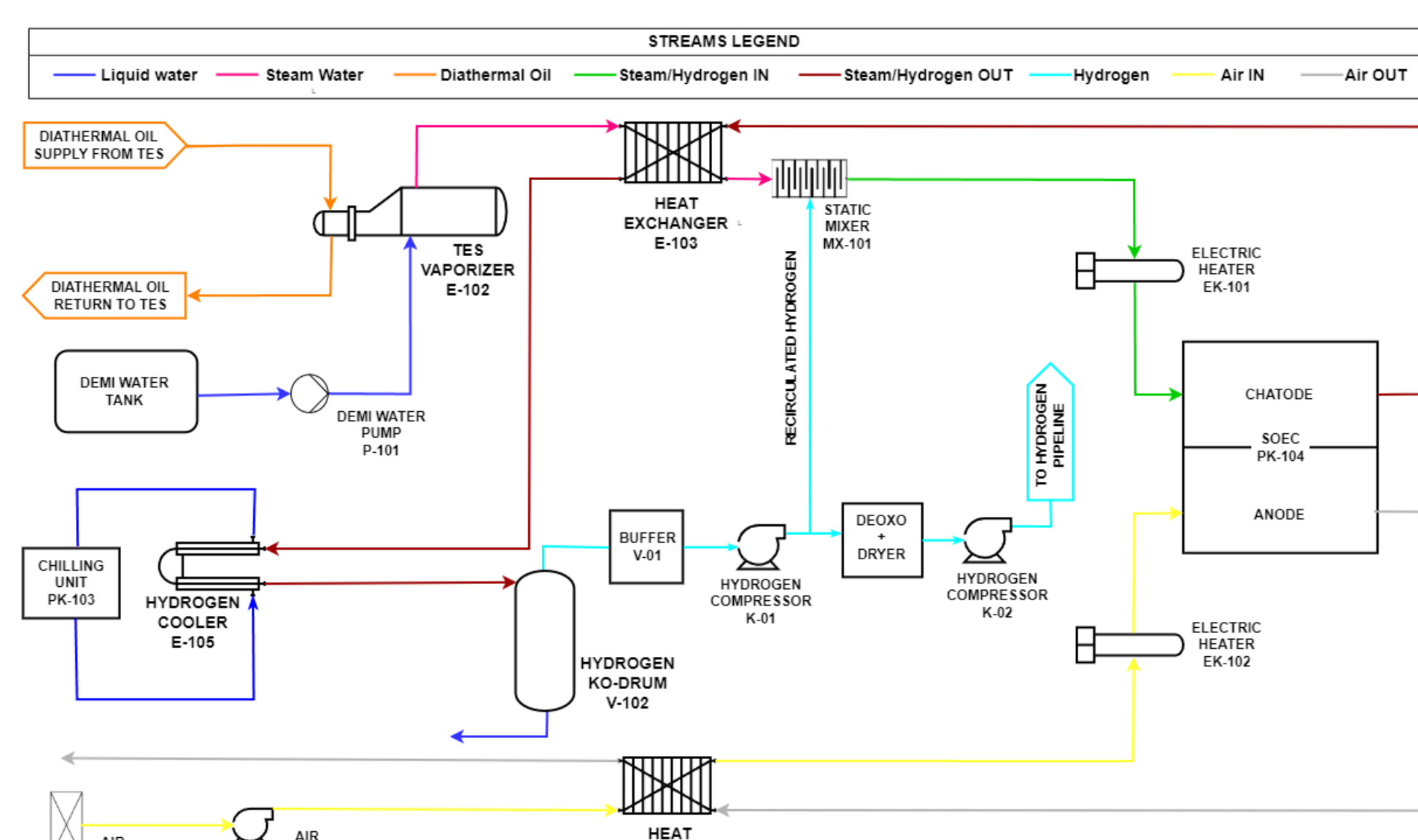


Figure 2 Process Flow Diagram

KEY COMPONENTS

➤ TES VAPORIZER

The E-102 is a **custom-designed vaporizer** fed with diathermic oil from the CSP system. It includes a **5.5 kW electric heater** for start-up or low-load operation. The unit vaporizes water into saturated steam using heat from the diathermic oil.

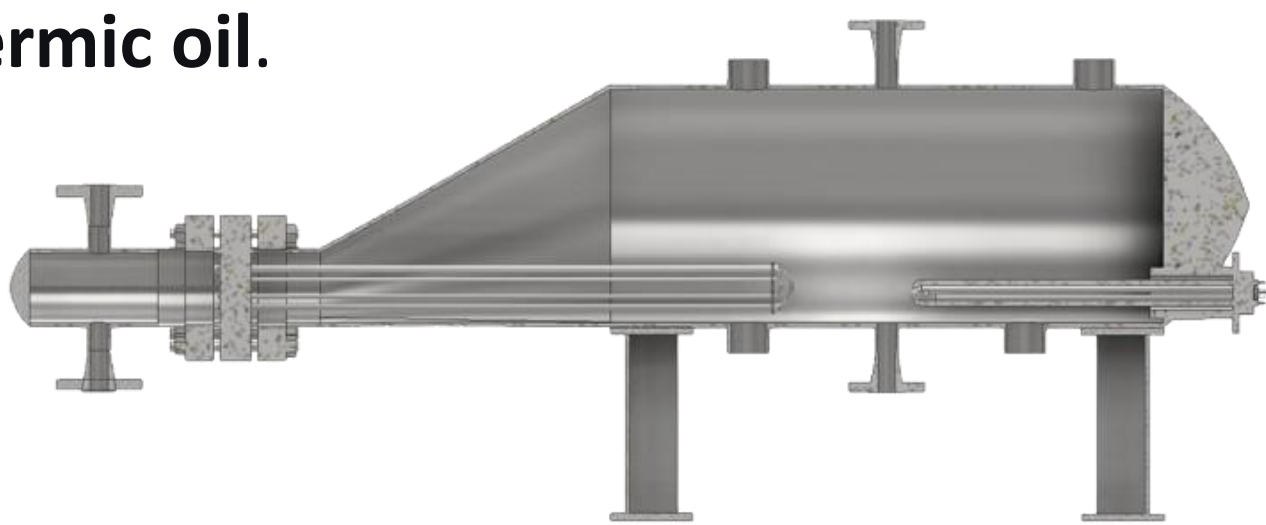


Figure 3 TES Vaporizer E-102

PARAMETER	WATER SIDE	DIATHERMIC OIL SIDE
Inlet temperature	20 °C	280 °C
Outlet temperature	133 °C	250 °C
Operating pressure	2 barg	3 barg

➤ HEAT EXCHANGERS

Key elements for **system efficiency** are the **E-103** and **E-104** heat exchangers, which were specifically designed and built to maximize heat recovery. **Both units reduce the electrical power required by the downstream heaters**. E-105, in turn, cools the produced hydrogen before it enters the knock-out drum.

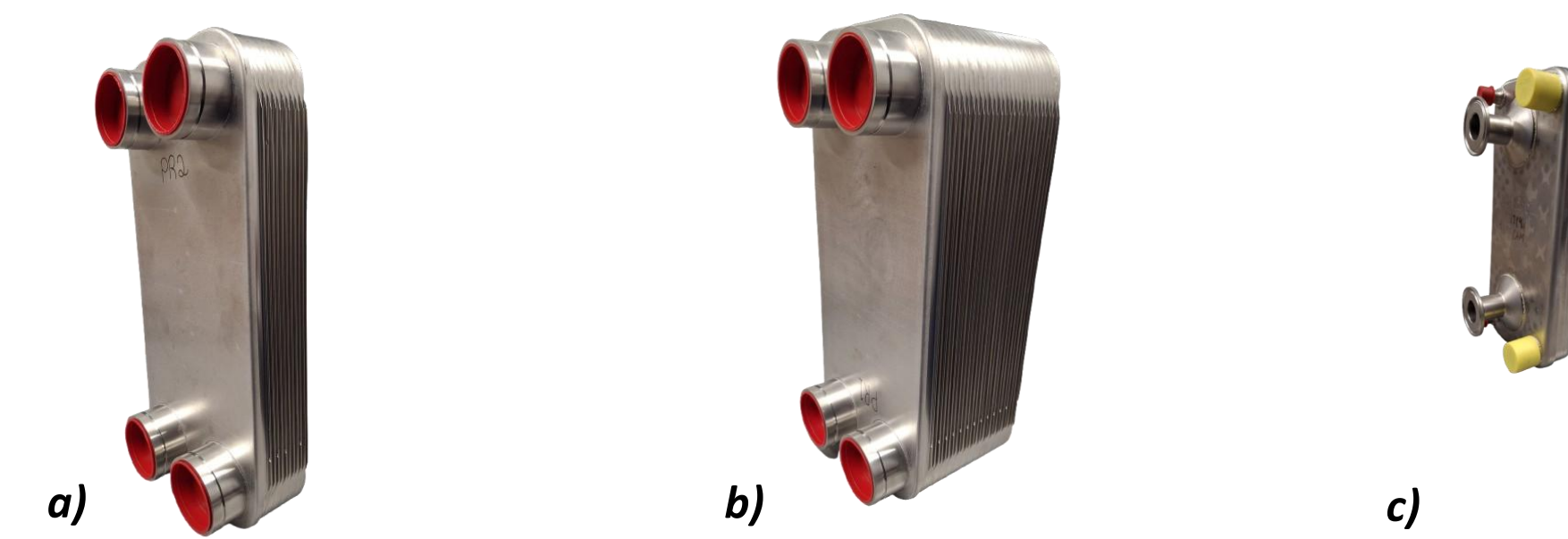


Figure 4 a) E-103 Cathode Feed Effluent Heat Exchanger
b) E-104 Anode Feed Effluent Heat Exchanger c) E-105 Hydrogen cooler

TAG	COLD SIDE			HOT SIDE			Heat Duty [kW]
	Stream	T In [°C]	T Out [°C]	Stream	T In [°C]	T Out [°C]	
E-103	Steam/H ₂ in	125	656	Steam/H ₂ out	715	198	2.3
E-104	Air in	125	577	Air out	715	540	4.5
E-105	Cooled water	5	12	Steam/H ₂ out	198	11	2.8

➤ 25kW SOEC

This single-stack SOEC operates at 680–780°C, producing up to **17.7 kg/day** of hydrogen (137 slm). It draws 24 kW DC per stack at 233 A and 104–108 V, with steam utilization of 0.8–0.9. Key precautions: avoid cathode reoxidation above 300°C and keep fuel pressure above air pressure.

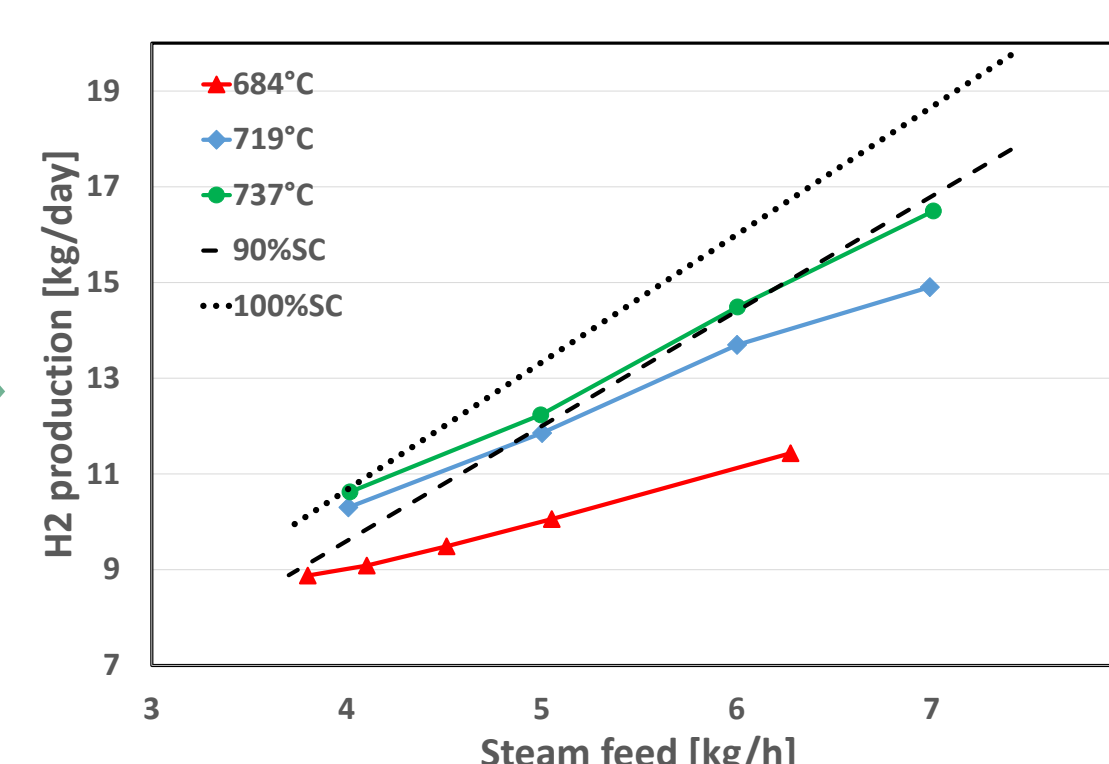


Figure 5 25 kW SOEC and hydrogen production trend versus steam feed rate.

➤ ELECTRIC HEATERS

Two electric heaters are used to achieve the SOEC operating conditions. A **7.7 kW** electric heater has been designed and commissioned on the anodic side, featuring **Incoloy 800** heating elements. Similarly, the cathodic-side electric heater has an installed power of **2.5 kW**. Both heaters are capable of reaching temperatures up to **750 °C**.

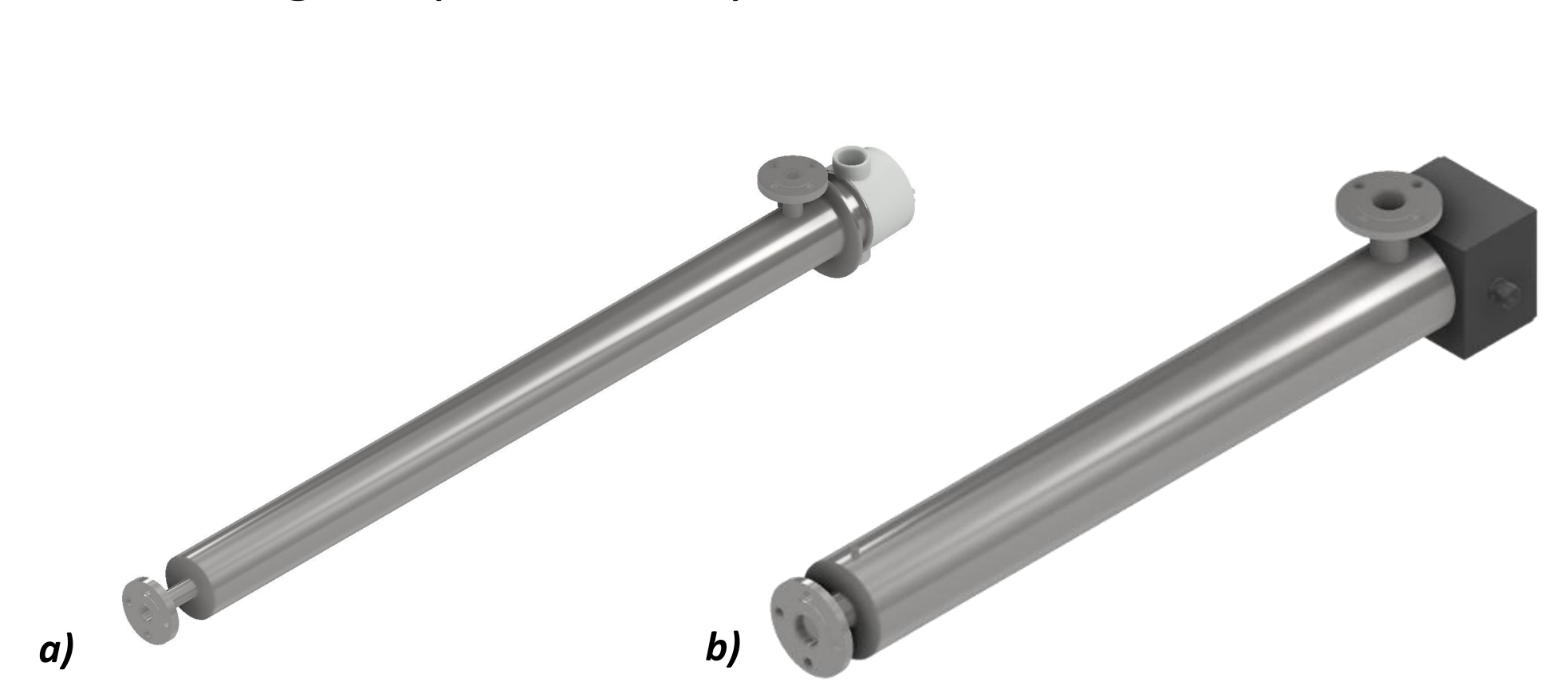


Figure 6 a) EK-101 Cathode Feed Effluent Electric Heater b) EK-102 Anode Feed Effluent Electric Heater

LAYOUT 3D

The BoP of the PROMETEO plant is installed in a **custom 20-foot ISO skid**, partially open to minimize the formation of potentially explosive atmospheres (ATEX), while improving ventilation and intrinsic safety. Inside the skid, a segregated area is dedicated to control and instrumentation systems, which are operated remotely, ensuring safe operation from a distance in compliance with ATEX requirements.

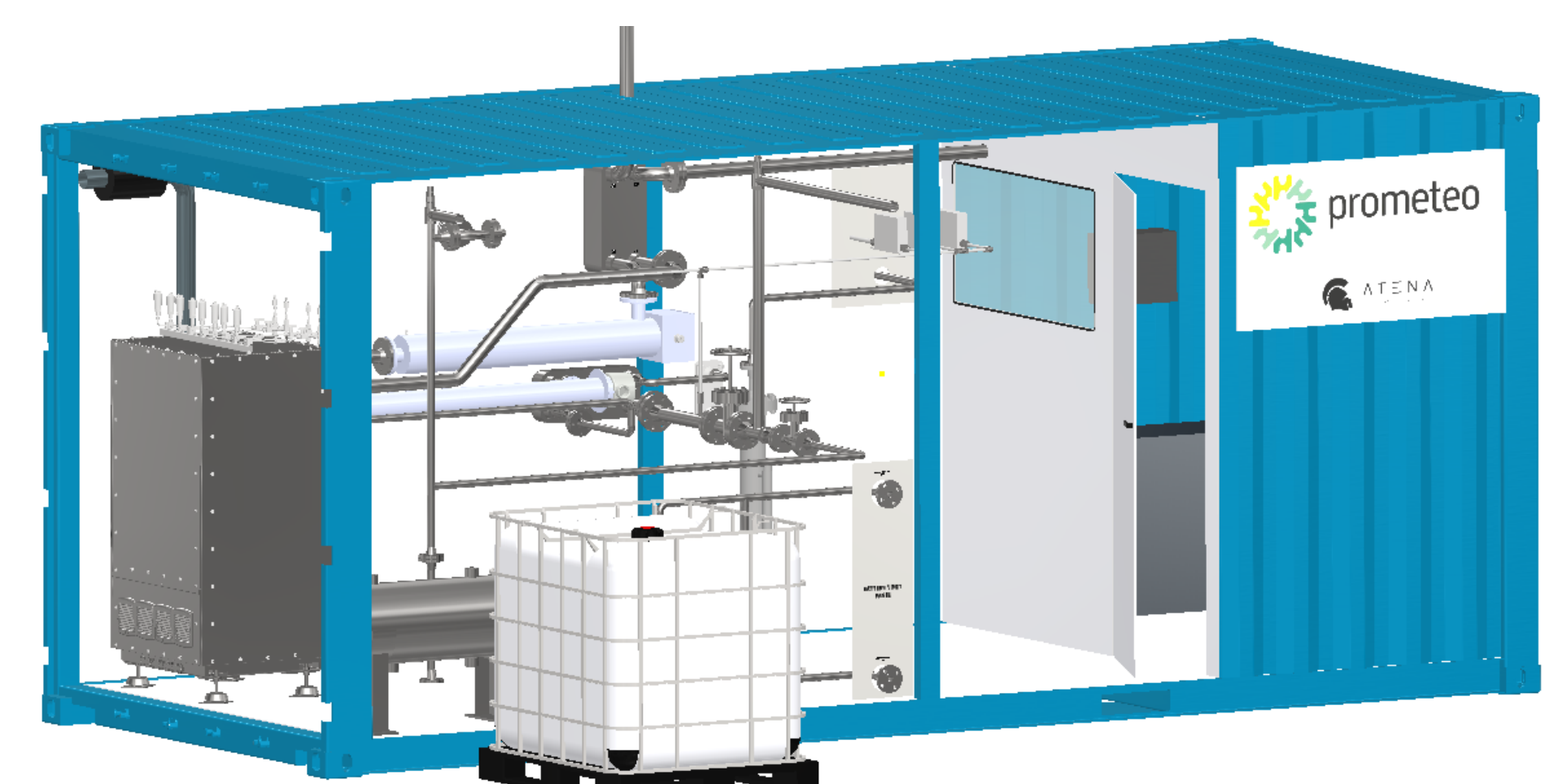


Figure 7 Layout 3D BoP PROMETEO

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