FONDAZIONE BRUNO KESSLER
Center for Sustainable Energy

DIRECT AMMONIA FUEL CELL

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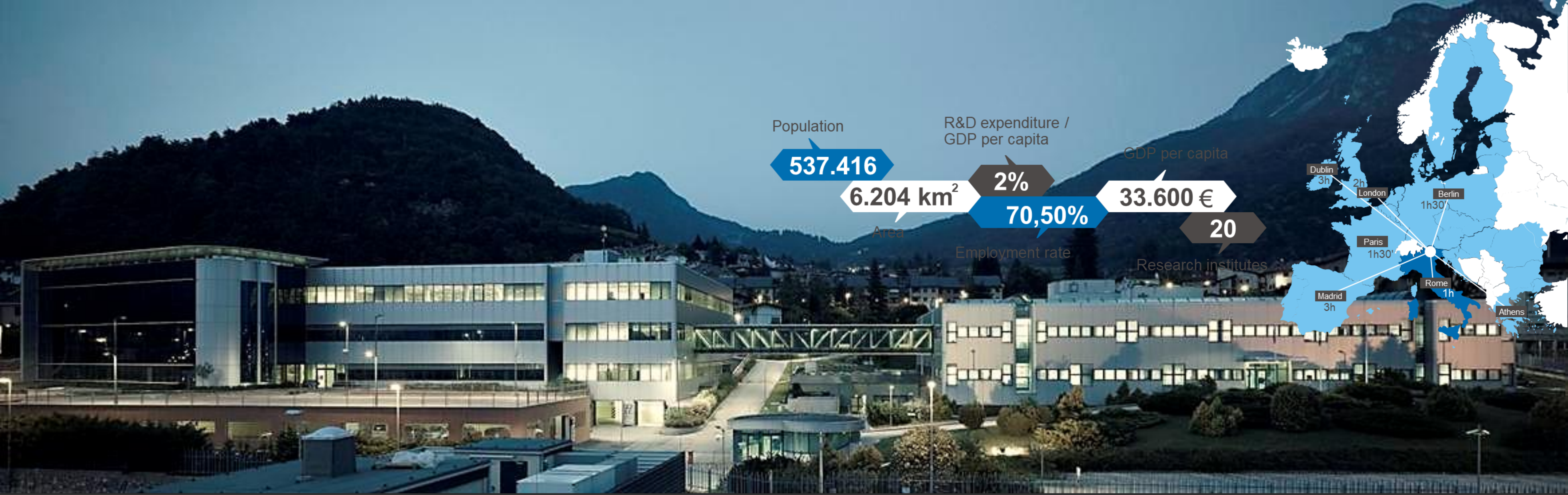


11 RESEARCH CENTERS (SCIENTIFIC AND HUMANISTIC STUDIES)

ABOUT 700 EMPLOYEES

7 LABORATORIES / 3.600 m^2 – SILICON FACILITY, BIOTECH, SURFACE ENGINEERING, ENERGY SYSTEMS&TECHNOLOGIES

30 SPIN OFF / START UP COMPANIES

100 SCIENTIFIC EVENTS / YEAR, 100 PhD students from 25 countries

CENTER for SUSTAINABLE ENERGY
OUR MAIN CHALLENGES

FBK-SE's mission is to support the **deep decarbonisation** of our society based on **sustainable and flexible technologies** in line with **Green Deal**'s objectives, with a plan on 2 main Research and Innovation Units:

R&IU BET "Battery and Electrification Technologies"

Promote the optimal use of renewable energy sources in electric grids through novel battery energy storage solutions and advanced management systems, also supporting the development of more sustainable batteries for mobility

R&IU HyRES "Hydrogen and Resilient Energy systems"

Develop novel solutions to accelerate the use of hydrogen as a sustainable zero-emission energy vector considering production, storage, distribution and final uses, including mobility (e.g. FCEV, H2 trains) and hard-to-abate sectors (e.g. steelmaking industry)

Strategic positioning in hydrogen and battery sector

- Role in EU platforms: Clean Hydrogen and Batteries European Partnerships
- Connections with national and EU institutions (MISE, MITE, MIMS, EC)
- Involved in strategic initiatives (IPCEI) and collaborative research projects

Luigi Crema (SE Director):

- President Hydrogen Europe Research
- Vicepresident H2IT

HyRES - HYdrogen Technologies and Resilient Energy Systems– SE002
Our objectives

Three Main objectives addressing the boost in the deploy of H2 :

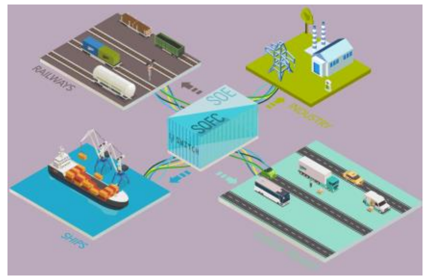
1. **Develop novel system and technologies** for H2 production/use and handling with focus on performance and cost (i.e TCO)
2. Support the deployment of H2 in **Hard-To-Abate**, **heavy-duty mobility** and **power generation application.**
3. **Support** the **deep decarbonization** based on the **introduction of green gases** primally **hydrogen** and other (i.e. ammonia), including **support on the definition of policies**.

H_2 PRODUCTION

- All low TRL electrolysis (PEM, AEM, SOE-PCC)
- Innovative and advanced materials
- Component development and system design
- Validation at the relevant industrial scale

H2 HANDLING

- Key techniques for distribution, use of ammonia
- High pressure trailer (550 bar)
- Hydrogen storage: small-large scales, solid-state materials to underground
- Compression/Purifications/BoPs



END USES

- Heavy duty (i.e.. trains, buses, trucks), HRS
- Territorial ecosystems, hydrogen valleys
- Hard to abate sector such as refineries, steel making, ammonia, paper, ceramic, glass,...

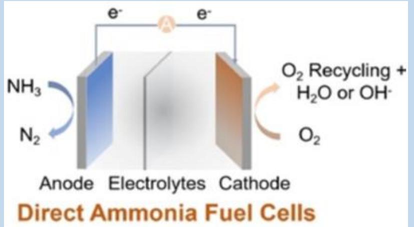
AMMONIA as CLEAN ENERGY CARRIER for POWER PRODUCTION

Power production

- Direct Combustion

- Indirect Fuel Cells

- Direct Fuel Cells
  - Low temperature (25°C – 100°C)
  - High temperature (500°C - 1000°C) ← SOFC



185 *Mt/year globally*

85% *in fertilisers*

45% *of H2 produced*

↑ Cogeneration applications

↑ High ammonia decomposition activity

↑ High efficiency and power density

→Ammonia have an extra gear especially in long-term energy storage and long-distance energy transport and could constitute a safer and less expensive alternative

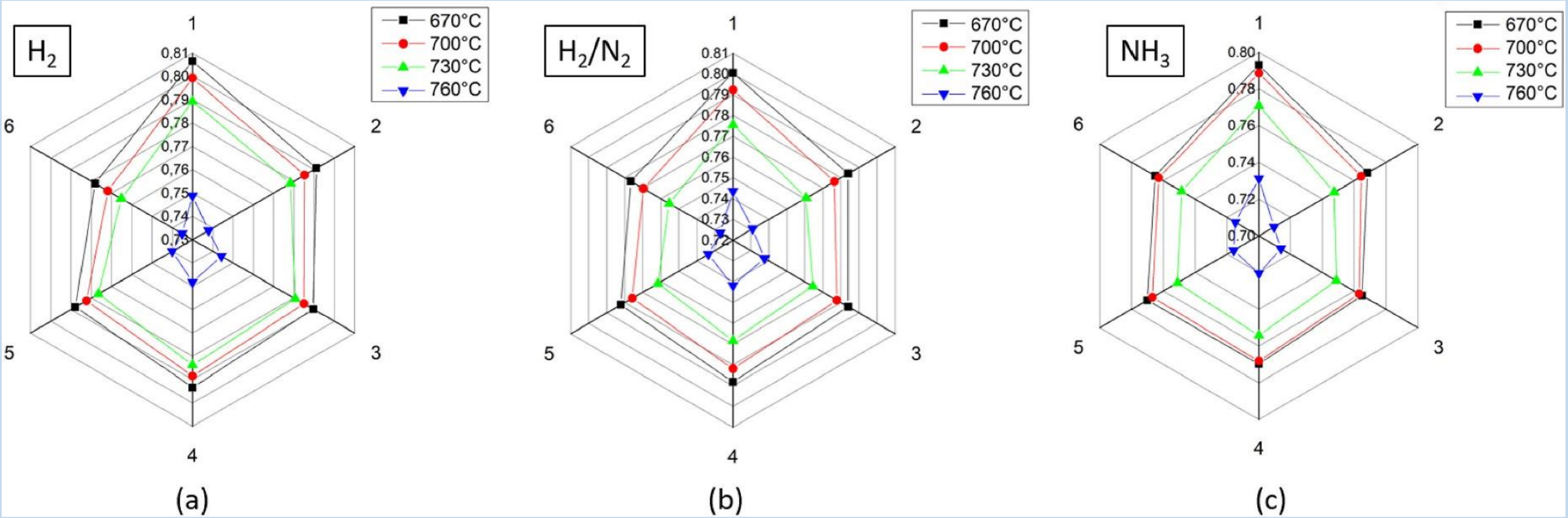
→Energy transition is likely to involve a combined solution of hydrogen and ammonia, but also of other energy storage and transporting technologies.

↓ Durability aspects

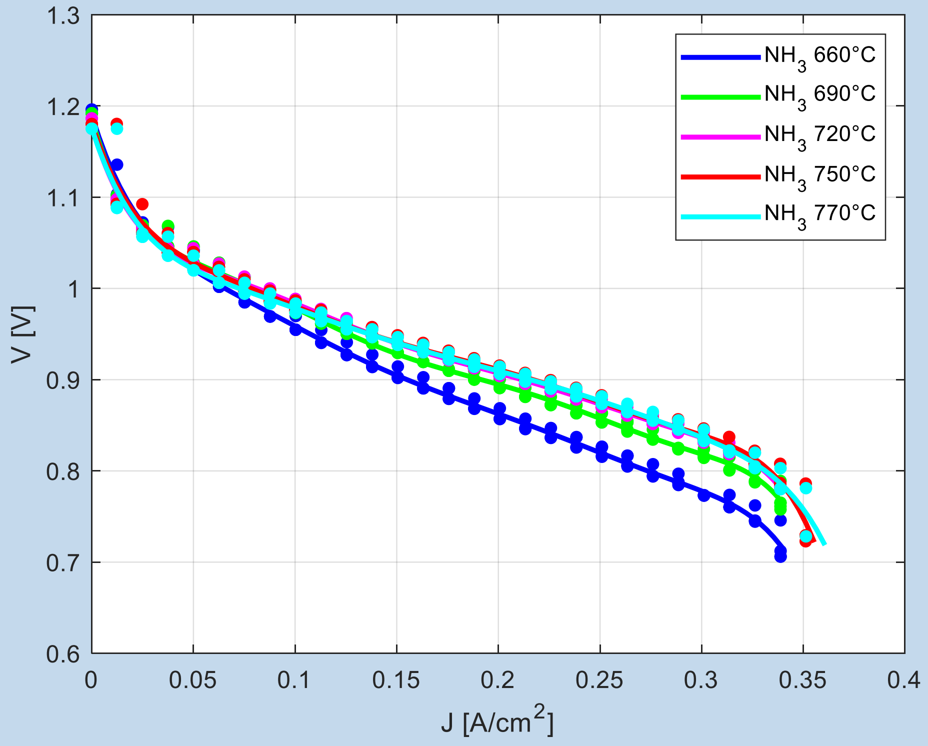
↓ Only stationary applications

↓ **Balance of Plant complexity**

Direct Ammonia SOFC



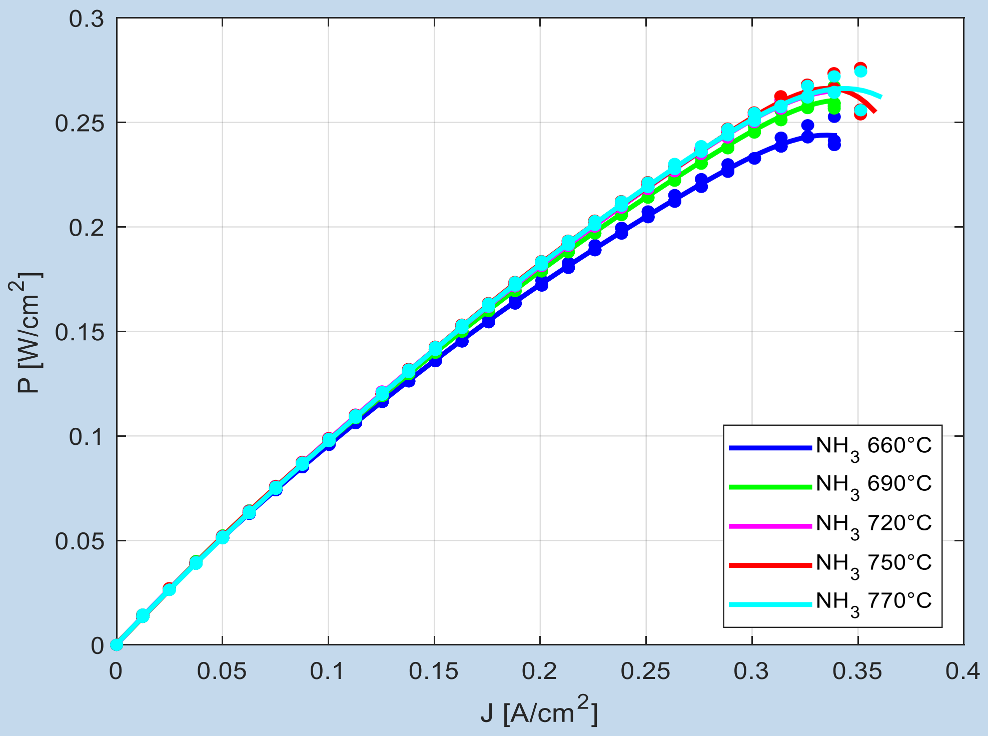
Voltage distribution in 6-short stack with : Pure H2, simulated cracked mixture (N2-H2) and pure ammonia.



Direct Ammonia SOFC in anode support 6-cells supplied by Solydera spa.

<-(**Right**)
VI profile with ammonia flow at different temperatures (690-770°C)

(**Left**)->
Power profile with ammonia flow at different temperatures (690-770°C)

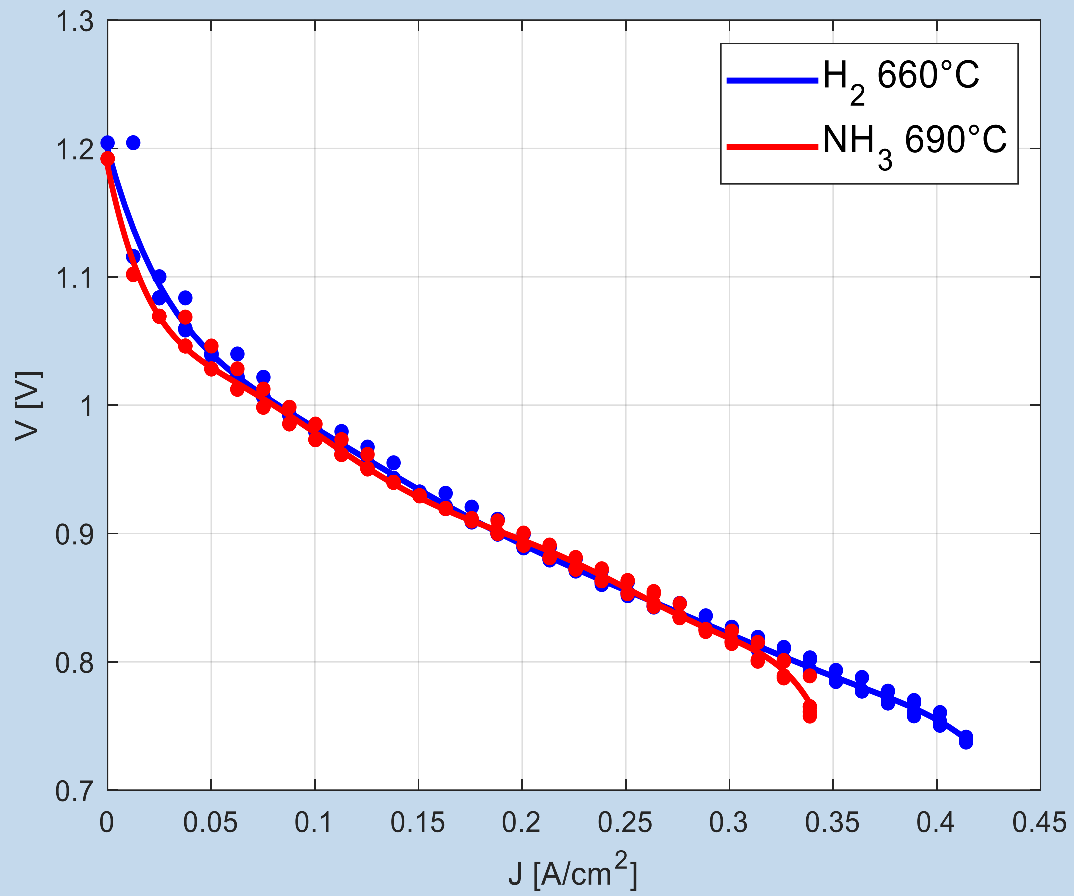


Direct Ammonia SOFC

Source:

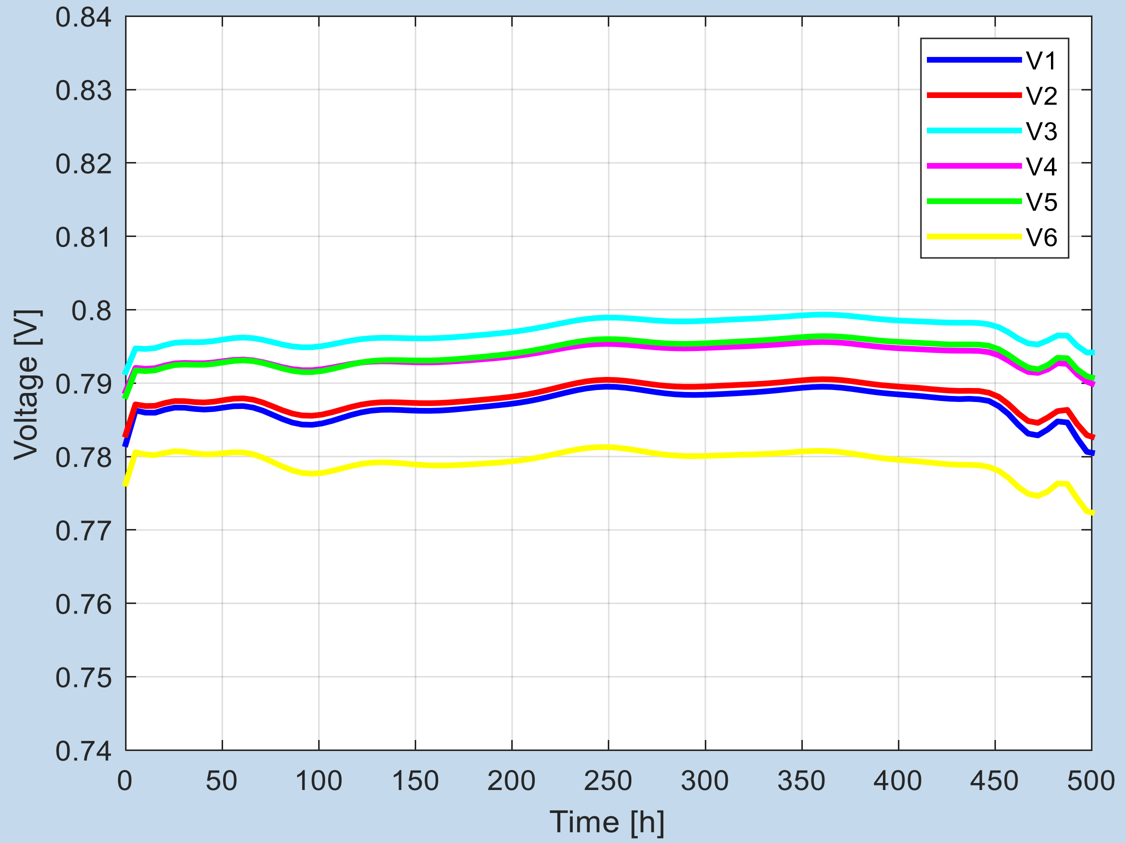
- Michele Zendrini, Matteo Testi, Martina Trini, Penchini Daniele, Jan Van Herle, Luigi Crema, Assessment of ammonia as energy carrier in the use with reversible solid oxide cells, International Journal of Hydrogen Energy, Volume 46, Issue 58, 2021,
- Master thesis, Chiara Cruzel, 2022
- https://www.fbk.eu/en/press-releases/direct-use-of-ammonia-in-fuel-cells/

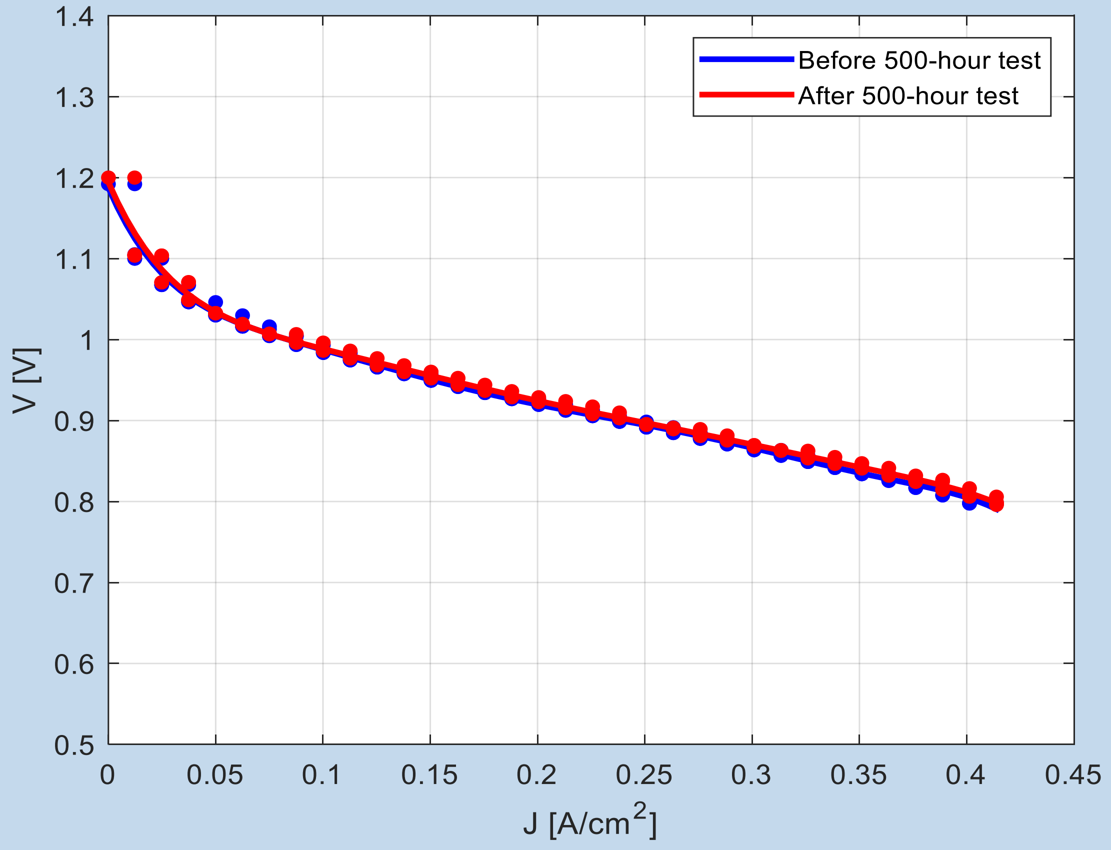
Hydrogen and ammonia comparison



Ammonia polarization curve at 690°C presents the same performance obtained with hydrogen at 30°C less (except for the concentration and activation losses), as effect of the endothermic reaction of cracking (and different reaction product)

500-hour continuative working test exploiting ammonia





Direct Ammonia SOFC

AMMONIA TO POWER

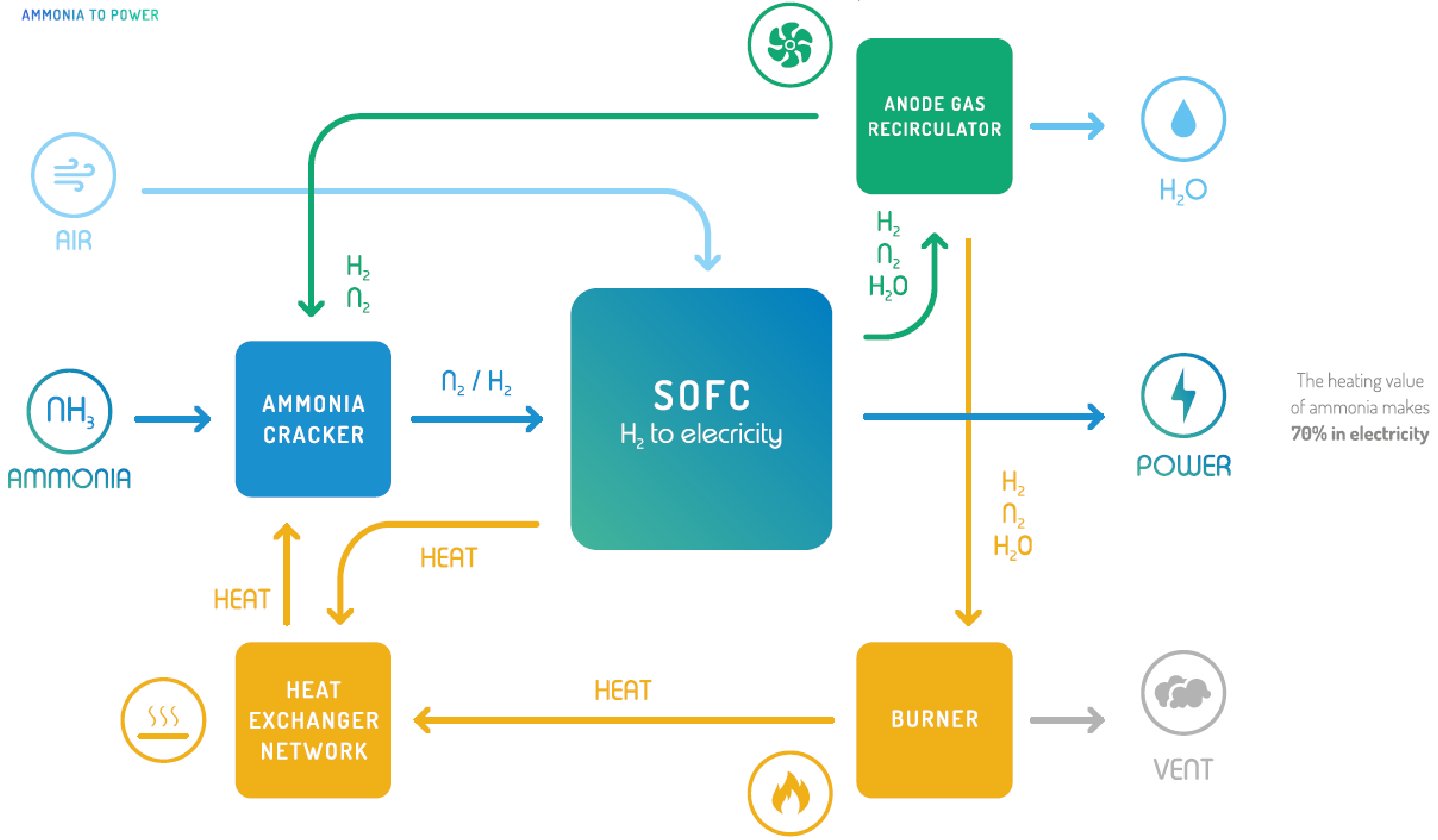
Development of a next generation AMmONia FC system

Clean Hydrogen Partnership

Co-funded by the European Union

The project is supported by the Clean Hydrogen Partnership and its members Hydrogen Europe and Hydrogen Europe Research, under Grant Agreement No 101101521

AMMONIA TO POWER



- System prototype up to **8 kW**
- Electrical **efficiency** higher than **70%**
- **Demonstration** for at least **3000 hrs**
- **Availability** of system higher than **90 %** and **dynamic operation range** between **30-100%**

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AMMONIA TO POWER

Development of a next generation AMmONia FC system

FBK
Fondazione Bruno Kessler
(Italy)

SolydEra
(Italy)

Alfa Laval Technologies AB (Sweden),
Alfa Laval Aalborg AS (Denmark),
Alfa Laval SPA (Italy)

SOL

KIWA Nederland BV (The Netherlands)
e KIWA Cermet (Italy)

VTT Technical Research Centre of Finland
(Finland)

Technical University of Denmark
(Denmark)

Ecole Polytechnique Fédérale De Lausanne
(Switzerland)

Electrolyser & Fuel Cell Forum
(Switzerland)

Fachhochschule Zentralschweiz Hochschule Luzern
(Switzerland)

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AMMONIA TO POWER

Development of a next generation AMmONia FC system

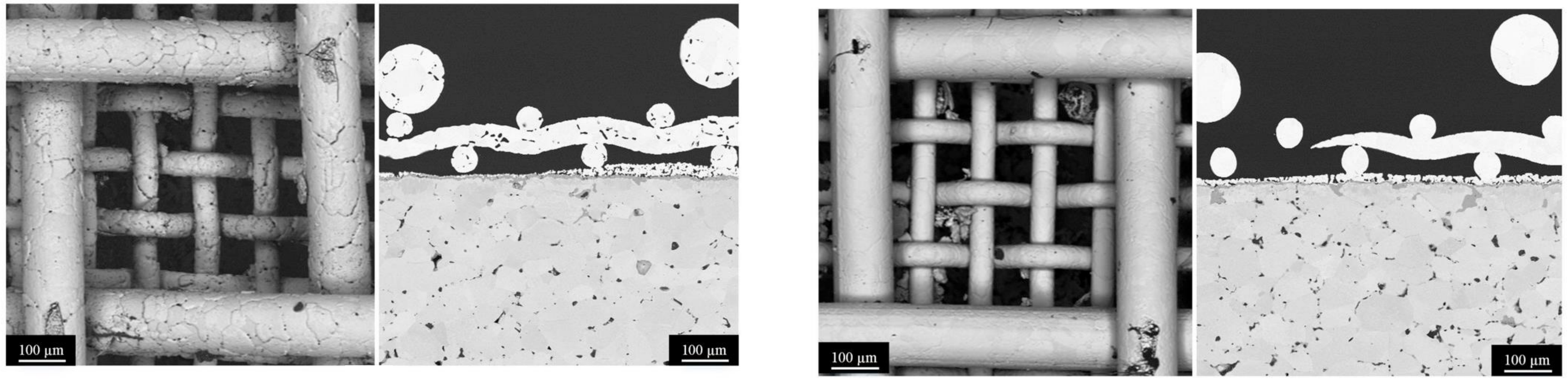
Main Challenge: Ni nitriding

Courtesy of:
DTU, Technical University of Denmark , Department of Energy Conversion and Storage · Solid State Electrochemistry

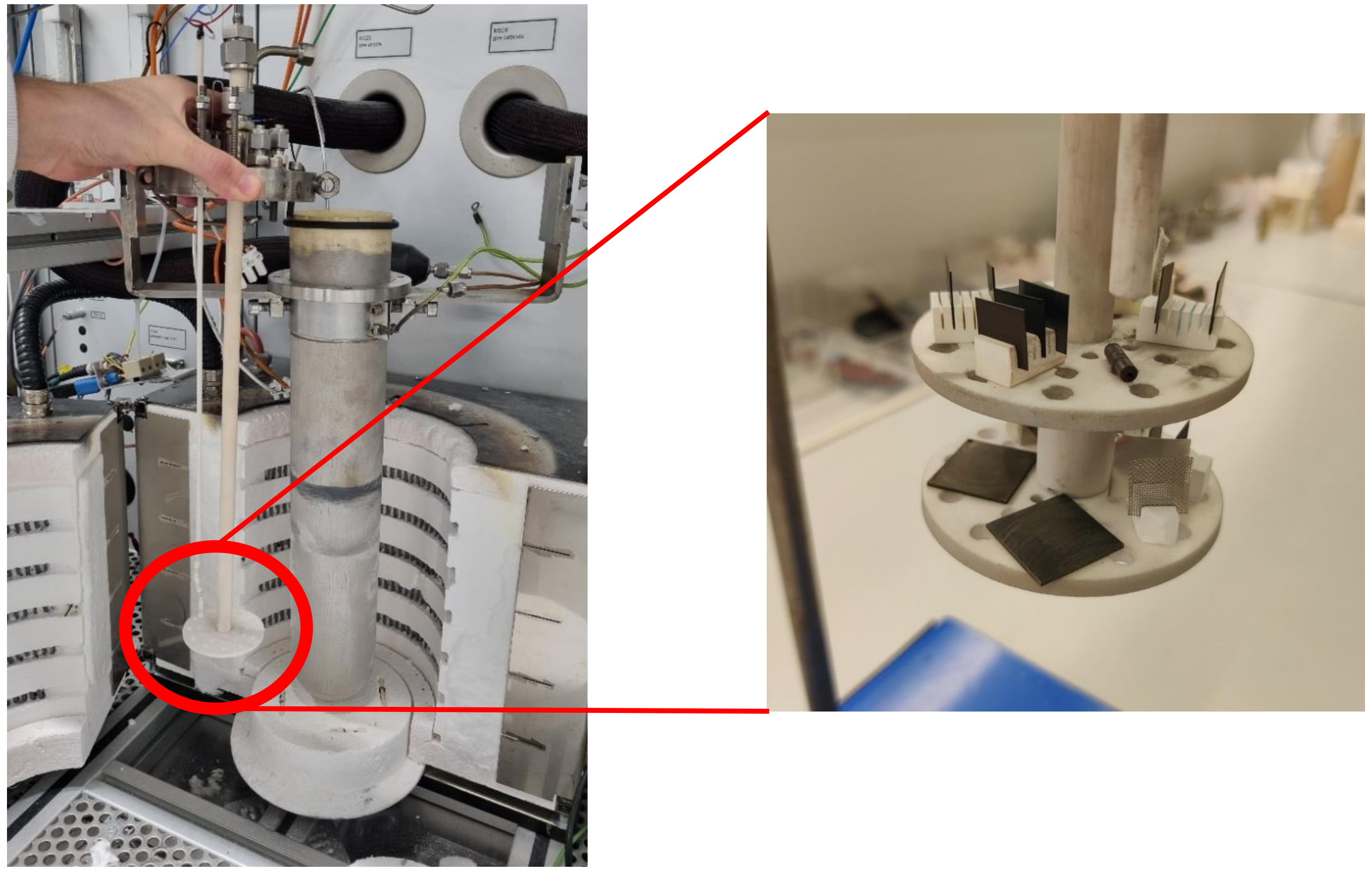
DTU activity
INVESTIGATION ON THE IMPACT OF AMMONIA ON THE NITRIDING OF SOFC COMPONENTS

Fuel inlet

Fuel outlet



Microscopy images Ni contact meshes at the fuel inlet and fuel outlet region [1].



Investigated materials:

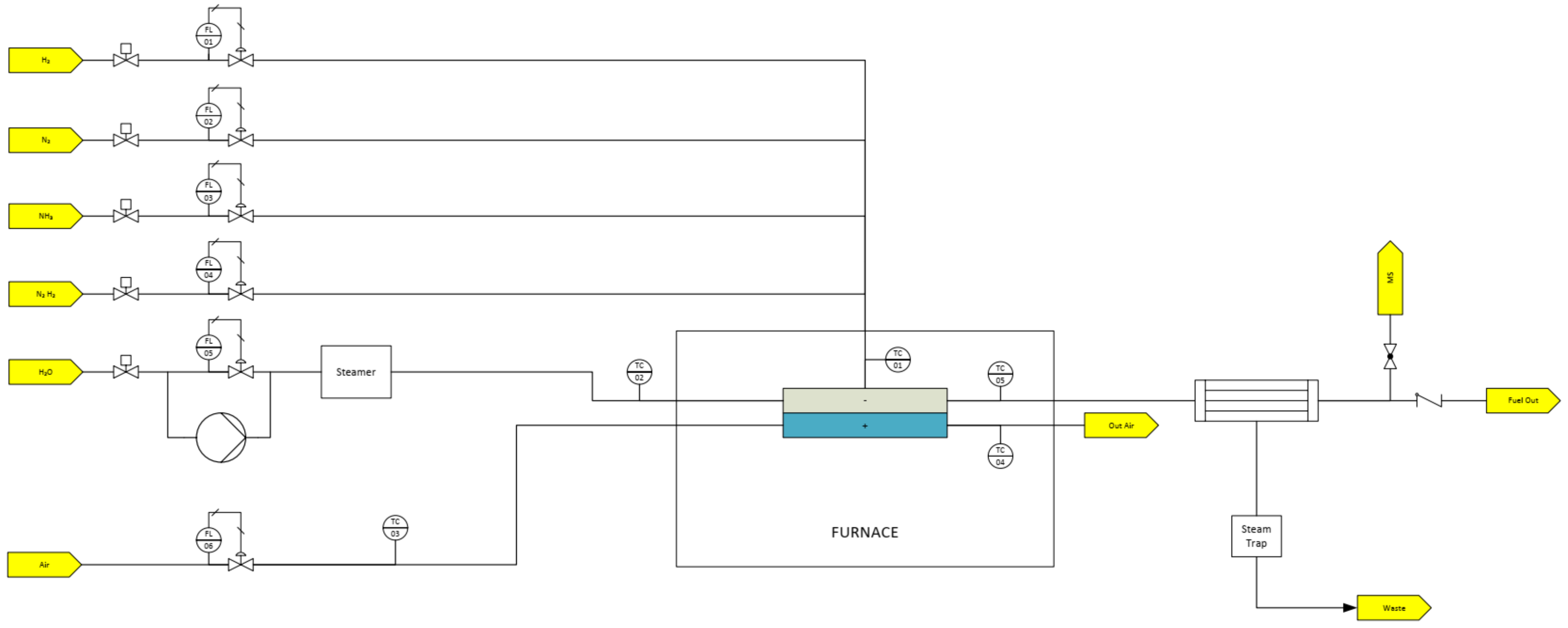
- AISI 441
- AISI 253MA
- Crofer 22APU
- 310S

[1] Bernhard Stoeckl, Michael Preininger, Vanja Subotić, Stefan Megel, Christoph Folgner, Christoph Hochenauer, Towards a wastewater energy recovery system: The utilization of humidified ammonia by a solid oxide fuel cell stack, Journal of Power Sources, Volume 450, 2020, 227608,

NEST SPOKE 4

Task 4.1.2 Development of functional components, cells and systems to exploit advanced functionalities for electrolytic cells, such as readiness in using H2 carriers (ammonia, LOHC etc.) and reversibility of operation to widen the possible uses and enhancing the flexibility of the overall system.

FBK is developing a dedicate test bench for direct ammonia SOC/PCC



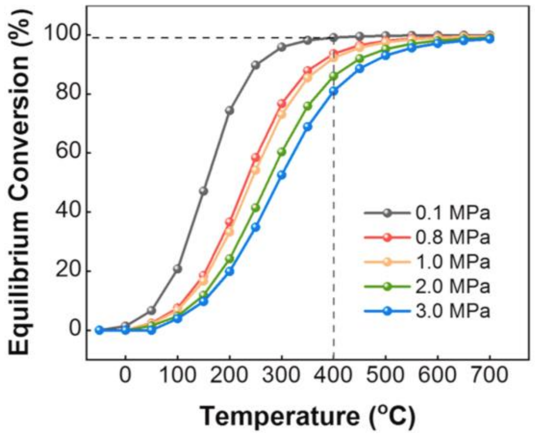
Including syngas inlet for Co-electrolysis (Task 4.2.6) activity.

Objectives:

1. Continue NH3 assessment
2. Long term test evaluation
3. Anode recirculation impact evaluation

Test on 6-cells in collaboration with Solydera spa.

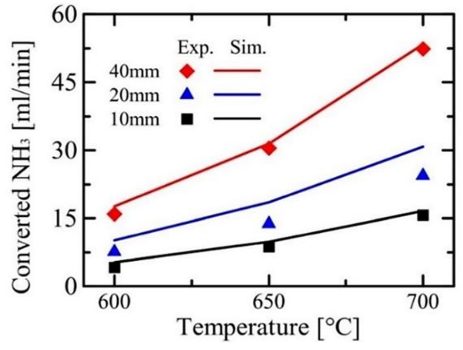
FBK develops dynamic modeling (1D) based on modelica code for the ammonia cracking and DA-SOFC



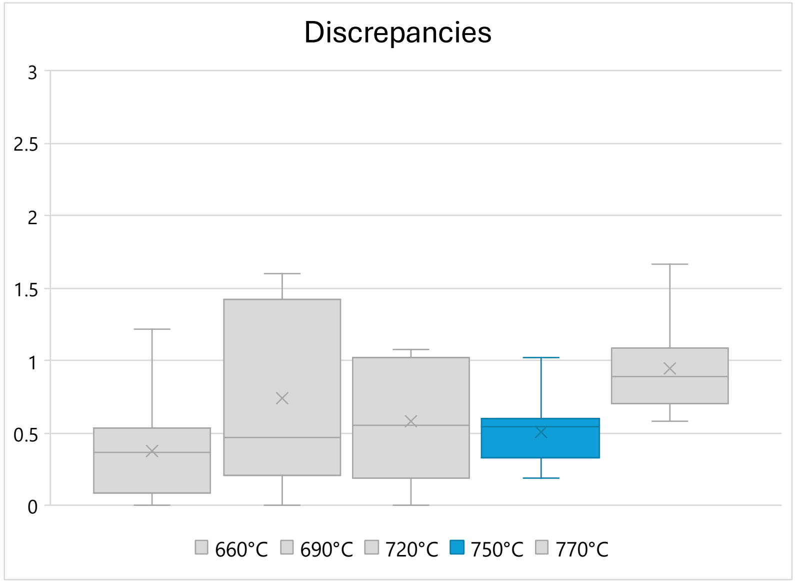
$$R_{dec}^{Ni-pore} = A\, exp\left(-\frac{E_a}{RT}\right) p_{NH_3}^{a} \left(p_{H_2} + c\right)^{b}$$

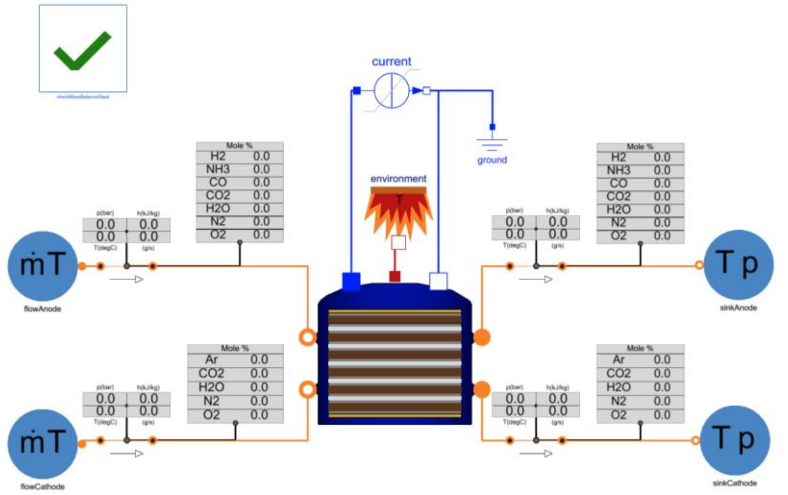
$$\Delta H = -40265.95 - 24.23214\,T + 0.00946\,T^2$$

$$Q = \Delta H \cdot R_{dec}$$



Introducing of cracking reaction on anode side, with relative tuning of parameters to fit experimental data





thank you.