

# **Non-Electric and Hybrid Applications of Nuclear Energy Workshop**

## **GIF Hydrogen Production PMB and overview of WP4 on integration technologies**

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Busan, 26th of april 2024

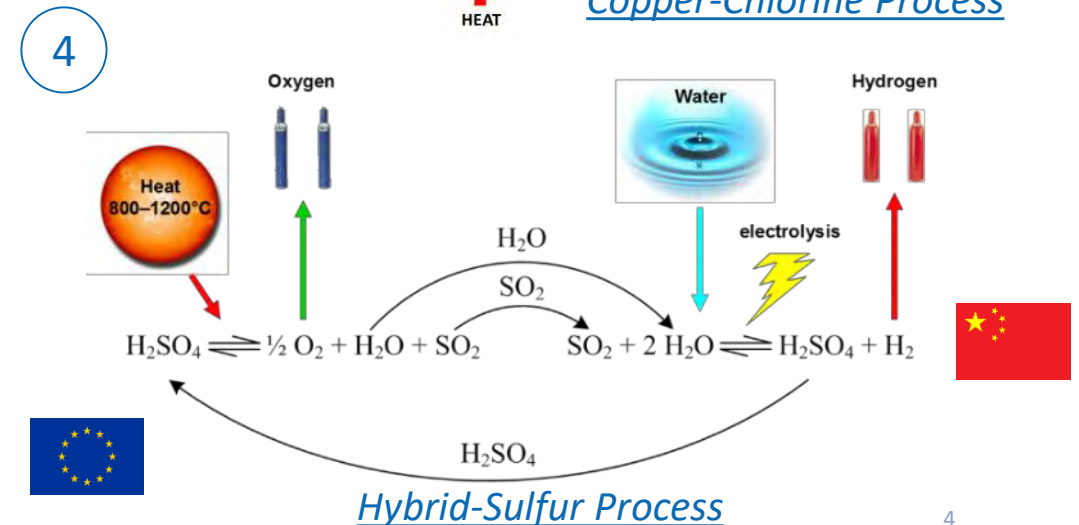
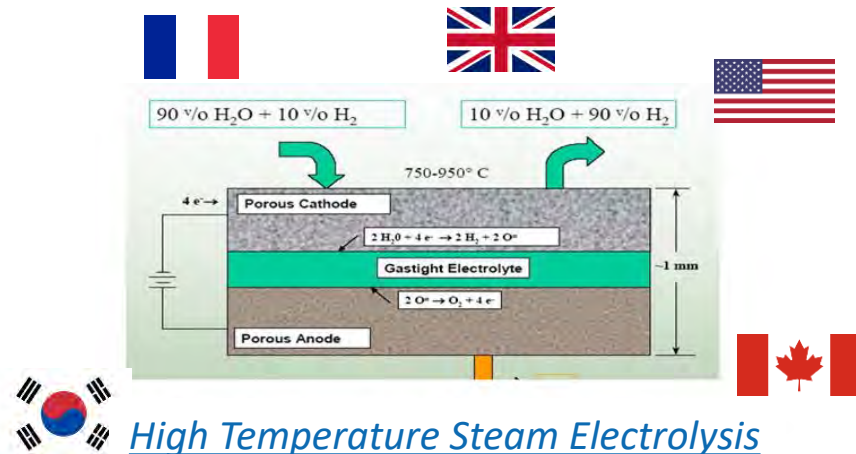
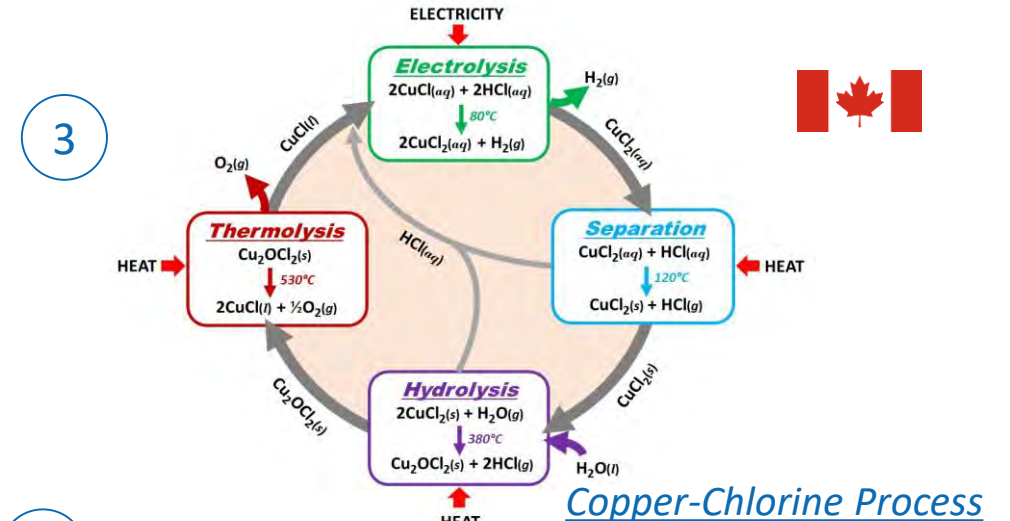
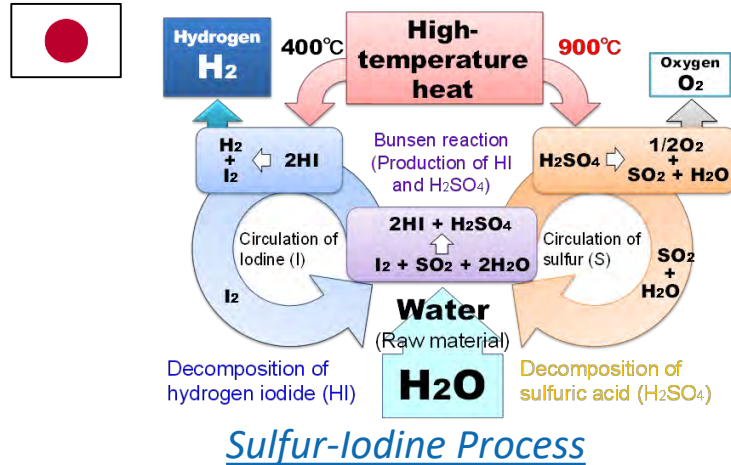
# SUMMARY

1. General Overview of Hydrogen Production Project
2. Update on R&D status
3. Integration System and Coupling Evaluation
4. Conclusion and Perspectives

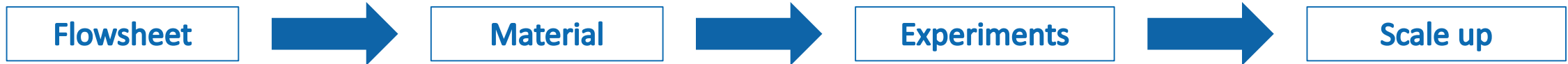
# General Overview of GIF VHTR Hydrogen Production PMB

# VHTR Hydrogen Project Overview

- The **VHTR hydrogen production project** aims at developing and optimizing high temperature thermochemical and electrolysis water splitting processes, as well as defining and validating technologies for coupling any Gen IV Nuclear Reactor system to such process plants safely and securely through an international collaborative program



# Workplan



## • WP 1: Sulfur/Iodine (S/I) Process



- ✓ Flowsheet evaluations for the S/I process
- ✓ Material database: screening of materials in various environments relevant to the S/I thermo-chemical cycle
- ✓ Experimental component testing

## • WP 2: High Temperature Steam Electrolysis



- ✓ Flowsheet evaluation of HTSE plants
- ✓ Dynamic experimental testing of HTSE cells, stacks, and systems
- ✓ Heat Exchanger Development for High Temperature Steam Electrolysis
- ✓ Thermal Integration with Simulated Nuclear or Other Heat Source
- ✓ Pilot scale experiment

## • WP 3: Cu-Cl and Hybrid Sulphur Cycle (HyS)

- ✓ Technical evaluation, flowsheet analysis and experiments
- ✓ Evaluation of economics (hydrogen production processes and coupled to a nuclear reactor)
- ✓ Copper-Chlorine Cycle development
- ✓ Development of HyS process
- ✓ Laboratory-scale test and optimization



## • WP 4: Coupling System Evaluation

- ✓ Safety
- ✓ Simulation
- ✓ System integration

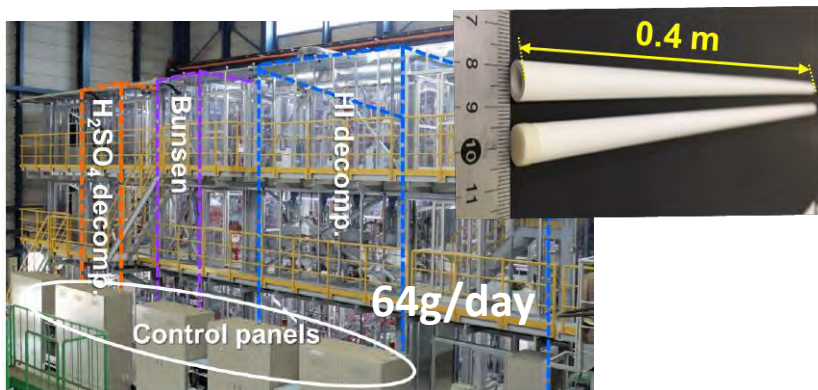


# High Temperature Hydrogen Production System progress (WP1-3)

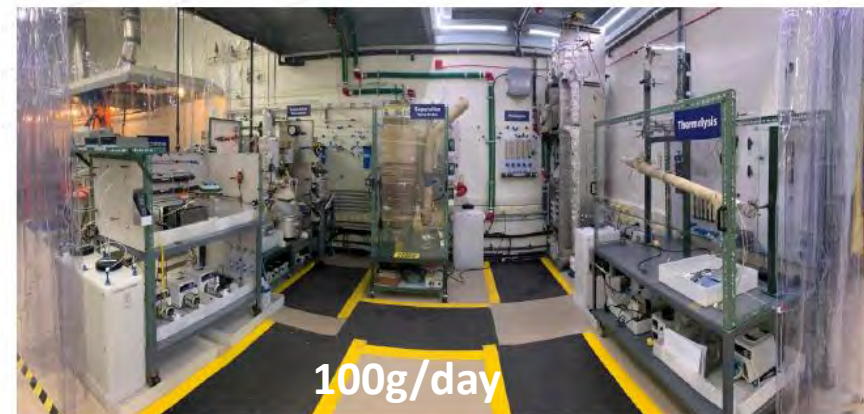


# HTSE vs THERMOCHEMICAL PROCESS : A GAP OF MATURITY LEVEL BETWEEN

WP1



**Sulfur-Iodine Process**



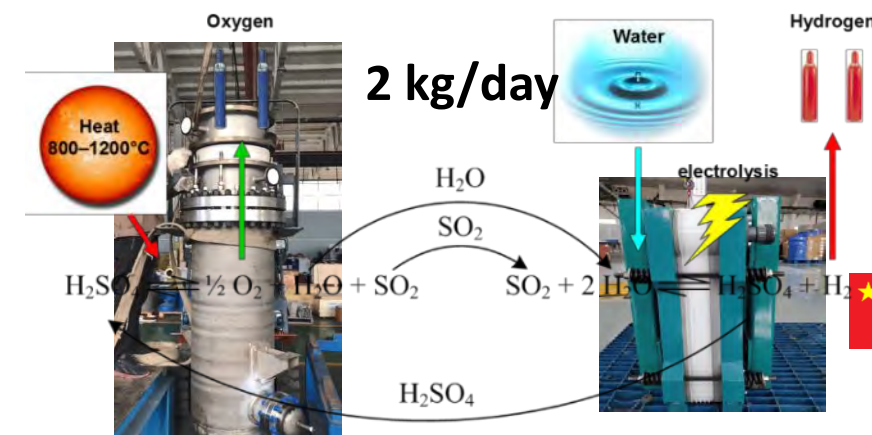
**Hybrid Copper-Chlorine Thermochemical Cycle**

WP3

WP2



**High Temperature Steam Electrolysis**



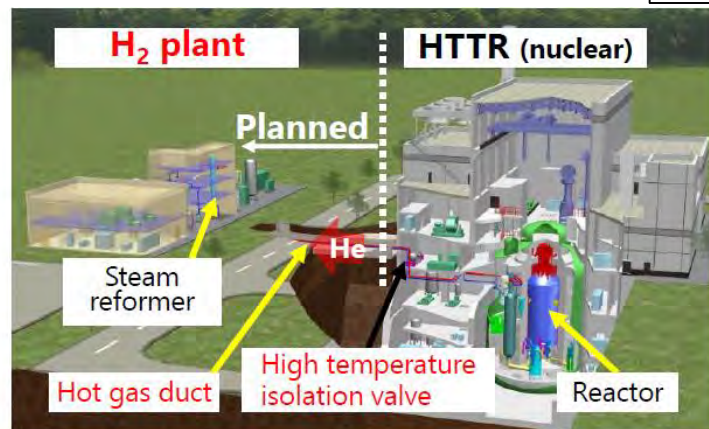
**Hybrid-Sulfur Process**



## Integration System and Coupling Evaluation (WP4)



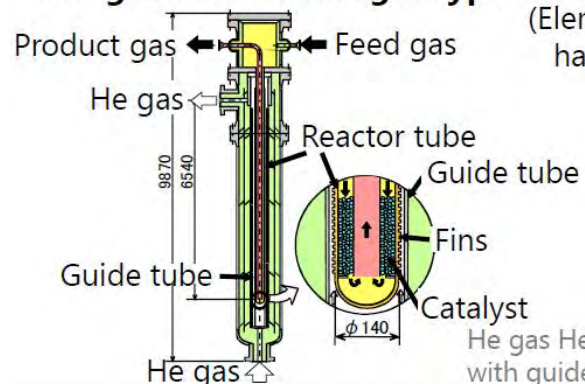
# Test Facility for coupling Hydrogen Production System with HTGR in Progress



Conceptual drawing of HTTR-heat application test

## He gas heat exchanger type steam reformer

(Elemental technologies have been developed\*)



He gas Heat transfer enhancement with guide tube and fins

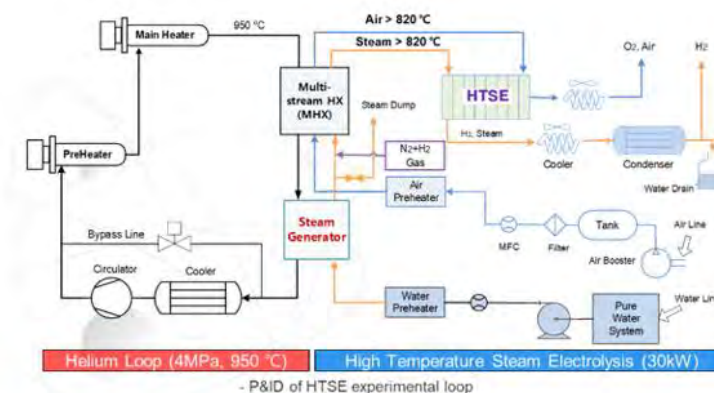


## Xcel Energy: Prairie Island Plant

- H<sub>2</sub> production beginning in 2024
- Bloom Energy high temperature solid-oxide electrolysis cell (SOEC) module

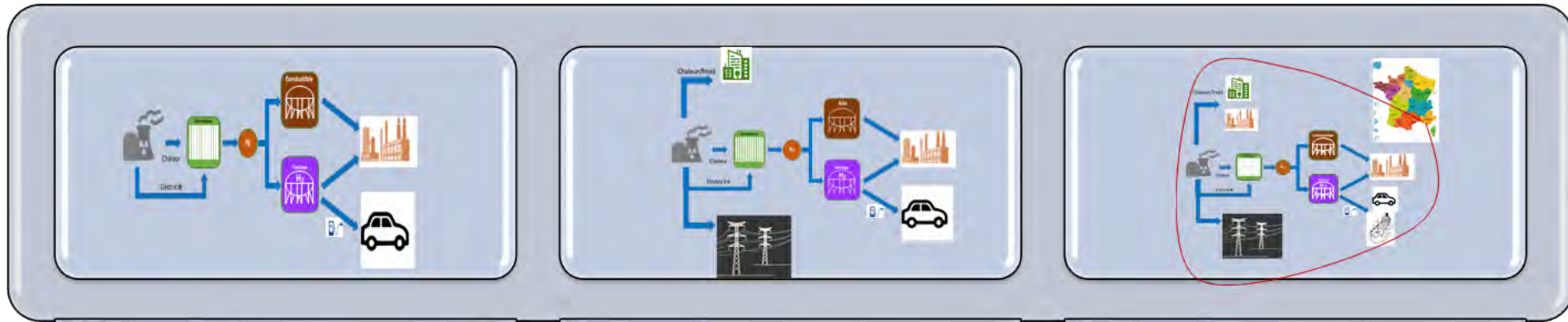
## Integral test facility for High Temperature Steam Electrolysis

- Maximum 820°C of steam supply from the closed helium gas loop
- Operation capability: 30 kWe HTSE system
- Initial stack testing will be carried out at 6 kW next year



Helium experimental loop

Some examples of **hybridation use cases and optimization parameters** for SMR-HTSE coupling  
3 different scenarios, 3 technical configurations and 3 tech-eco evaluations



## Use Case n°2: Flexible H2/power

Driver: Maximizing RoCE by switching between power and H2 markets

Driver: Maximizing response to specific energy supply of an area

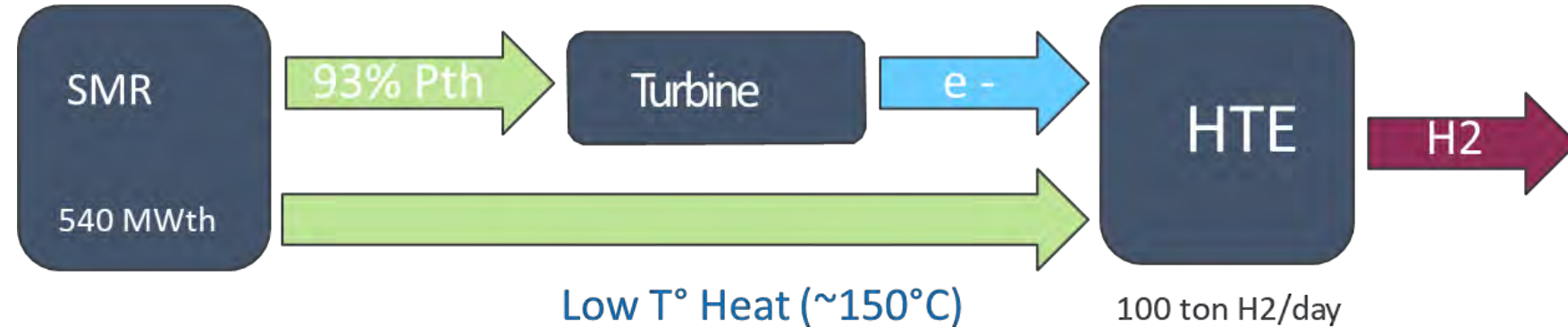
### Return On Capital Employed



# A Thermal integration challenge for HTSE technology

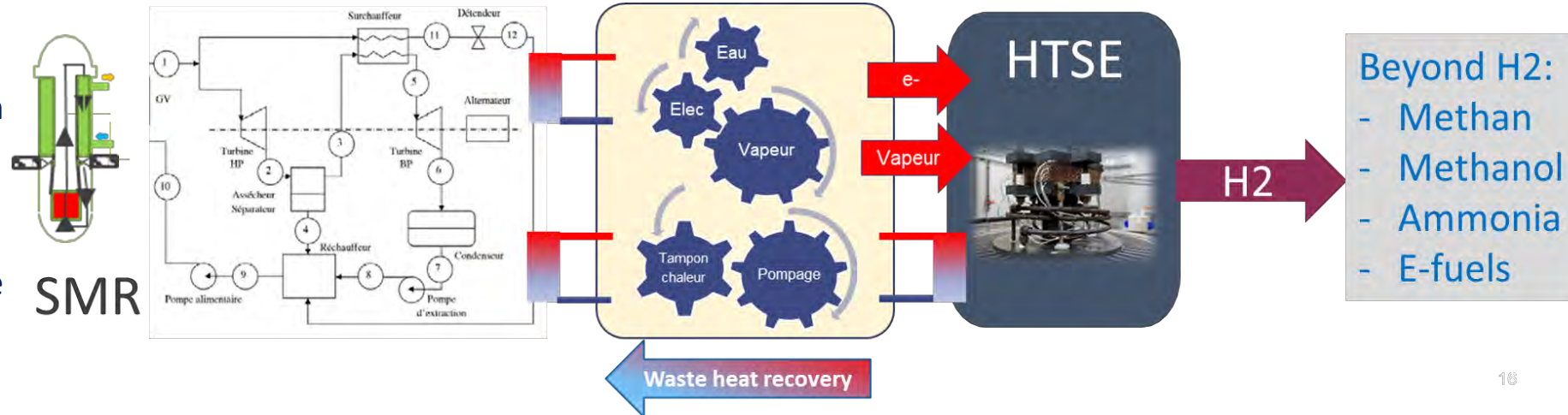
## 1. Global thermal balance

- Primary nuclear heat ratio
- Level of temperature required by HTE



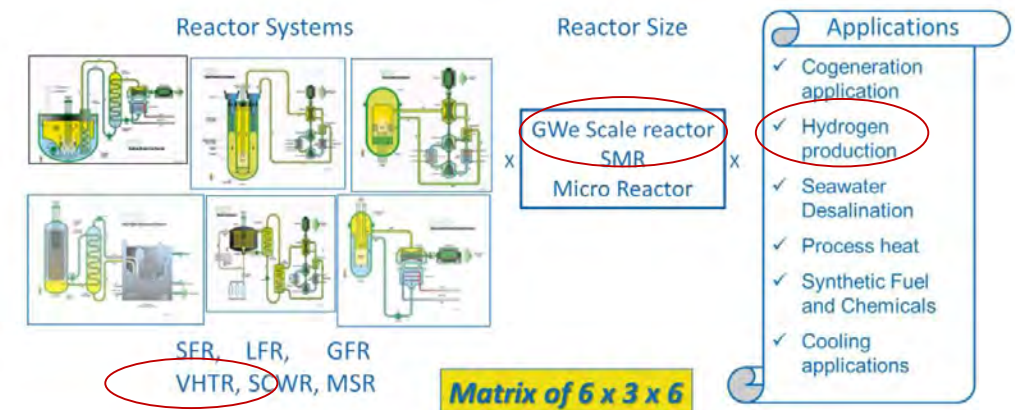
## 2. Coupling configuration (under progress)

- Identify modality of heat supply
- Define connection point in Rankine Scheme : **heat intake and recovery waste heat from HTSE**
- Modelize and evaluate the energetic efficiency



## Conclusion & Perspectives

- **Thermochemical cycle is still at lab scale**
  - ✓ 2 or 3 order of magnitude
  - ✓ Some Innovation and development are promising
- **Scaling up and global prototyping are still in progress**
  - ✓ HTSE : MW (SOEC is more mature and propose pre commercial product)
  - ✓ Pilot line for Thermocycle
  - ✓ Cu-Cl : subject to transfer to Start-up
- **Extend studies on**
  - ✓ coupling with conventional reactors, New Industrial Uses (heat, chemical, co-electrolysis...)
  - ✓ Strengthening links with related initiatives : NeANH, IEA/HyNE, IAEA
    - ➔ Contribute matrix 6x3x6 of business cases to NeANH
    - ➔ Align with IEA-NEANH KPI
  - ✓ Business Model/Use Case Scenario analysis
    - ➔ Mitigate Commercial Risk for Investors in SMR
    - ➔ Secure Energies Supply for new low carbon Industrial plant
  - ✓ Safety, Regulation, Code, Standard



**Thank You for Your Attention**

