# SMR Program

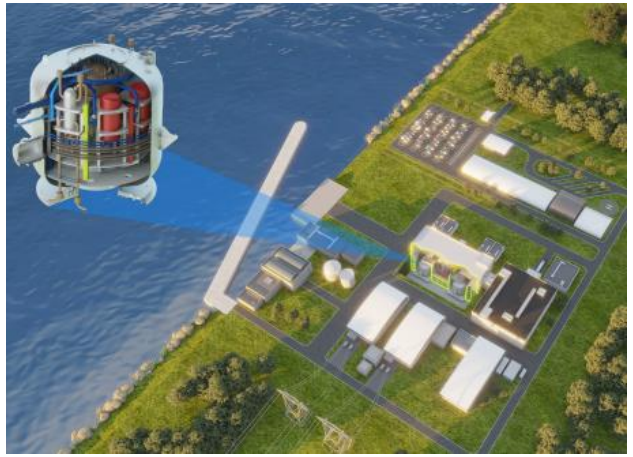
## Co SMR

## Innovative Decarbonized Nuclear Energy System project

# SMR program

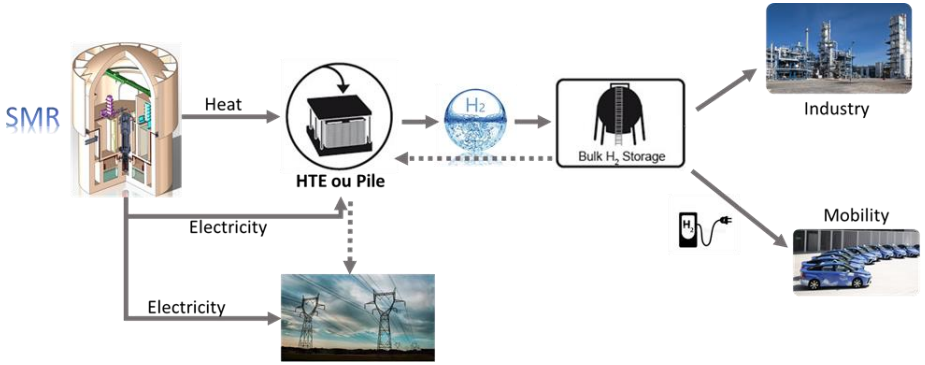
- CO SMR
- IDNES Project

**NUWARD Development**



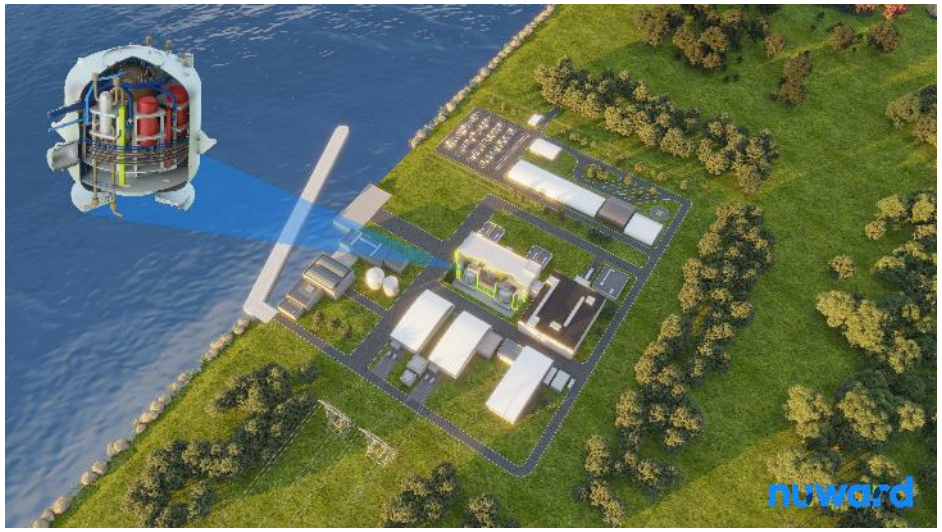
**Hybrid Systems Studies using SMR beyond electricity**

- Innovative Decarbonized Nuclear Energy Systems initiative
- Market driven approach of energetic system
- Multi energy vectors for nuclear application



## NUWARD™: the EDF' solution for international deployment

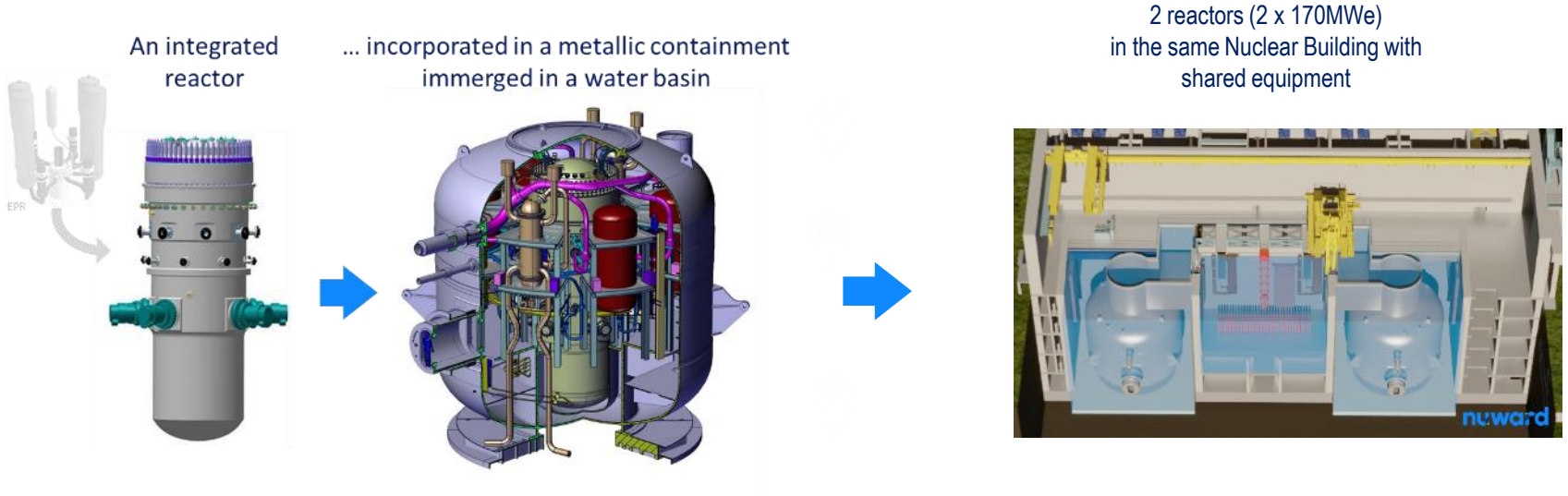
- NUWARD™ design is developed to support **load following,** and to be adaptable to **various environments** and a wide range of sites across the world.
- NUWARD™ targets 3 main market segments:
  - replacing coal-fired power plants in the 300-400 MWe range
  - supplying remote municipalities and energy-intensive industrial sites,
  - powering small grids with limited capacity for large power plants
- NUWARD™ is designed to be adaptable to **other-than-electric carbon-free usages**: hydrogen production for transport, heat & electricity cogeneration, district heating, water desalination.




**NUWARD™: serving an international vision to meet global market needs by 2030**

# SMR STUDIES : NUWARD CONCEPT

- A 340 MWe Pressurized Water SMR plant with 2 reactors (2x170 MWe) in the same Nuclear Building
- A fully integrated design based on a combination of proven and innovative concepts
- The highest standards of safety with a Generation 3+ reactor meeting post Fukushima requirements:
  - ✓ A design robust against accident scenarios, embarking passive safety systems
  - ✓ Reinforced protection against external hazards with a semi-buried Nuclear Island
- NUWARD™ includes some technology innovation to increase safety and competitiveness: Compact Steam Generators (CSG), Submerged Rod Cluster Control Mechanisms (SCM), and Passive cooling system (RRP).



# SMR: NEW APPLICATIONS « HYDROGEN / HEAT »

Within the energy transition program (carbon neutrality by 2050), a new research field has been launched at CEA on PW-SMR and hybrid systems

## Axis #1 : Market studies and needs identification (hydrogen and heat) @ 2040-50

- Definition of the expected performances for the innovative SMR systems

## Axis #2 : Studies on SMR dedicated to hydrogen production

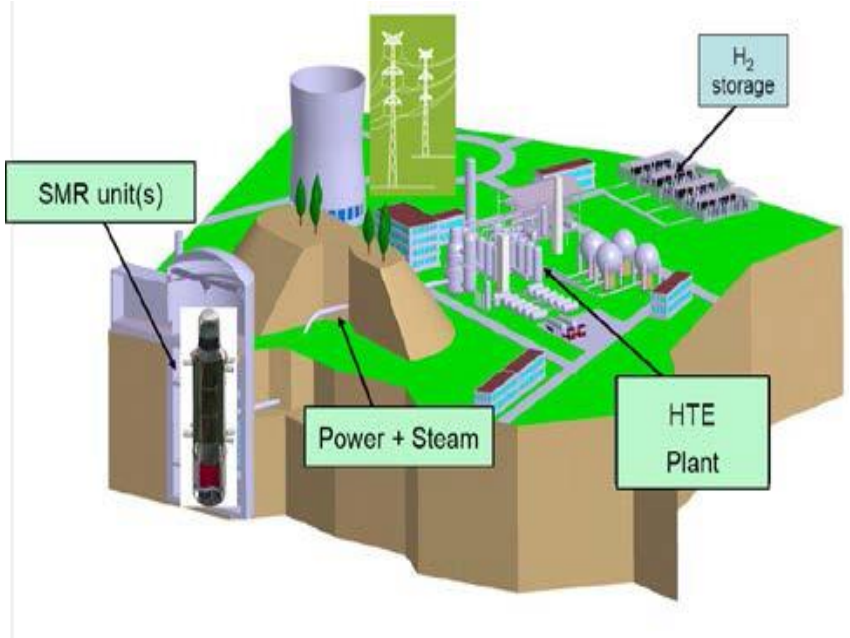
- Systems with a SMR coupled to HTE (High Temperature Electrolysis)
- Performances & cost versus market needs & systems safety

## Axis #3 : Studies on SMR dedicated to heat

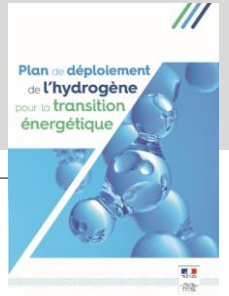
- Preconception studies on heat-supply SMR concepts
- Performances & cost versus market needs & systems safety

## Axis #4: R&D on innovative Energy Conversion Systems (ECS)

- Study on multi-vector ECS (power, heat, H2, drinking water)
- Optimization when considering storage (battery, thermal energy, gas...)
- Integration with other energy sources : PV, wind turbines, fuel cells...



# (1/2) SMR FOR HYDROGEN: CHALLENGES OF “DECARBONIZED" H2




## Towards a decarbonized hydrogen production:

- Mobility vector with electricity
- Decarbonize industrial hydrogen

+

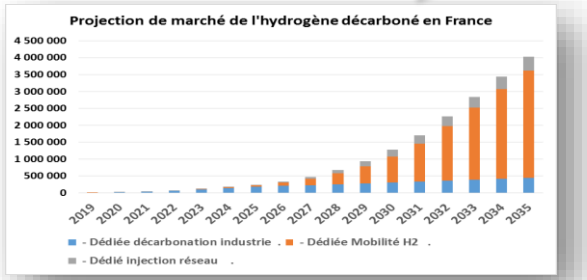
**500 $MW_{th}$**

**97 tons/day ~ 35 000 tons/year**

20.000 cars/day

**or**

1.200 trucks or bus per day



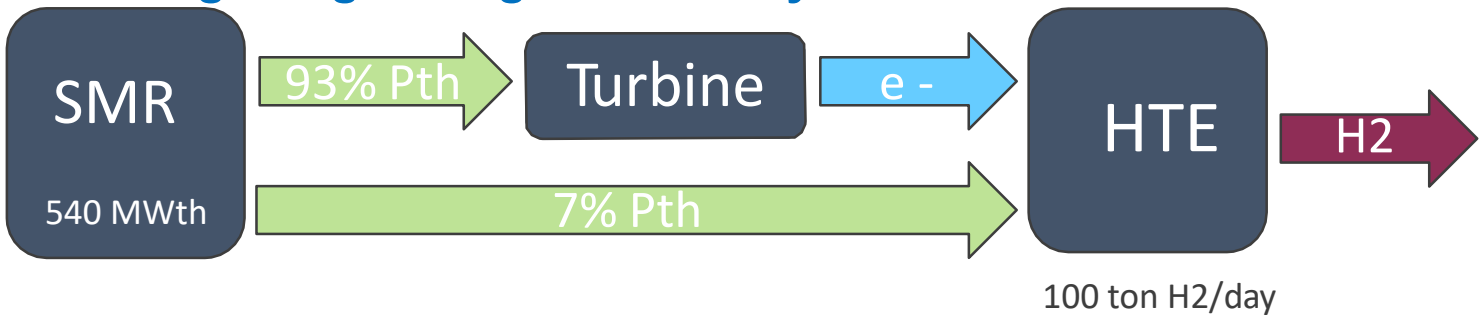

1% of the French production in 2035 (4.000.000 tons/year)

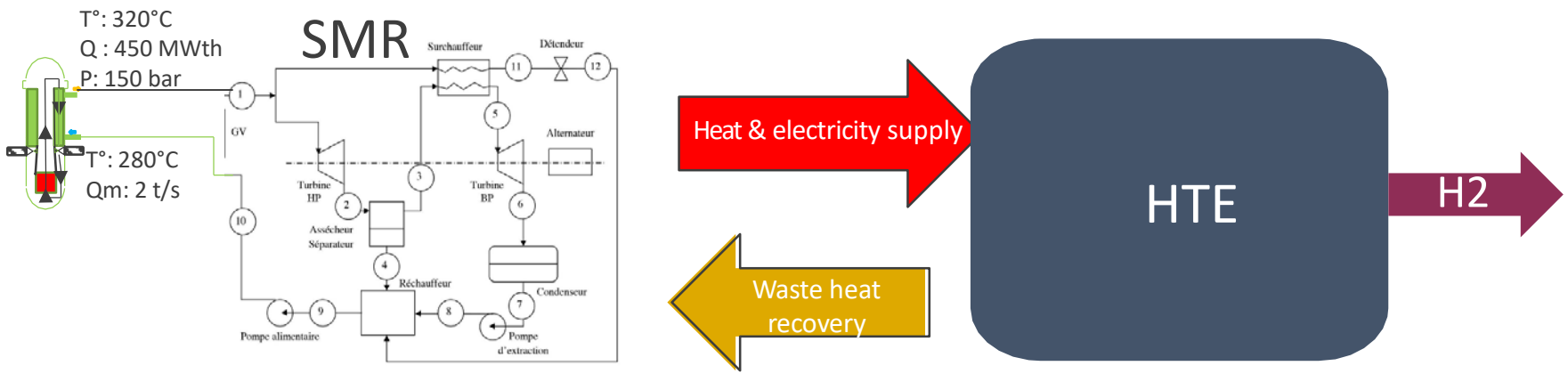
4% of the national production in 2020 (900.000 tons/year)

## Association of 2 technological bricks developed at CEA:

- High temperature electrolysis : high yield, need for heat & electricity, possible use as SOFC and thus power supply
- SMR : heat and electricity supply in cogeneration mode, power consistent with a H2 production unit, location close to the H2 demand

## Thermal integration challenge : High Energetic efficiency




## Ongoing technical work:

- Vapor / heat Intake points in SMR Scheme
- Direct / indirect supply mode
- Recovery of waste heat from EHT to SMR

## First results:

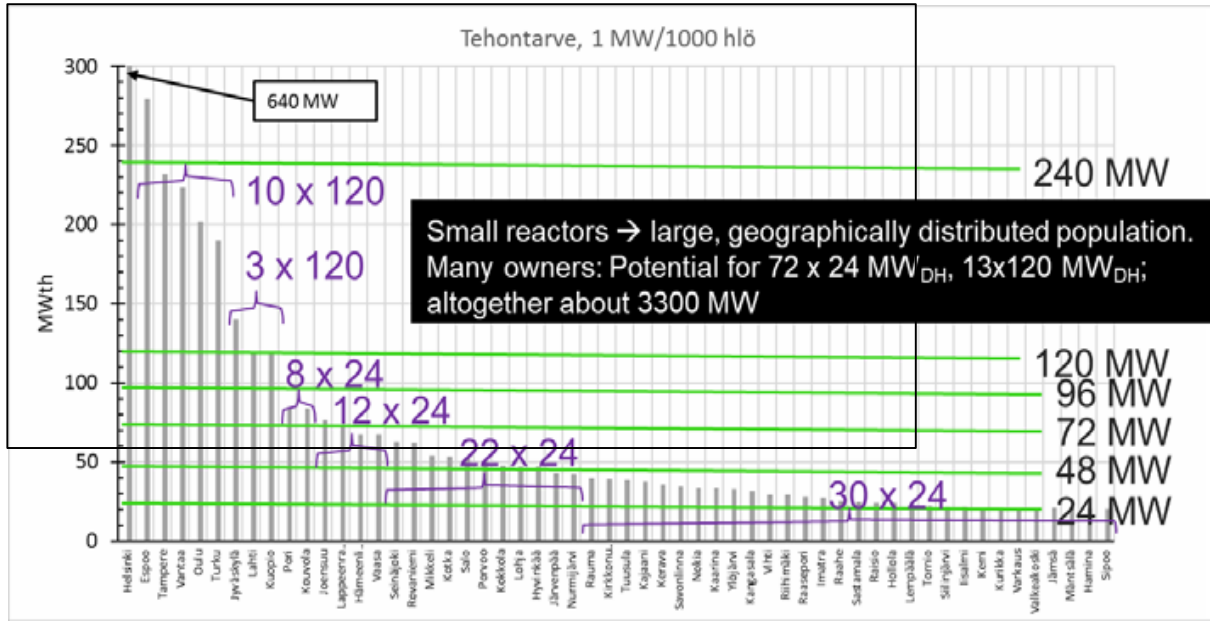
- Yield increase compared to the reference where EHT unit is solely connected to the electrical grid

# (1/2) SMR FOR DECARBONIZED HEAT: MARKET ONGOING WORK

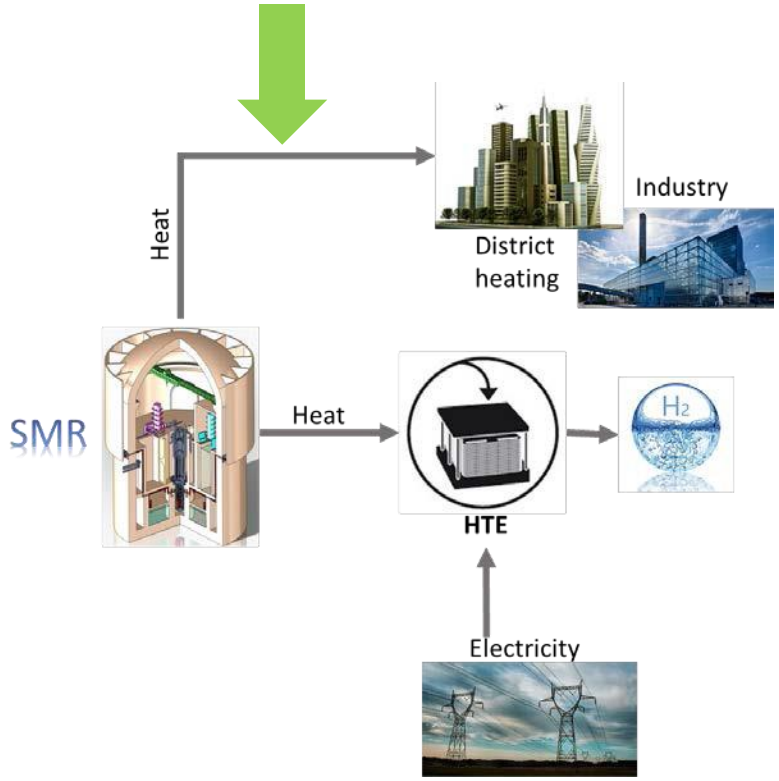
## Finnish Market analysis : 56 towns > 20 000

- 13 units of 120MWth
- 72 units of 24 MWth

Prof. Juhani Hyvärinen
Lappeenranta Univ. of Tech.
NUGENIA Forum, Paris, 2019




- Need to update the market analysis for district heat and industrial needs at horizon 2040 for Europe
- Design studies to Downsize the nominal Power from 100 to **20 MWth and include a thermal storage**



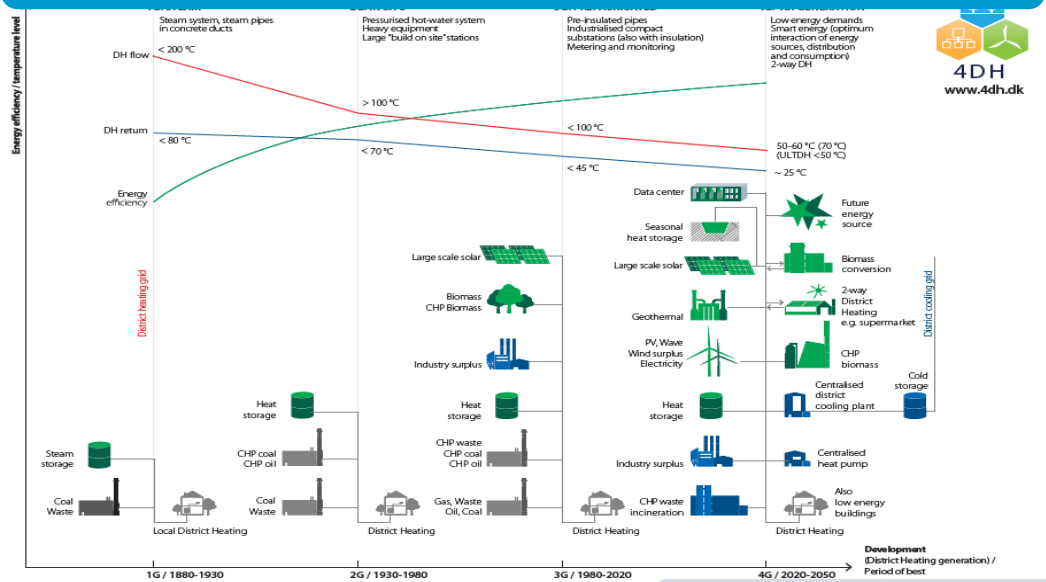

## French Market, need for heat <250°C

- 100 TWh for industriel needs
- 450 TWh for district heating
- Average power of district network 40MWth

## SMR functional requirements :

- Adapted power (20-100 MWth)
- Adapted temperature to network Generation
- Optimized CAPEX & OPEX

Downward trend in the temperature level of heating networks

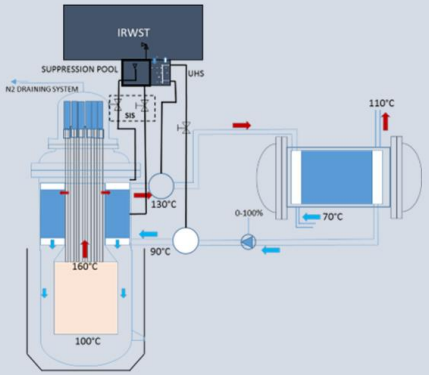



## 2 Sketchs of integrated reactor under progress

- Heat network operating T°<100°C
- Heat Network operating T°> 100°C

Dedicated design including pressure considerations

### Integrated reactor (Primary 100/160°C - 10 bar)

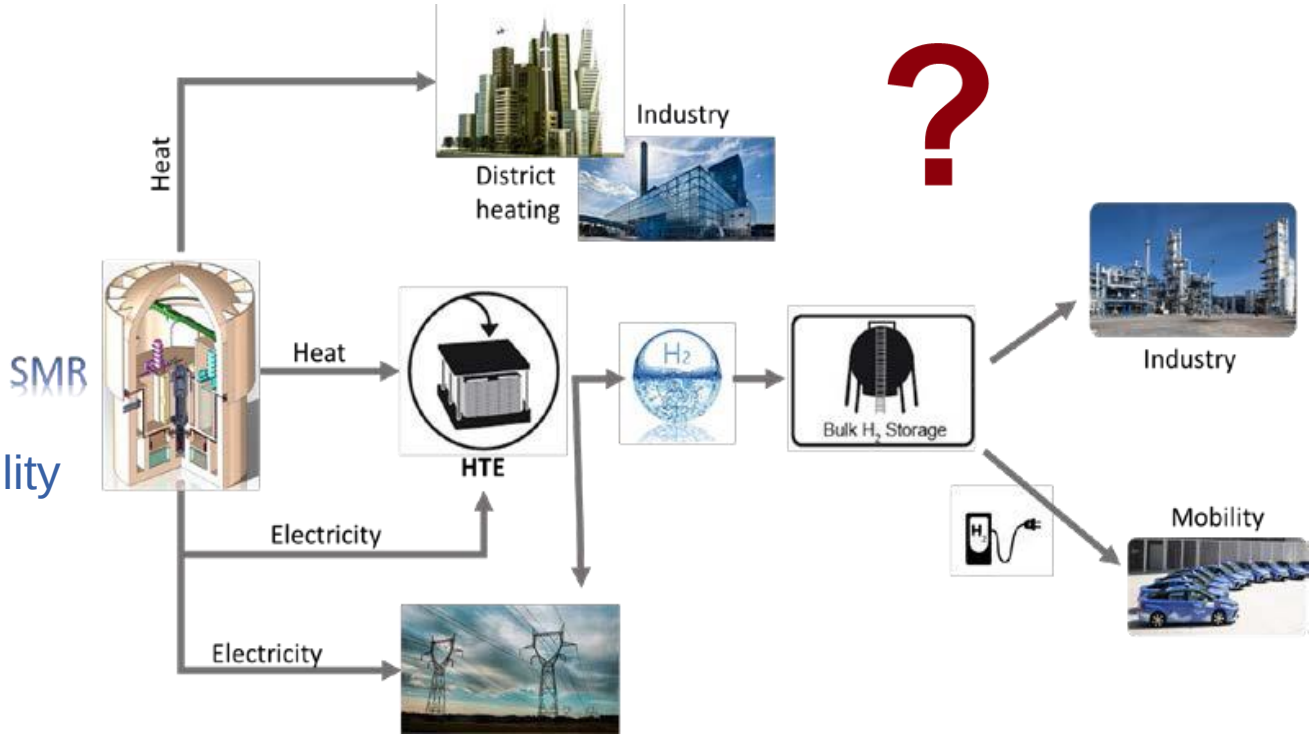


# SUMMARY OF R&D ON SMR BEYOND ELECTRICITY PRODUCTION

- Market driven approach using systemic approach at the 2050 horizon

- First studies of technological bricks
  - SMR for district heating or industry
  - Coupling SMR / High Temperature Electrolyze

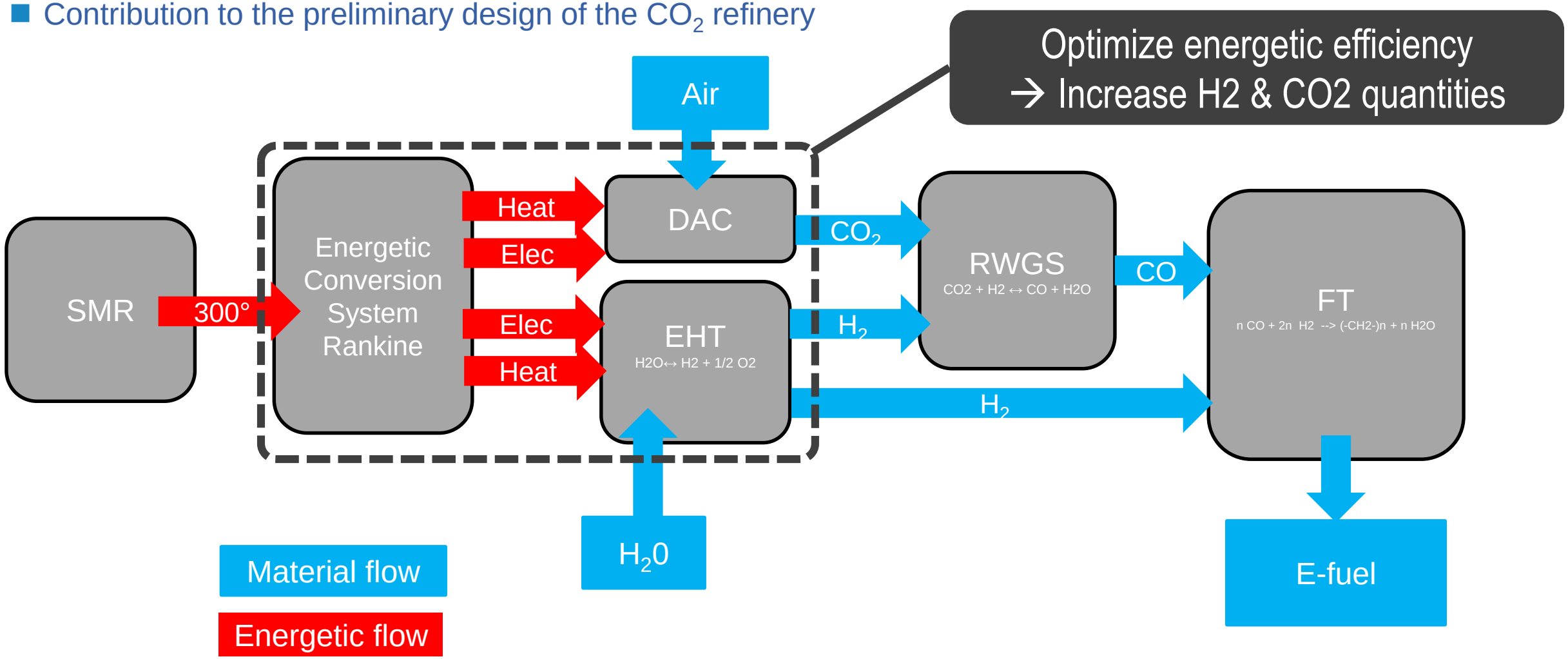
- Objective to propose Innovative Conversion Energy Systems to ensure reliable energy production and stability of the networks using:
  - Mix of sources : Nuclear, PV, Fuel Cells and wind turbines
  - Storage of different size (hours, month, season) and type (heat, gas, electrochemical...)
  - Cogeneration: electricity, hydrogen, desalination, heat
  - Power to X conversion to produce e-molecules




Post doc topic in 2022

# (1/2) POST DOC OPPORTUNITY FOR 2022

- Contribution to the preliminary design of the $CO_2$ refinery




RWGS : Reverse Water Gas Shift
FT : Fischer Tropsch

# (1/2) POST DOCTORAL OPPORTUNITY FOR 2022

- Contribution to the preliminary design of the $CO_2$ refinery , list of tasks :

1. Direct Air Capture technology benchmarking
2. Simulation of coupling DAC-Rankine CES
3. Integration with X to X conversion system (RWGS & FT)
4. Preliminary sketch with prelimianiry indicators
5. Technico-economic evaluation
6. Relevance tu use AMR for heat supply (higher T°)

In association with another CEA Post doctoral