FR 22 – Keynote Speech – CEA/FRANCE

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FAST NEUTRONS REACTOR DEVELOPMENT CONTEXT IN FRANCE

One through Pu recycling is currently implemented

- #34000 tons of UNF reprocessed in La Hague, #2600 tons of MOX fuel produced
- **24** of the 56 French nuclear reactors are authorized to use MOX fuel
- Based on the principle : recovered Pu = reactor needs (#10 tons/yr)

The “Multiannual Energy Plan 2019-2028” confirms that France remains committed to the closed fuel cycle policy, at least until 2040

- An intermediate step : Pu multi-recycling in PWR (development program : conceptual and performance study, demonstrate the feasibility at the SA scale)
- The ultimate, long term objective remains the complete closure of the fuel cycle **with fast neutron reactors** (better utilization of U resources)

Regarding fast neutron reactors

- SFR is the reference technology: further development of the concept and technology
- Other concepts are considered for exploratory studies

Investment Plan announced by the French President on Oct. 12, 2021

10 objectives to understand better, live better and produce better in France by 2030

€30 billion over five years

Energy Sector:

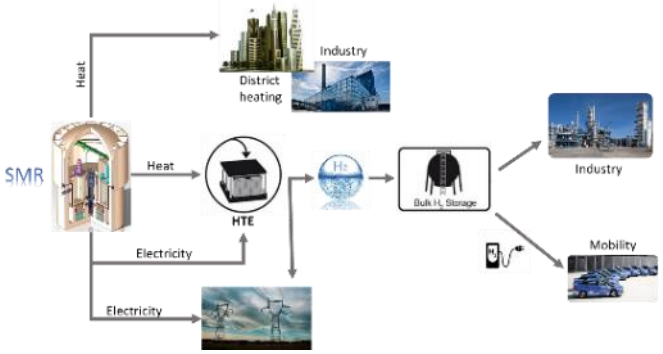
- **Objective 1:** To help develop innovative, small-scale nuclear reactors, with better waste management
- **Objective 2**: To become the leader in green hydrogen. In 2030, France will have at least two gigafactories of electrolyzers, mass producing hydrogen and all useful associated technologies
- **Objective 3**: To decarbonize France's industry by reducing greenhouse gas emissions by 35% compared with 2015

BIG PICTURES ON FRENCH PROJECTS

Small Modular Reactors

EDF, CEA, TA, Fra, Naval Group +

+ SMR for heat or H2

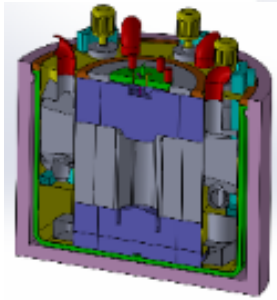


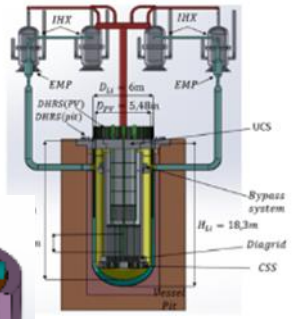
Short and middle term markets

Advanced Modular Reactors

Fast reactors

ATRIUM (SFR)
ANAIS (SFR)





ARAMIS (MSR)

orano

SFR R&D

Materials, fuel, severe accident, technologies, simulation

Sustainable energy and new use of nuclear heat

Waste management

ISAC
Innovative System for Actinides Conversion
MSR dedicated to Am transmutation
(CEA, EDF, Fra, Orano, CNRS)

Technological survey

MMR and space reactors

Breakthrough innovations

French startups created in 2021

naarea
MMR MSR

Jimmy
MMR HTR

TRANSMUTEX
Nuclear Waste to Green Energy
ADS

AMR SFR

Objective

- Assess benefits and limits of the AMR approach for SFR in terms of safety, economics and fuel cycle.
- Large SFR are relevant for Pu multirecycling and close the fuel cycle but lack of economics
- Reduce the power to change the SFR economics model ?

2 sketches AMR-SFR (~150MWé)

ATRIUM

- Breakthrough innovation,
- LOOP type,
- Inherent safety with CADOR core

Towards practical elimination of the whole core melting

- No secondary loops
- No whole core melting
- DHR totally passive through the vessel

ANAIS

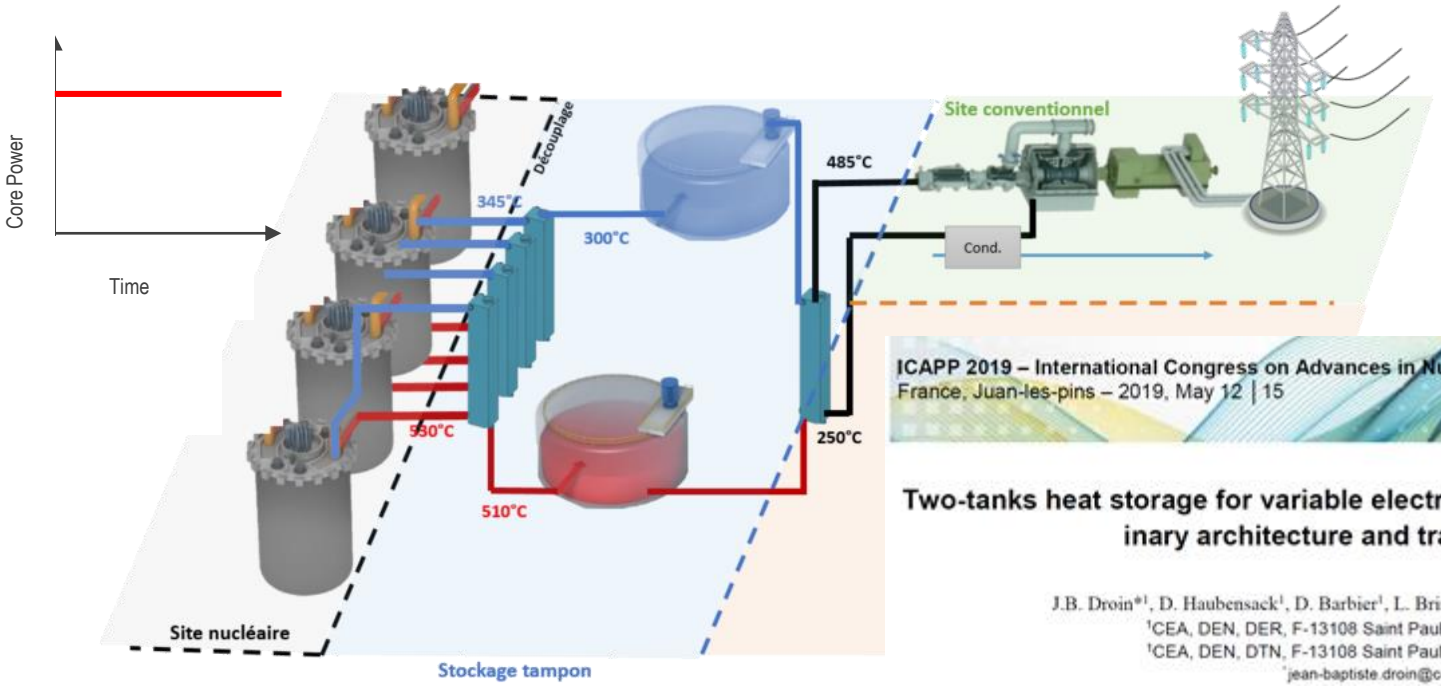
- POOL type
- Inspired by ASTRID design
- CAPEX reduction as a main goal
- Multi-unit (2 or 4)

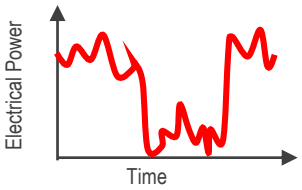
+ modularity, load following and heat applications (industry, H_2, NH_3, CH_4, e-fuels, desalination)

AMR SFR : A RENEWED VISION OF FAST REACTORS

SEVERAL AMR WITH MUTUALIZATION OF SYSTEMS (FUEL HANDLING…)
THERMAL STORAGE ENABLES DECOUPLING BETWEEN NEUTRONIC POWER AND ELECTRIC POWER
FAST LOAD FOLLOWING (20%/MIN) WITHOUT REACTOR POWER VARIATION

1 – Electricity Market Flexibility





ICAPP 2019 – International Congress on Advances in Nuclear Power Plants
France, Juan-les-pins – 2019, May 12 | 15

Two-tanks heat storage for variable electricity production in SFR: preliminary architecture and transient results

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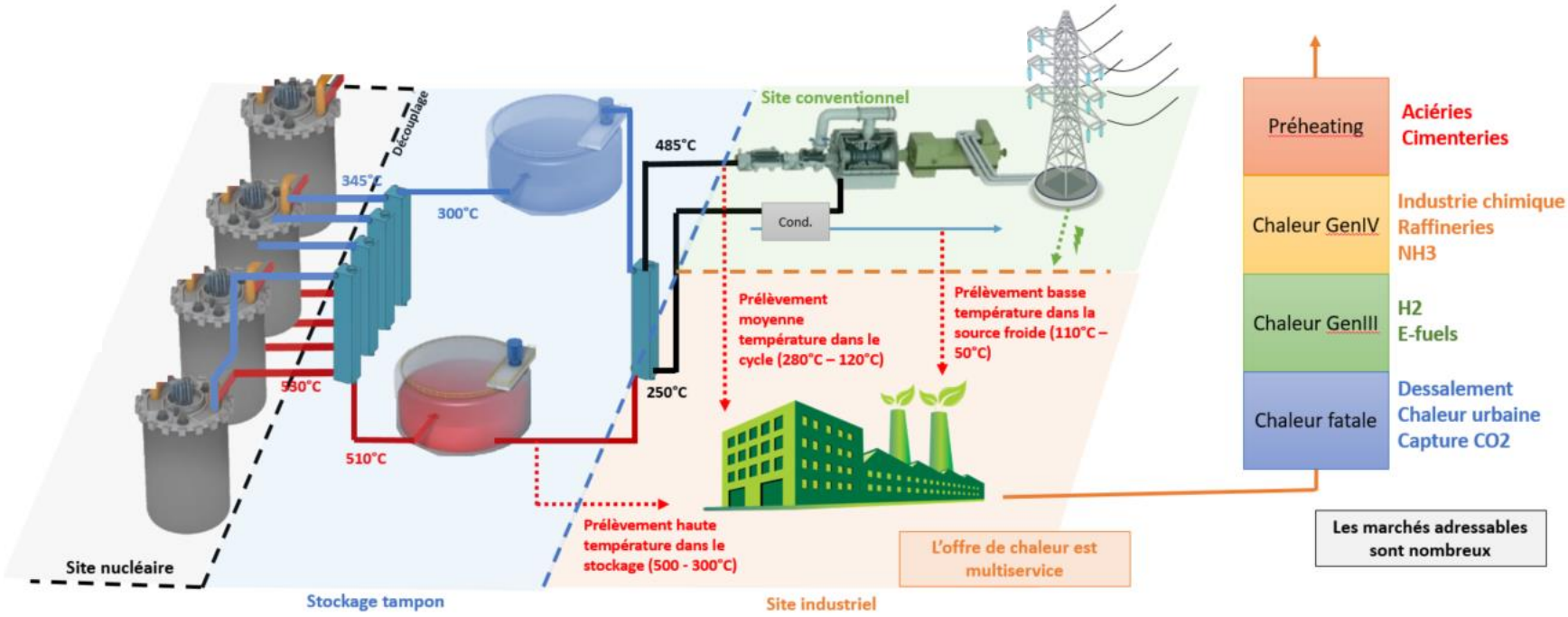
REPLACEMENT OF COAL/GAS PLANT DEDICATED TO GRID SECURITY

HEAT SOURCES IN THE THERMAL STORAGE OR IN THE PCS OFFERS A LARGE BRACKET OF T° FOR INDUSTRY OR BY-PRODUCTS



Big question : does these new uses make fast reactors profitable at a reasonable horizon ?

WHY IS FRANCE INTERESTED IN FAST MSR ?

Potential assets

Nuclear fuel cycle

- Multirecycling of Pu
- Minor actinides transmutation

Intrinsic safety

- Potentially no severe accident
- Strong negative neutronics feedback
- No pressure
- Salt solidification in case of leakage

Flexibility

- Load following capability

Feasibility issues

Salt chemistry

- Mastering solubility and precipitation issues
- Lack of data
- Uncertainties for operating the system

Materials

- Corrosion
- High temperature
- Structure irradiation (no clad as 1st barrier of containment)

Safety in operation

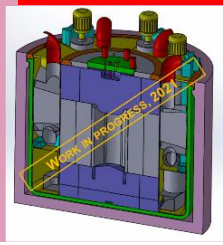
- Operation and maintenance processes
- Fission products management, radioprotection

orano

- R&D program started in 2020 aims at assessing the feasibility of fast MSRs and confirm their potential assets

Complementary with main R&D ongoing on Gen4 SFR

- Development of the ARAMIS Fast Reactor



CONCLUSIONS AND PROSPECTS

- AMR studies start in 2020 at CEA

❑ One AMR-SFR loop-type driven by **inherent safety** >> **ATRIUM**

❑ One AMR-SFR pool-type driven by **cost reduction** and new use of heat (thermal storage & flexibility or industry) >> **ANAIS**

❑ One AMR-SFR **multi-services** driven by quick deployment

❑ One **fast-spectrum MSR with chloride salt dedicated to actinides conversion >> ARAMIS**

Short term objective for AMR-SFR : assessment of opportunities of AMR-SFR in terms of safety, fuel cycle and market needs
>> if green lights >> development of the concept with industry

Mid-term objective for MSR : Feasibility of fast MSR for actinides management

THANK YOU FOR YOUR ATTENTION