Orano perspectives and activities on MSR development

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01 • Orano: a vision with human values

Since its creation, Orano has always driven progress, upholding a vision and espousing human values that are deeply rooted in its identity.

Orano is a **strategic player** in the nuclear industry, **acting with responsibility and commitment for** both current and future generations (for the climate, for the planet and for health). Its know-how across every stage of the fuel cycle and its ability to innovate are its key success factors.

Orano translates these aims into its fundamental purpose.

To develop know-how in the transformation and control of nuclear materials, to protect the climate, health, and for a resource-efficient world now and tomorrow.

01 • Orano is innovating today to meet tomorrow's challenges

Orano is developing innovative and original solutions that bring value and progress for society's future. Its strategy is to accelerate its innovation cycles, and explore new activities to serve its customers in tomorrow's markets, for a more sustainable future.

An open innovation strategy.

To speed up its innovation cycles, Orano is bringing in new skills, including those in **design and landscape architecture**; is diversifying the ways it cooperates with international startups in deep tech; and is placing confidence in **partners who are expert in and recognized for Business Innovation.**

Over 1,800 start-ups in our ecosystems 40 + innovative solutions deployed

€120 M + in global R&D outlay



01 • Orano - World expert in the nuclear fuel cycle



Orano's technologies allow 96% of spent nuclear fuel to be recycled. The 4% of final waste is conditioned to make it safe and stable



The La Hague plant is a strategic asset which has addressed Back-End challenges for LWRs spent nuclear fuels for 50 years



02

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Orano's La Hague plant includes two production lines, based on PUREX process

Two production lines • UP2-800 (~800 tHM/y capacity)





~10,500 tHM reprocessed for **6** other countries

A first-of-a-kind nuclear mechanical and chemical plant with complex process to operate by remote







Orano La Hague plants: A fault tolerant design

- \rightarrow
- Maintenance by design, a key pillar of the engineering process applied to La Hague
- A complete maintenance organization and processes, taking into account
 - Scheduled operation
 - Unscheduled operation

Hardened and proven technologies for remote maintenance, as well as skilled operators





Chloride fast MSRs are particularly promising for use as actinide (Pu and MA) converters

- The neutronic spectrum can be hardened (in Chloride salt)
- **No fabrication of solid fuel** (complex at industrial scale with MA, need of costly shielded chains)
- No cladding limitation to burn up, so the actinides remain in the core until they fission and are thus totally "burned"
- Operation in Pu or Pu+MA cycle, i.e., without Uranium → maximized consumption of Pu/MA
- No degradation by MA of counter-reaction factors → possibility to increase the MA content in the core (vs. FR with solid fuels)
- Chloride salts enable synergies with the La Hague facilities, which fluoride salts cannot do



Since 2019 Orano has been exploring the potential of fast Chloride MSR to add value to the utilities : use Pu + MA as fuel and provide a global solution where the customer is left with glasses with FP only

Beyond U/Pu recycling, an additional service to LWR operators to close the fuel cycle and reduce High Level Waste (HLW)

- Treatment of spent nuclear fuel with no return of Pu
- Transmutation of MA → less ultimate waste, reduced long term radiotoxicity

The molten salts could be produced and recycled in La Hague, and FP vitrified in La Hague



Orano's strategy is to enable the emergence of Chloride Fast MSR models, with a first demonstrator of CI Fast MSR in the 2030'

Orano has two ambitions :

- To contribute to the realization, with partners developing MSR concepts, of a first operational demonstrator of Chloride Fast MSR in the 2030s'
- To be able to produce PuCl₃-based salt to supply the first Chloride Fast MSRs in the 30's. This implies a very ambitious R&D roadmap.



International cooperation is vital to succeed in the R&D programs leading to commercial CI MSRs

We believe that international cooperation is vital to succeed in the R&D programs leading to commercial Chloride Fast MSRs

Several French and International collaborative R&D projects are already running.



MIM🖗SA

MultI-recycling strategies of LWR SNF focusing on MOlten SAlt technology Project 101061142 – HORIZON-EURATOM-2021-NRT-01

An EU funded project aiming at demonstrating multi-recycling strategies based on the use of molten salt reactors in European countries

The methodology is twofold : developing multi-recycling scenarios with MSRs, and advancing MSR technology beyond state of the art

1. MIMOSA develops and analyses tangible strategies for multi-recycling of LWR Spent fuels in EU countries, with a special focus on the role that MSRs could play in such advanced nuclear energy systems (WP1)

2. In parallel, MIMOSA focusses on the demonstration of several key aspects of technical feasibility and performance of CI MSRs simultaneously by calculations / simulations and experimental investigations





Globally, the MIMOSA project will raise the TRL of several CI MSR related technologies, processes and materials from 1 or 2 (initial status) to 3 or 4 (final status), depending on topics.

* Funded by the European Union. Views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union or Euratom. Neither the European Union nor Euratom can be held responsible for them.

04 •

Orano commitment to France 2030 CFP on AMR technology

France 2030 "advanced reactors" Call For Projects (CFP) has a 500 M€ budget for 10 years with the following objectives

- Foster French deep tech startups focused on innovative nuclear reactors development
- Accelerate prototype implementation



CFP phase 1 files submission is complete

Waiting for the last award-winners announcement early 2024

Orano partner with startups developing Chloride Fast MSR to get funding for the development of the salt scope, and accelerate TRL ramp up of this MSR technology





04 Orano's R&D program main objective : to facilitate the pathway to a MSR Demo



An extensive R&D program has been initiated on various aspects of the MSR fuel cycle to accelerate technological development.



Development & qualification of process and equipment (inactive)



Lab & Large pilot units, inactive or using U, Th

15

HRB (Hall de Recherche de Beaumont) for development of fission gas treatment solutions and maintenance solutions

CIME (Centre d'Innovation en Métallurgie Extractive) for large scale salt synthesis and loop tests

05 Conclusions and next steps...

Fast CI MSR are ideal candidates to close the fuel cycle and reduce Long-lived HLW

Using synergies with the industrial capabilities of La Hague can accelerate the development and deployment of such Back-End solutions for LWR (including LW-SMR) fuel



a unique value in terms of sustainability and public acceptance of nuclear energy in the future

Orano's strategy is to enable the emergence of Chloride Fast MSR models, with a first demonstrator of Cl Fast MSR in the 2030'

International cooperation is vital to succeed in the R&D programs leading to commercial CI MSRs



European SMR Industrial Alliance





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Giving nuclear energy its full value