

Orano's vision on MSR: potential, challenges and R&D needs

GIF Industry Forum, 05 October 2022

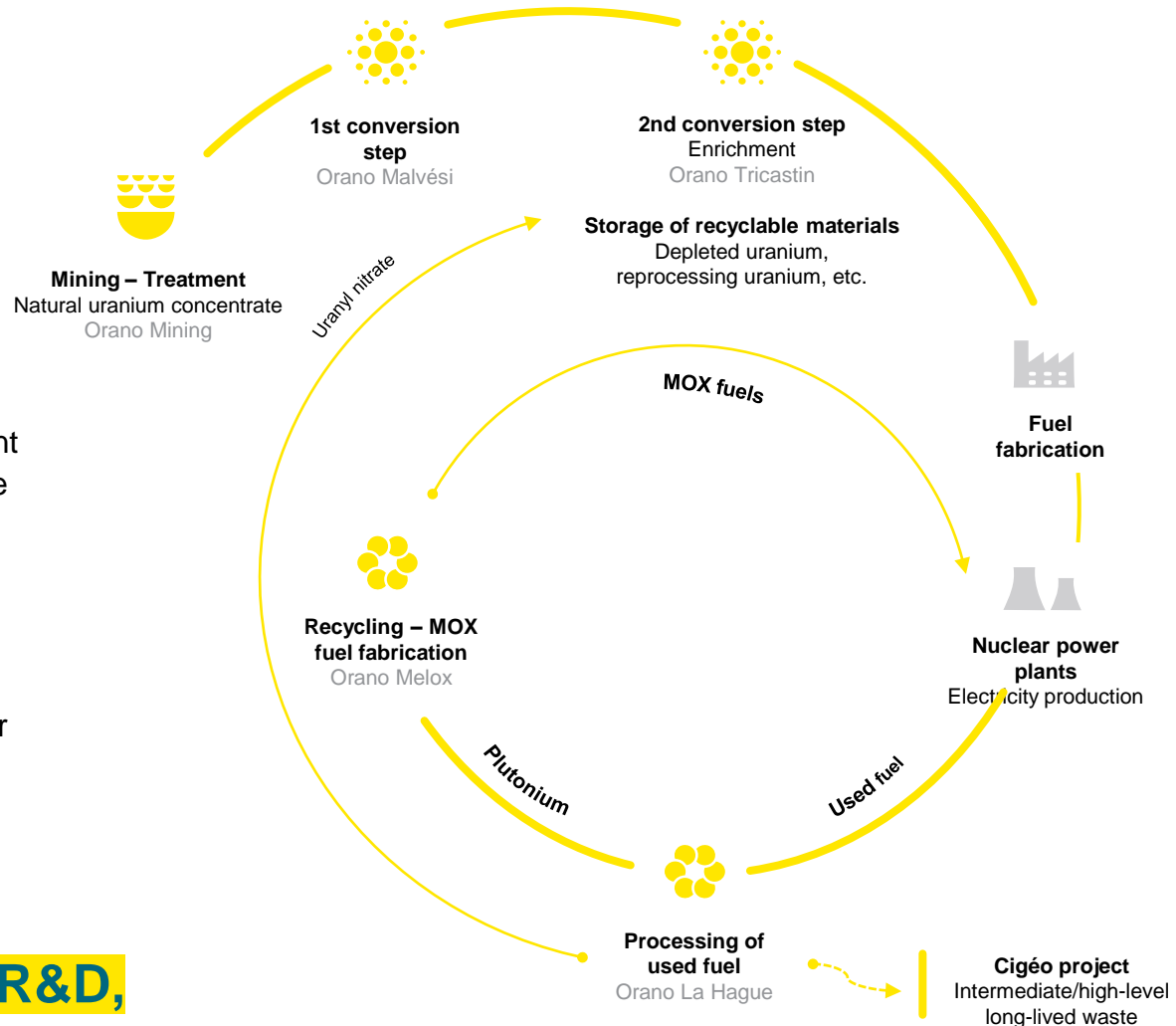
Elisa Capelli, R&D Department



Ensure excellence right across the fuel cycle...

The Group offers its customers efficient products and services, right across the cycle, from mining through to decommissioning, as well as in conversion, enrichment, recycling, logistics and engineering.

Orano is also a major player in nuclear medicine and targeted alpha therapy with ²¹²Pb, thanks to the work of its Orano Med subsidiary.



... and right across all service activities



Nuclear Packages & Services



Engineering



Decommissioning & Services



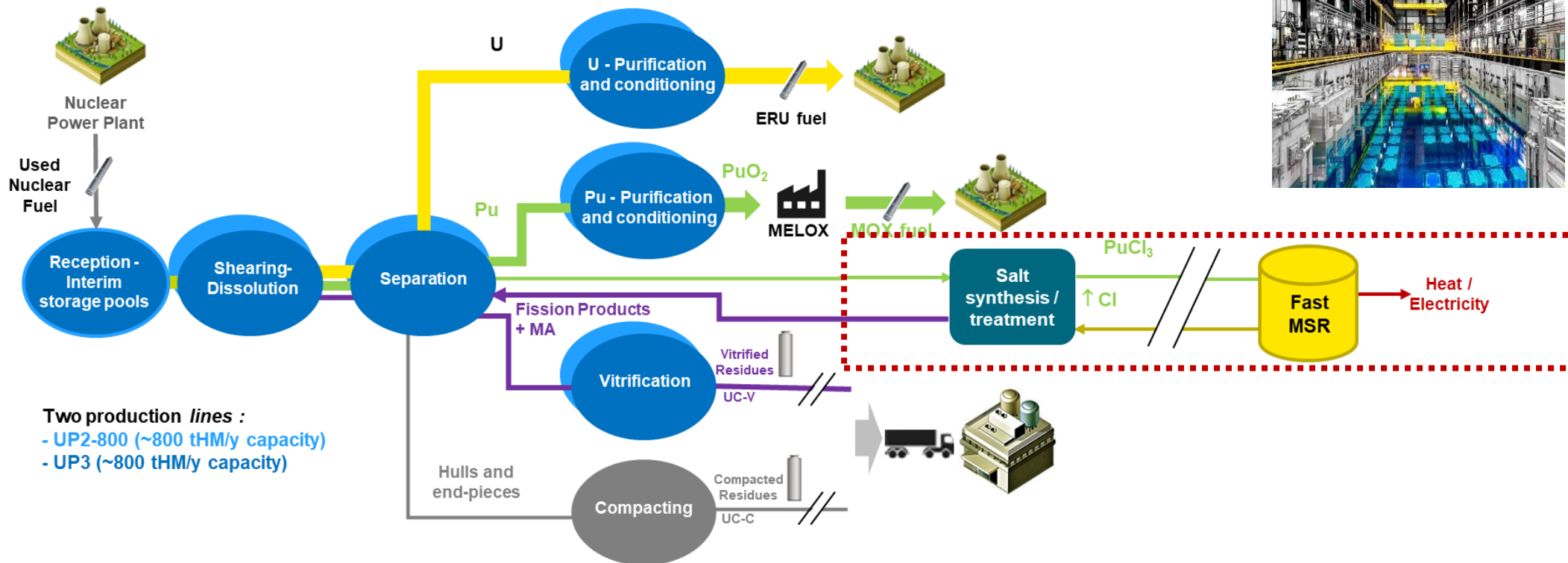
orano **Innovation and R&D,** an accelerator for the Group's growth

Orano is the global leader in the recycling of nuclear materials

Adding value to the standard SNF treatment service with an MSR actinide convertor and providing services related to salts all along the nuclear fuel cycle

+ 38,000

metric tons of fuel processed



Seizing the potential of Molten Salt Reactors

Although research fields and gaps in knowledge remain extensive, MSR is promising and rapid evolving technology

- From a technological point of view, MSRs show significant advantages in terms of intrinsic safety, simplified fuel fabrication and fission products management.
- Moreover, there is a clear potential for combining multi-recycling options with chloride MSR, offering a more integrated and responsible management of spent nuclear fuel, multi-recycling of plutonium and minimizing the required footprint for the high-level waste disposal in repositories and producing valuable isotopes for other applications.
- Reducing the volume and the radiotoxicity of high-level waste is a strategic issue for the sector and MSRs can contribute to this objective

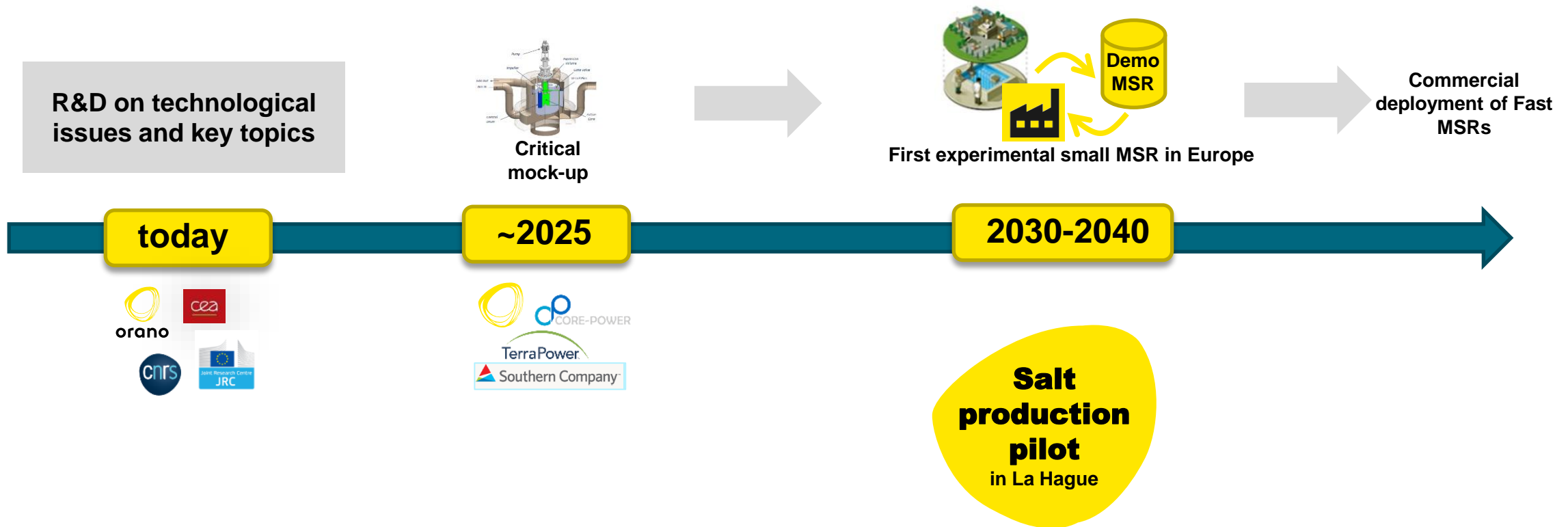


Design choices:

- **Fast spectrum** for a better conversion of MA
- **Chloride salts** for an increased solubility of the trivalent actinides, a harder neutron spectrum and a better compatibility with LH
- **[Pu] or [Pu + MA] cycle, without Uranium** to maximize the burning of Pu and MA

A development roadmap targeting a first Pu converter prototype operational in the early 30's

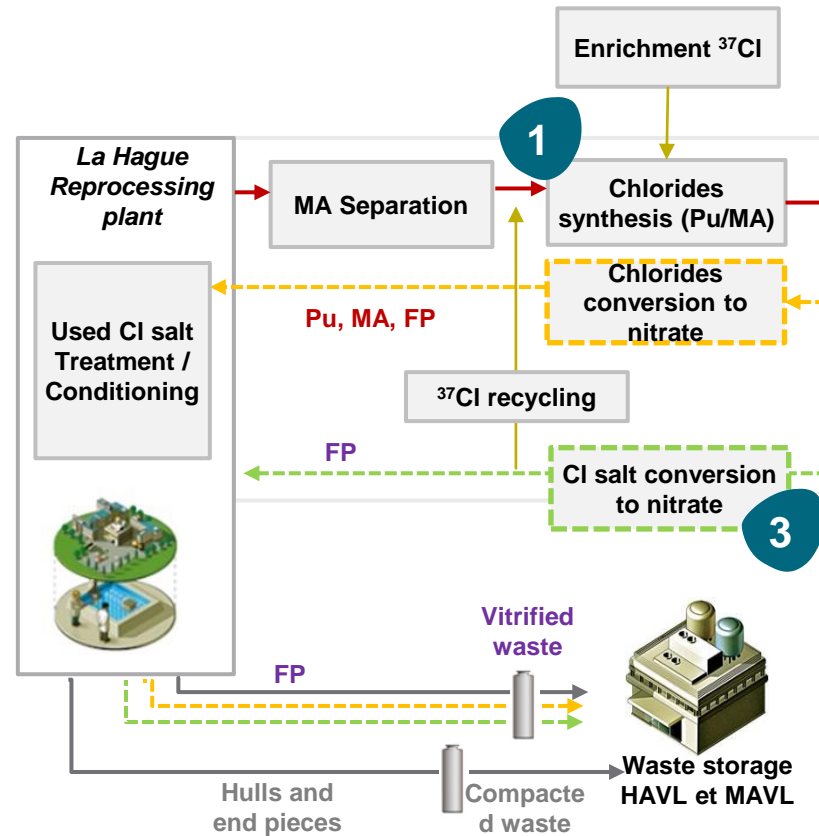
Orano is not a reactor designer. Our ambition is to realize, with partners, a first operational demonstrator that meets the interests of the sector and of Orano in the 2030s'



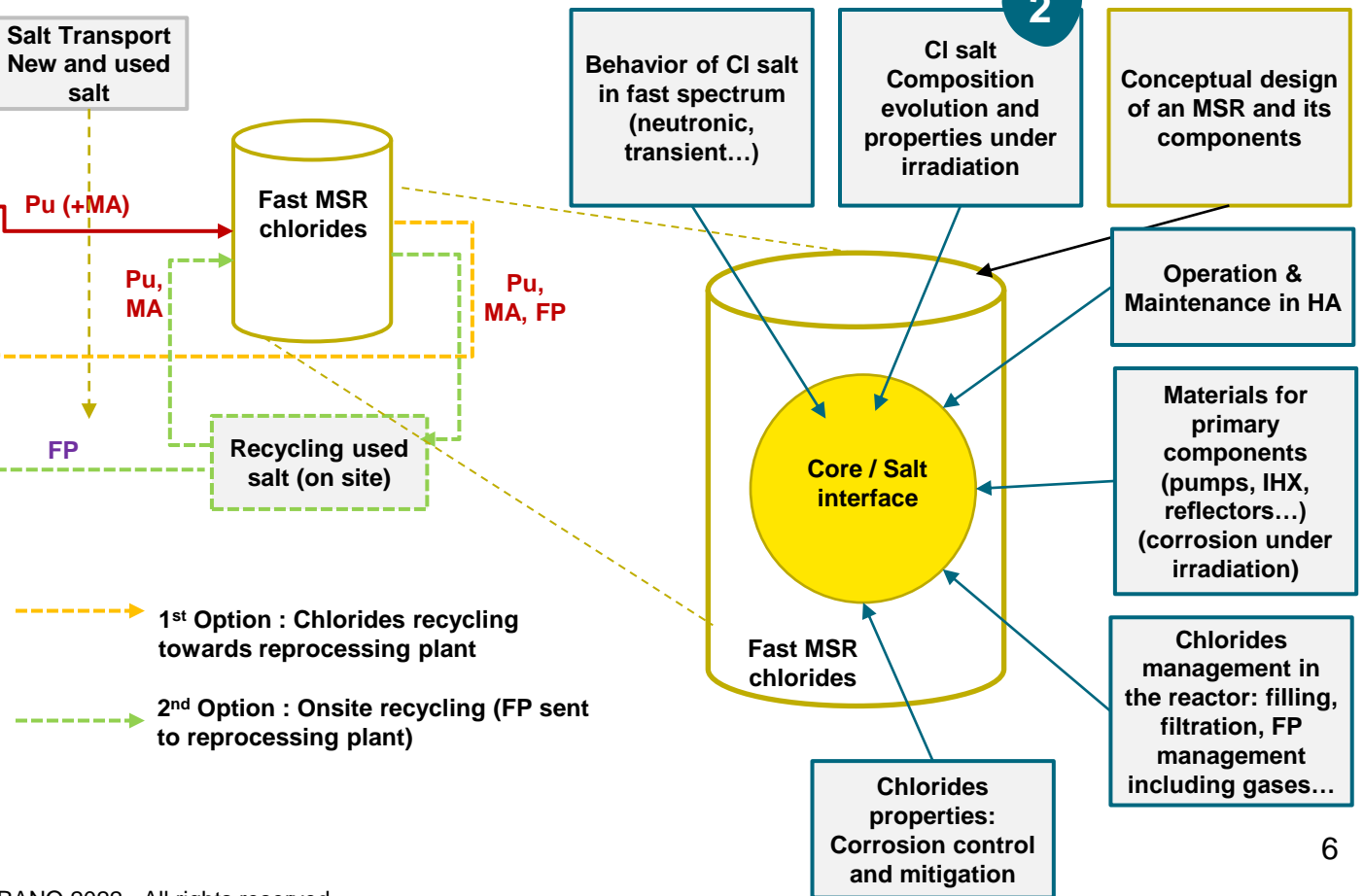
Overview of the R&D Program

Although a large variety of concepts and designs are considered worldwide, there are many common R&D aspects, in particular related to salt aspects and salt/materials interaction

Fuel Cycle

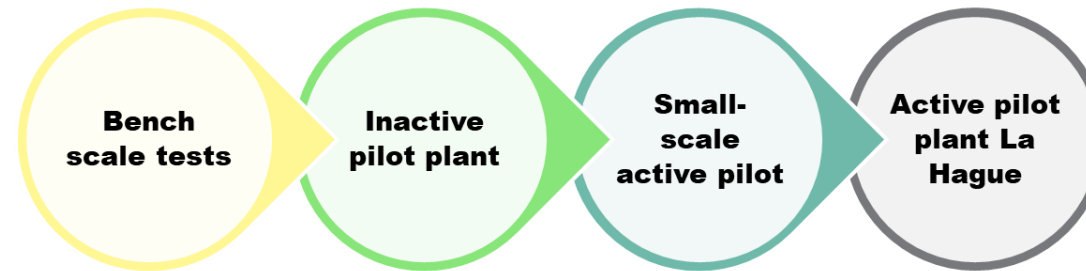


Reactor and fuel

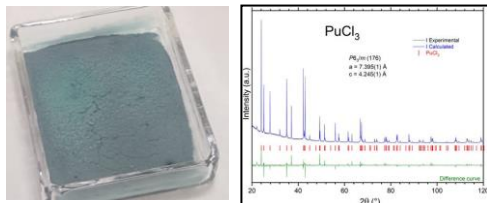


R&D on salt synthesis

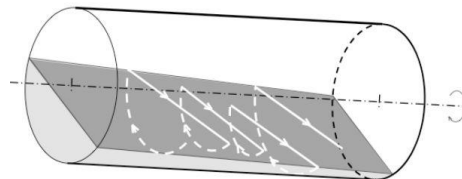
Production of actinide chlorides at industrial scale is a strategic development required for the success of most R&D programs



- Fundamental studies (reaction kinetics & conditions) on inactive simulant salts
- Proof of concept: batch production of PuCl_3 - batch production at gram scale



- Process scale-up, development and prototyping
- Process demonstration for inactive salts: continuous production at kg scale



Salt production in 2030

- Engineering studies to support process development



R&D on salt properties

Very little experimental data are available on chloride salts

	NaCl-UCl ₃	NaCl-PuCl ₃
Melting behaviour	✓	✓
Vapour pressure & Boiling Point	✓	✓
Heat capacity	✗	✗
Density	✓	✗
Viscosity	✓	✗
Thermal conductivity	✗	✗
Surface tension	✓	✗

Experimental characterization of fuel salts:

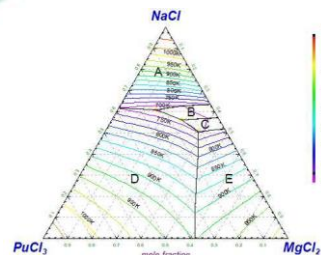
- Fill the existing experimental gap on chloride salts
- Provide a complete set of data on the key thermo-physical properties of the fuel salt required for reactor design and safety assessment

Salt irradiation

- Provide description of the fuel behavior during irradiation, i.e. behavior of fission products and evolution of thermo-physical properties
- Validate the developed model thermodynamic model as well as the neutronic model of isotopic evolution during burn-up
- Demonstrate chemical control in the fuel during irradiation

Model development:

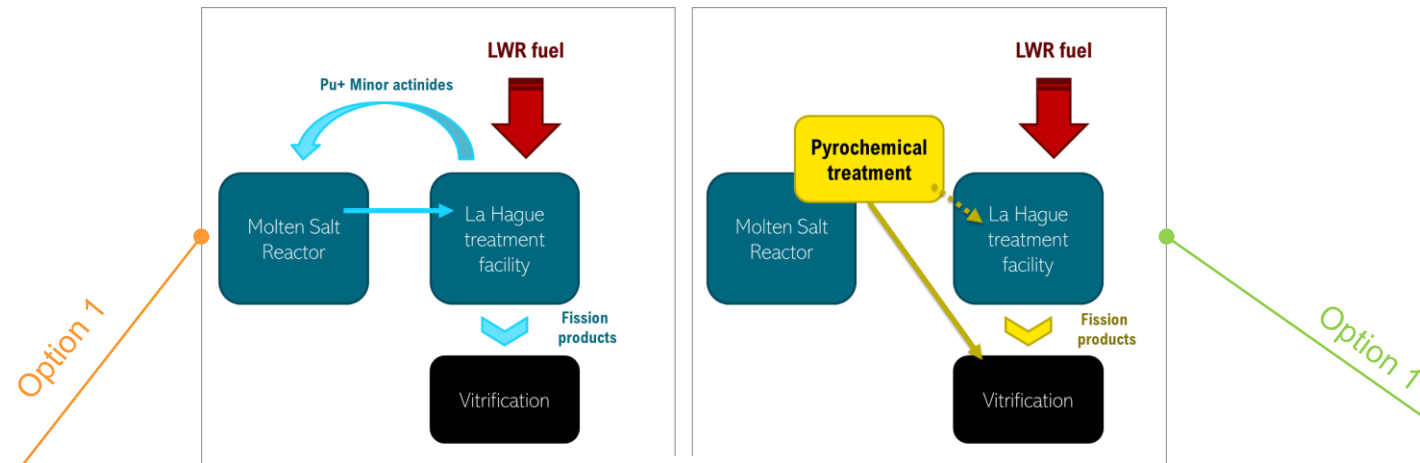
- Allow for development and validation of models required for simulation and properties prediction in a broader range of compositions and conditions



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R&D on salt treatment

Back-end options associated with the use of molten chloride salts as fuel need to be demonstrated. In order to minimize time to market, compatibility with the existing facilities is essential.



R&D on the key conversion step

- ✓ Dissolution experiments
- ✓ Requirements for compatibility with the existing process (e.g. effluents composition limits, cooling time).
- ✓ Requirements for fuel transportation and glass canisters.

MIMOSA

Funded by
the European Union

R&D on the pyrochemical separation

- ✓ Basic electrochemical studies on the separation of lanthanides and actinides
- ✓ Extraction methods
- ✓ Requirements for compatibility with the existing process



Conclusions

As Orano's core business is the **fuel cycle**, these aspects are at the leading edge of our R&D strategy on MSR.

We believe that **international cooperation** is vital to succeed in the R&D programs leading to a commercial MSR.

Orano is willing to increase engagement with key international partnerships and seek to **leverage synergies** with bilateral and multilateral programs.



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Giving nuclear energy its full value