Value added of MSRs in spent fuel management strategies

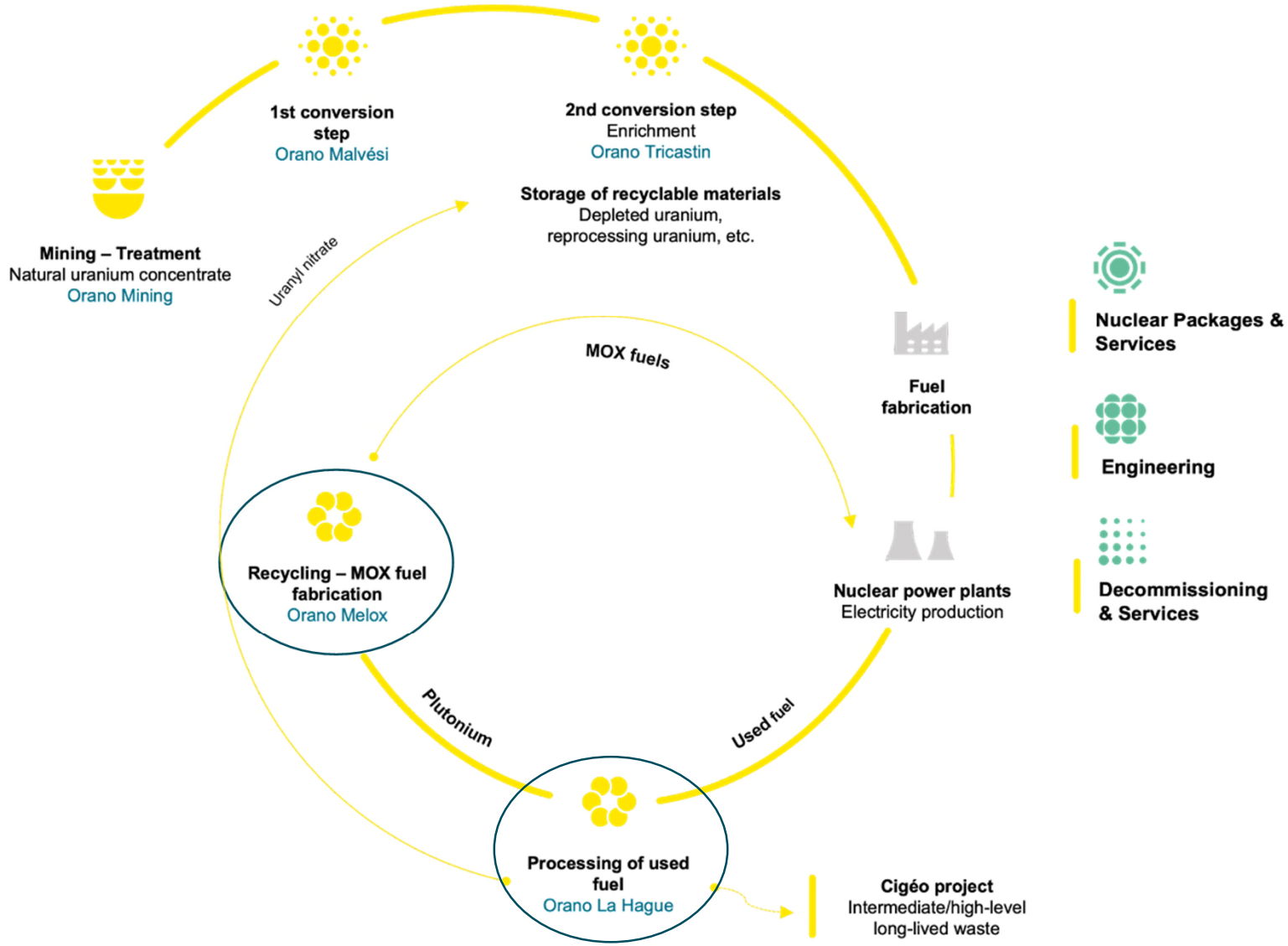
SAMOSAFER workshop

November 29, 2023

I. Morlaes

orano

01 Orano - World expert in the nuclear fuel cycle



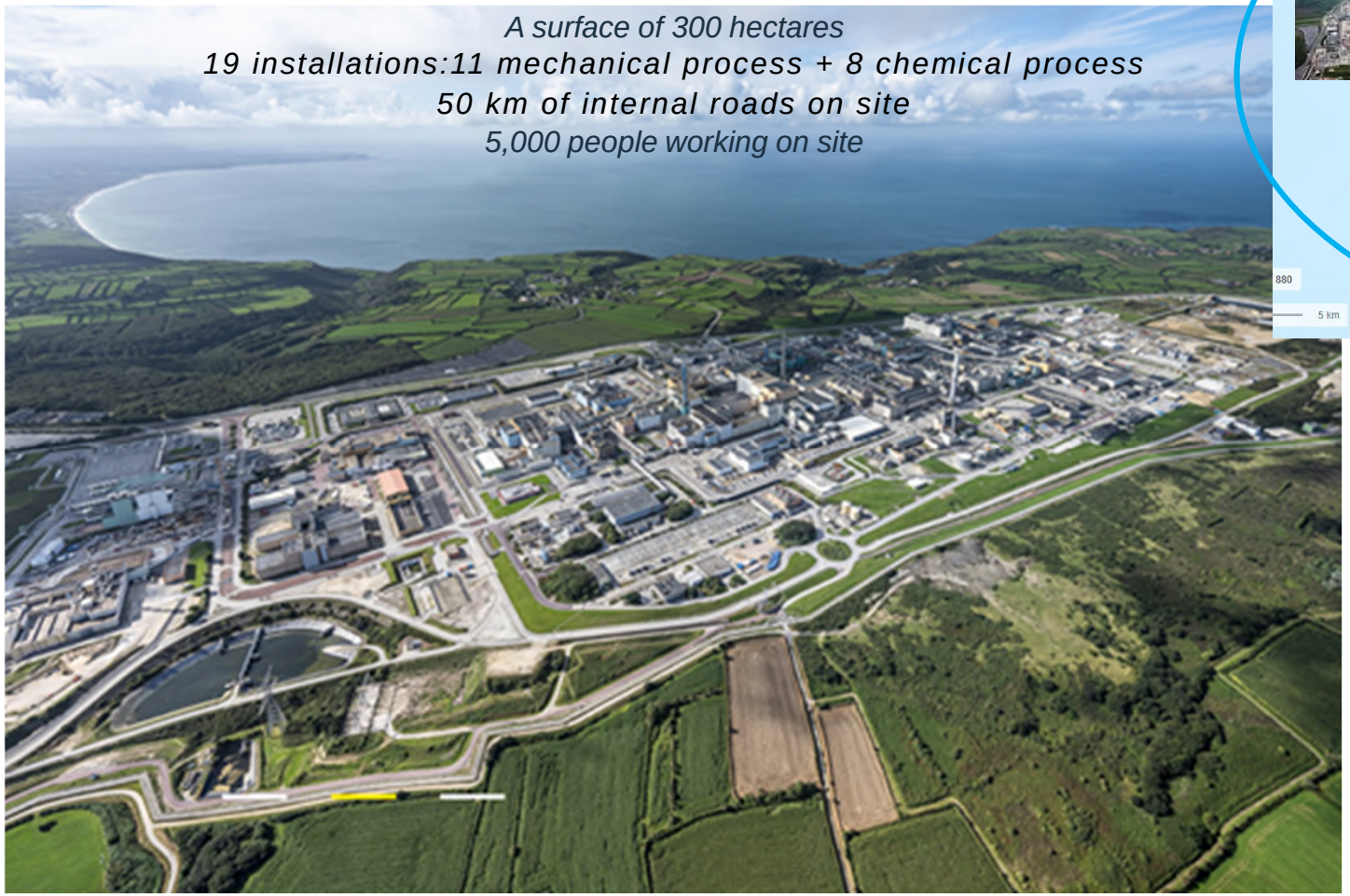
The Orano Group offers its customers high-performing products and services, in mining, conversion, enrichment, recycling, logistics, engineering and decommissioning.

Orano is also **a major force in nuclear medicine and targeted alpha therapy using ^{212}Pb,** through its subsidiary Orano Med.

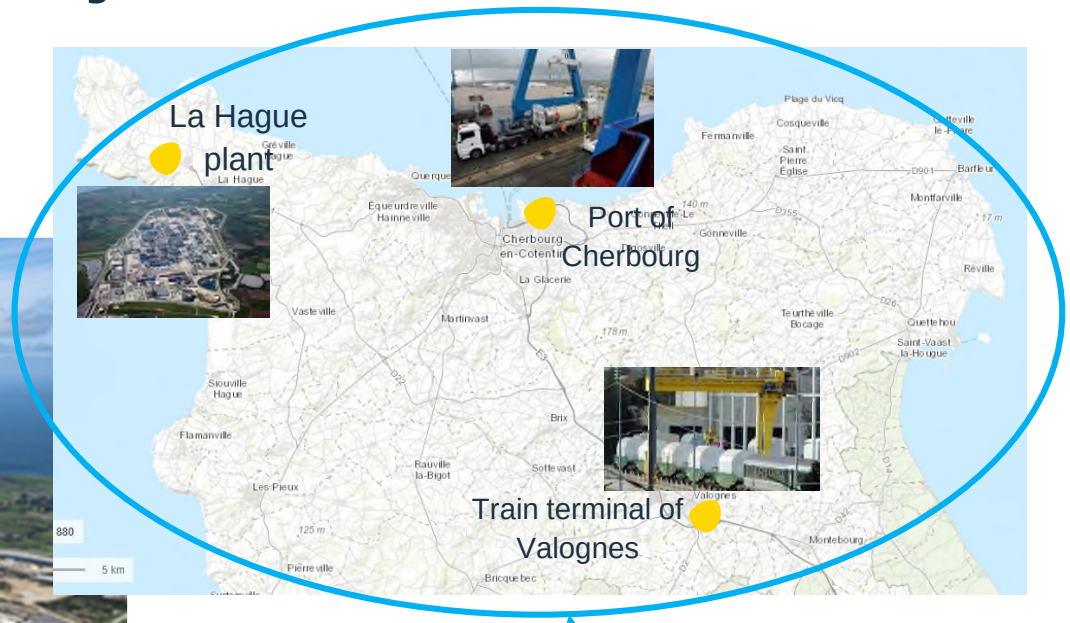
01

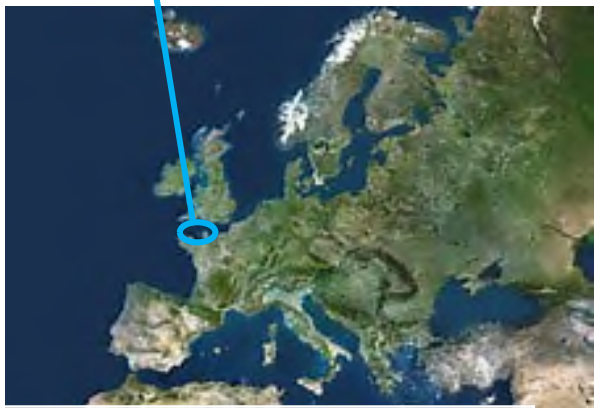
The La Hague plant is a strategic asset which has addressed Back-End challenges for LWRs spent nuclear fuels for 50 years

~28,000 tHM reprocessed for France
~10,500 tHM reprocessed for 6 other countries



A surface of 300 hectares
19 installations:11 mechanical process + 8 chemical process
50 km of internal roads on site
5,000 people working on site





https://youtu.be/V0UJSlKIy8g

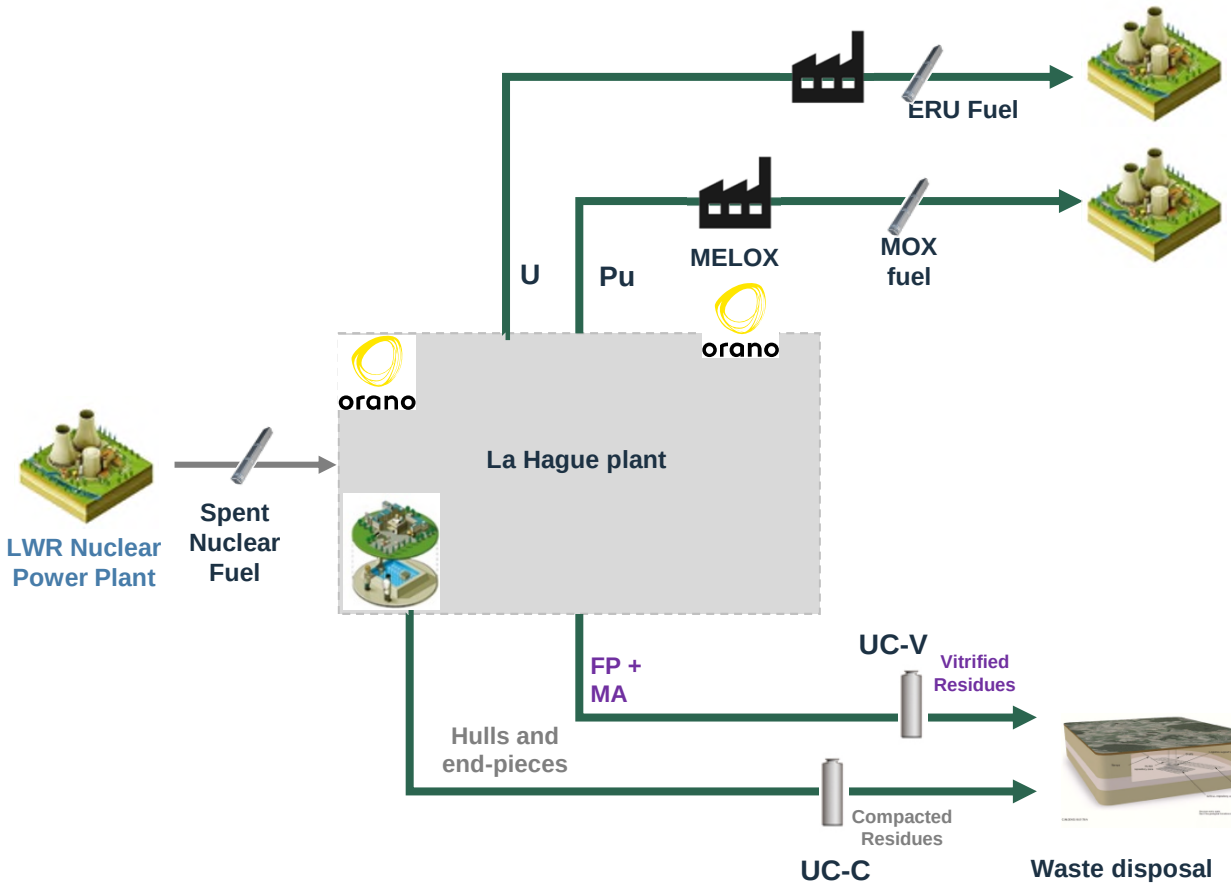
6 other countries : Germany, Belgium, Spain, Japan, Switzerland, Italy, the Netherlands

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

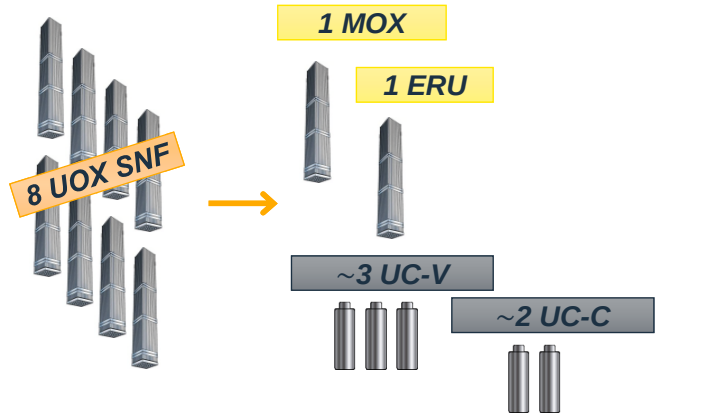
Two production lines

- UP2-800 (~800 tHM/y capacity)
- UP3 (~800 tHM/y capacity)

Based on PUREX Process
(Pu and U Refining by Extraction)



96% Recyclable materials



4% Ultimate wastes

- *96% recycled materials*
- *Up to 25% savings in Natural U*
- *HLW volume reduction by 5*
- *HLW radiotoxicity reduction by 10*
- *Safe & secure ultimate waste (without Pu)*

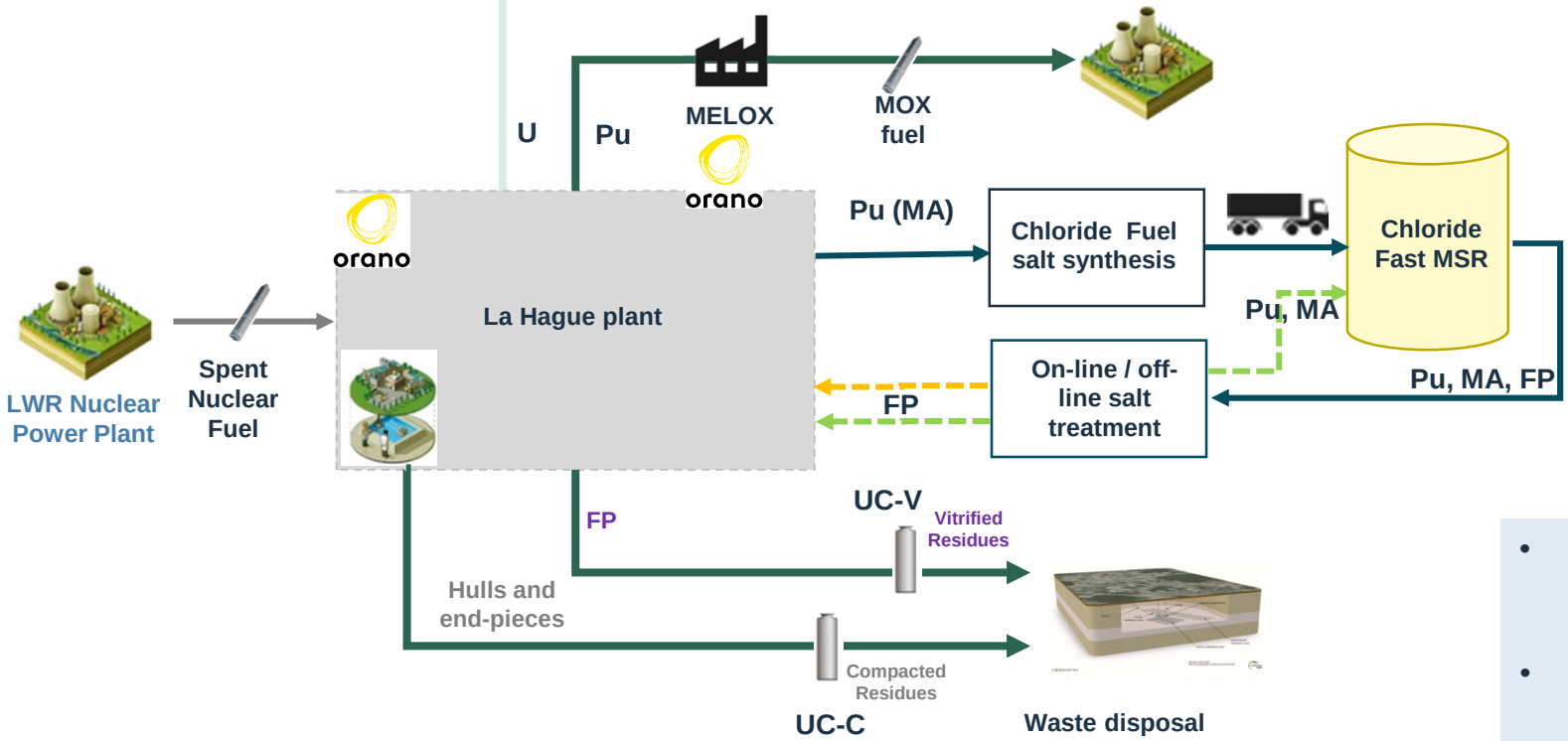
02

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

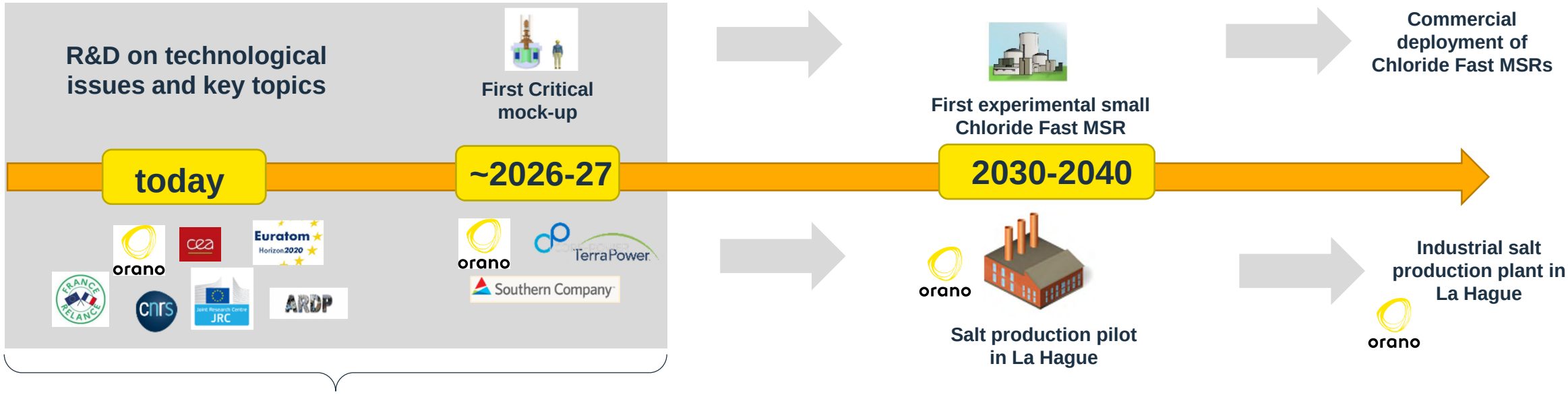


- **Option 1** : used salt (FP+MA) sent to La Hague for vitrification
- **Option 2 :** on-site salt polishing ➔ FP-only salt transportation to La Hague for vitrification

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

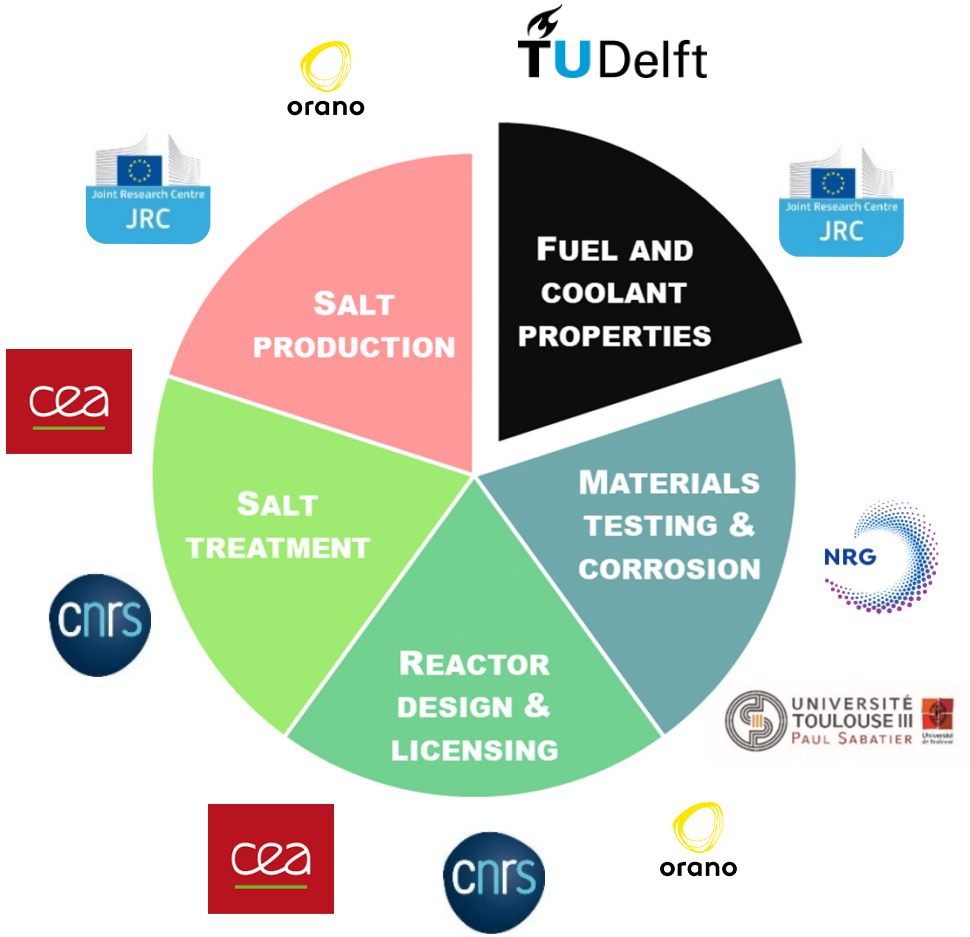
Orano has two ambitions :

- 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 $PuCl_3$-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 Cl MSRs

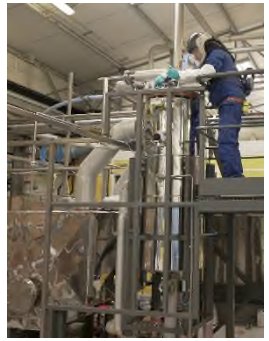
Orano's R&D program main objective : to facilitate the pathway to a MSR Demo



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

HRB

Development & qualification of process and equipment (inactive)



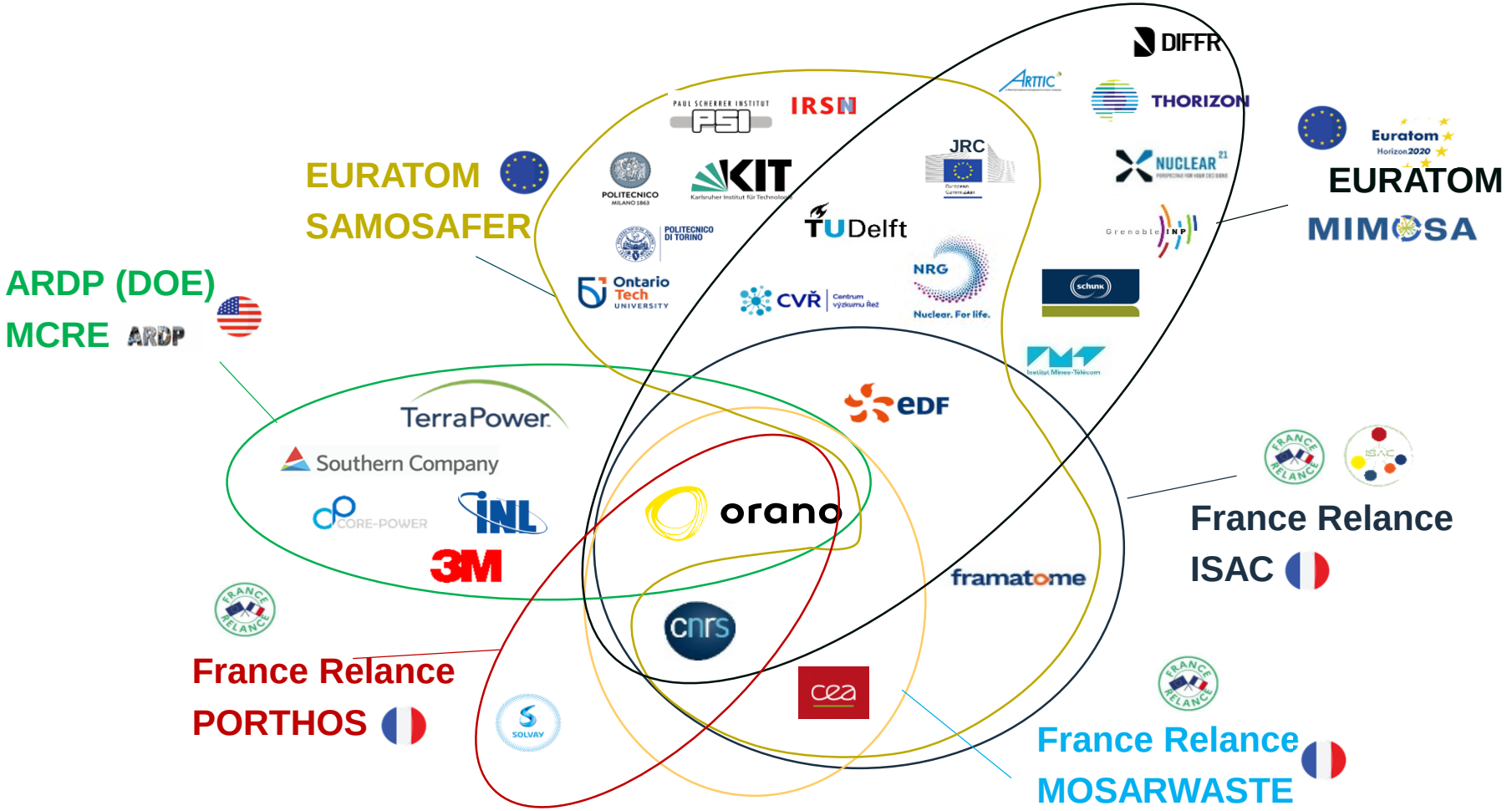
CIME

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

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

03

In parallel to the Orano's R&D program, several French and International collaborative R&D projects are running today



- **ARDP :** *Advanced Reactor Development Program* (DoE, USA) : 2022-2027
  - MCRE : *Molten Chloride Reactor Experiment* (1st critical Fast MSR mock up in U)
- **ISAC :** Innovative System for Actinides Conversion : 2022-2026
- **PORTHOS:** *PrOcédé de valoRisation du THOrium en Sels fondus :* 2022-2026
- **MOSARWASTE:** *MOlten SAlt Reactor WASTE management* : 2022-2026
- **MIMOSA:** *MultI-recycling strategies of LWR SNF focusing on MOlten SAlt technology* : 2022-2026

MIMOSA

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

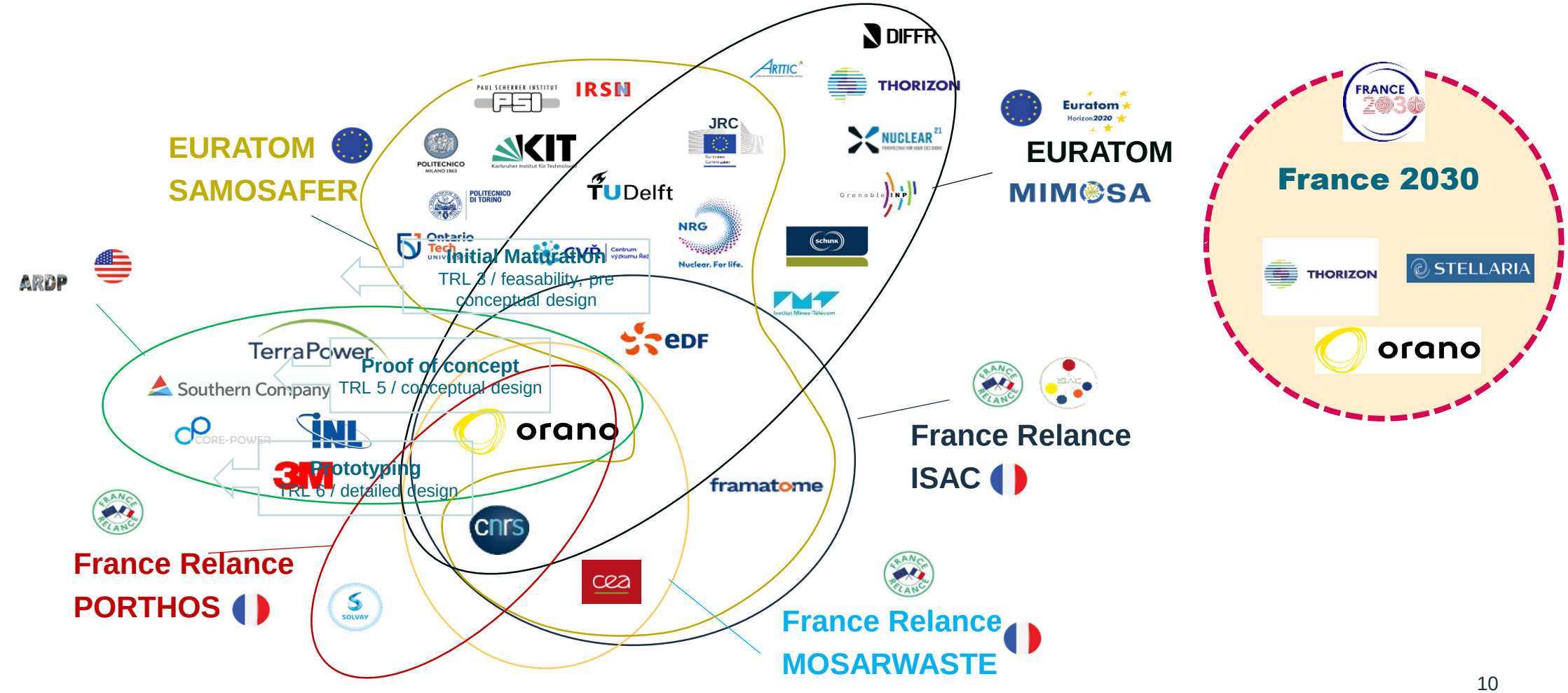
WP1 - Multi-recycling scenario analysis and roadmapping	WP2 – Molten salt properties	WP3 – Molten salt composition evolution in reactor	WP4 – MSR key technologies	WP5 – Molten salt recycling and back-end	**WP6 - Production and recovery of valuable isotopes**

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.*

In parallel to the Orano's R&D program, several French and International collaborative R&D projects are running today

France 2030 is the next program we are competing for…



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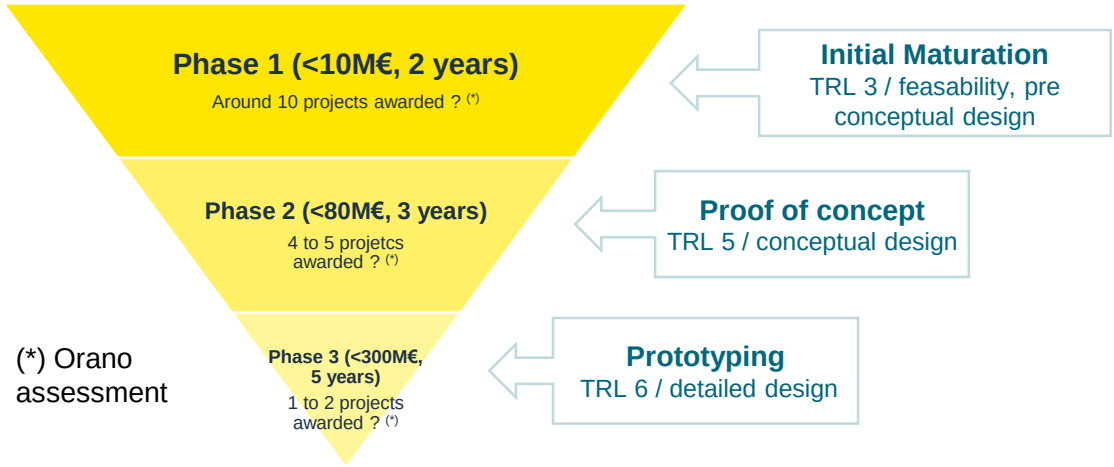
France 2030 "advanced reactors" Call For Projects (CFP) has a 500 M€ budget for 10 years with the following objectives

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



(*) Orano assessment

CFP phase 1 files submission is complete

- Waiting for the last award-winners announcement early 2024

04 Orano commitment to France 2030 CFP on AMR technology

Orano partners 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

Each of the 2 projects includes the same Scope of Work for Orano: the development of their common Fuel Cycle

Common WPs on Fuel Cycle :

PuCl3 pilot plant	Mixed Salt pilot plant
UCl3 pilot plant	Used salt interim storage
ThCl4 pilot plant	Fresh and used salts transportation

Conclusions …

Fast Cl 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 Cl MSRs

European SMR Industrial Alliance

France 2030

orano

Giving nuclear energy its full value