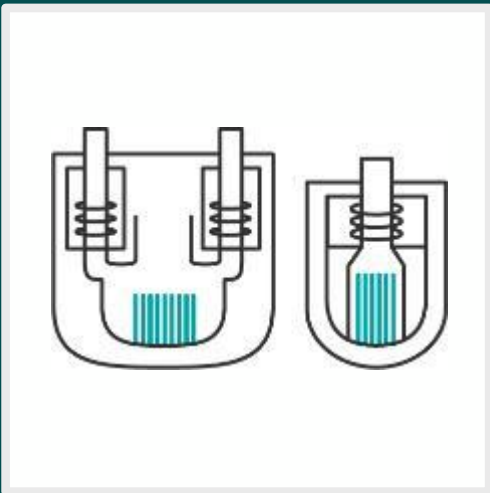


# ***newcleo's vision and R&D Programme***

**11 July 2024**

**Andrea Barbensi – LFR Engineering Director**

# A *new*, innovative player in nuclear energy



## REACTOR DESIGN: Small Modular (SMR) + Lead-cooled Fast Reactors (LFR) = AMR

*newcleo* is working to design, build, and operate Gen-IV Advanced Modular Reactors (AMRs) cooled by liquid lead



## FUEL MANUFACTURING: Mixed Uranium Plutonium Oxide (MOX)

MOX and Fast Reactors allow the multi-recycling of nuclear waste into new fuel with no new mining for generations

SAFE AND AFFORDABLE

CLEAN AND RELIABLE

CIRCULAR



Launched in  
**SEPTEMBER 2021**



Presence across  
**Europe**



## ACQUISITIONS

FUCINA ITALIA  
A *newcleo* company



RÜTSCHI  
A *newcleo* company



**700+**  
EMPLOYEES



**25+**  
YEARS OF  
RESEARCH



**14+**  
PATENTS



EUR400 MILLION of private funds  
~EUR50 MILLION turnover in 2024  
Currently raising up to **EUR1 BILLION**

# Nuclear energy's critical role in energy future

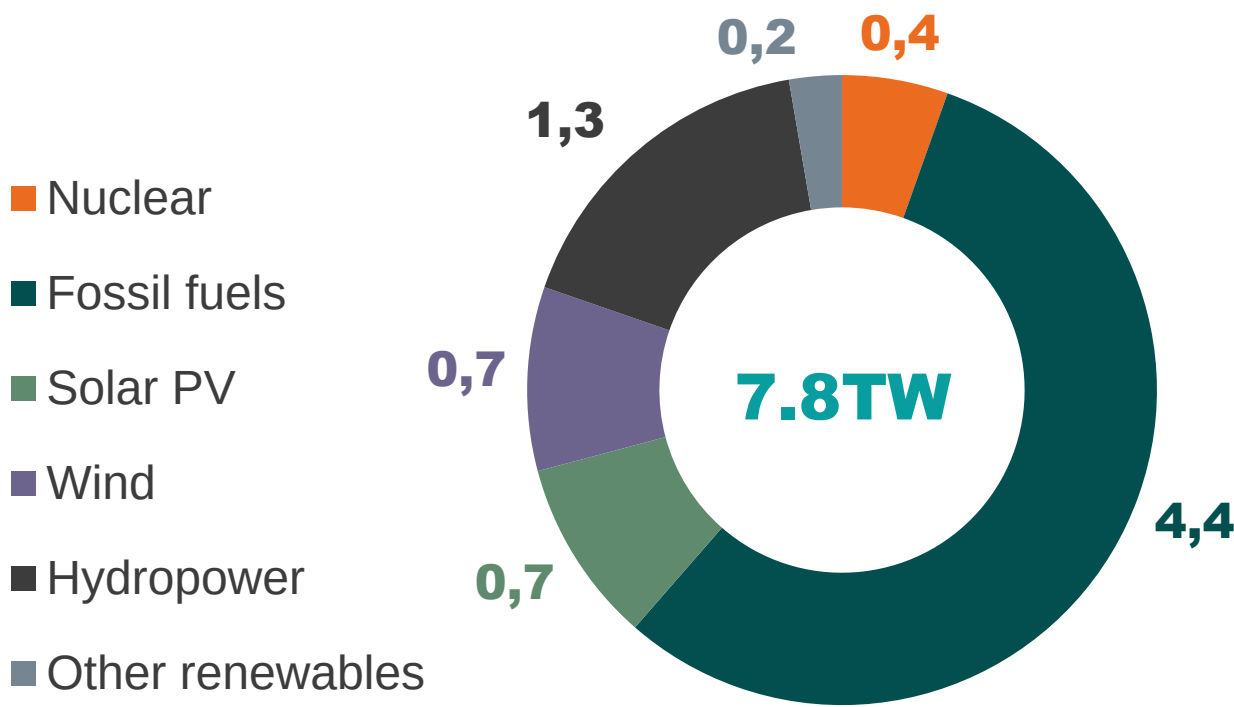
## Decarbonisation and energy security dilemma

- Growing energy demand
- Decarbonisation objectives
- Increasing installed intermittent renewable sources
- Higher electrification of end-uses
- Higher volatility of fossil markets
- Geopolitical security of supply
- Critical materials scarcity

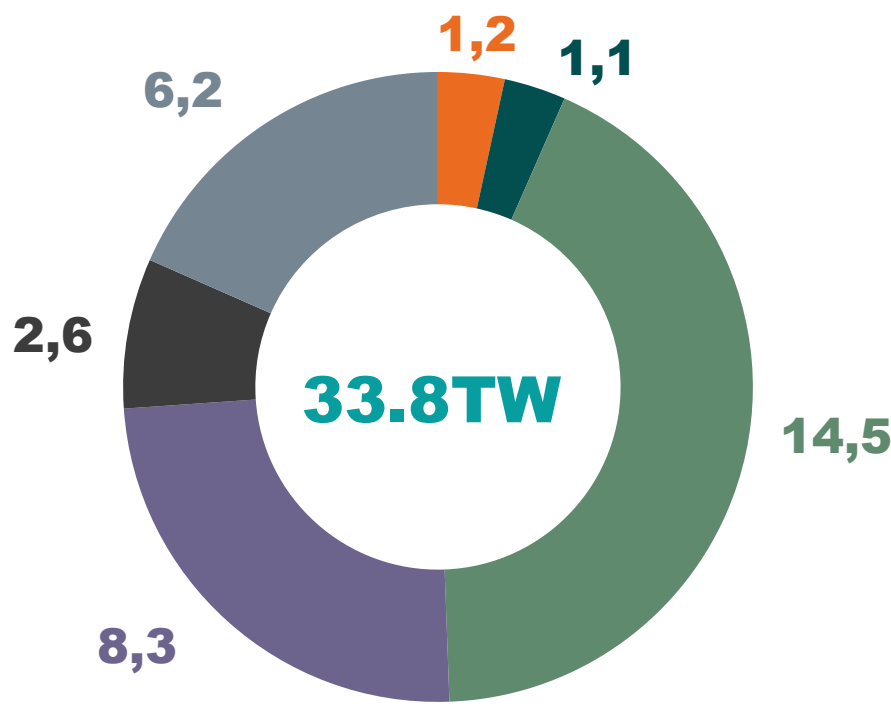
## Fission can be the answer:

- Reliable and dispatchable, complementing intermittent renewable sources
- Dense, with small footprint on the environment and large availability of fuel supply
- Enables energy security and independence
- No direct CO<sub>2</sub> or pollutants emission

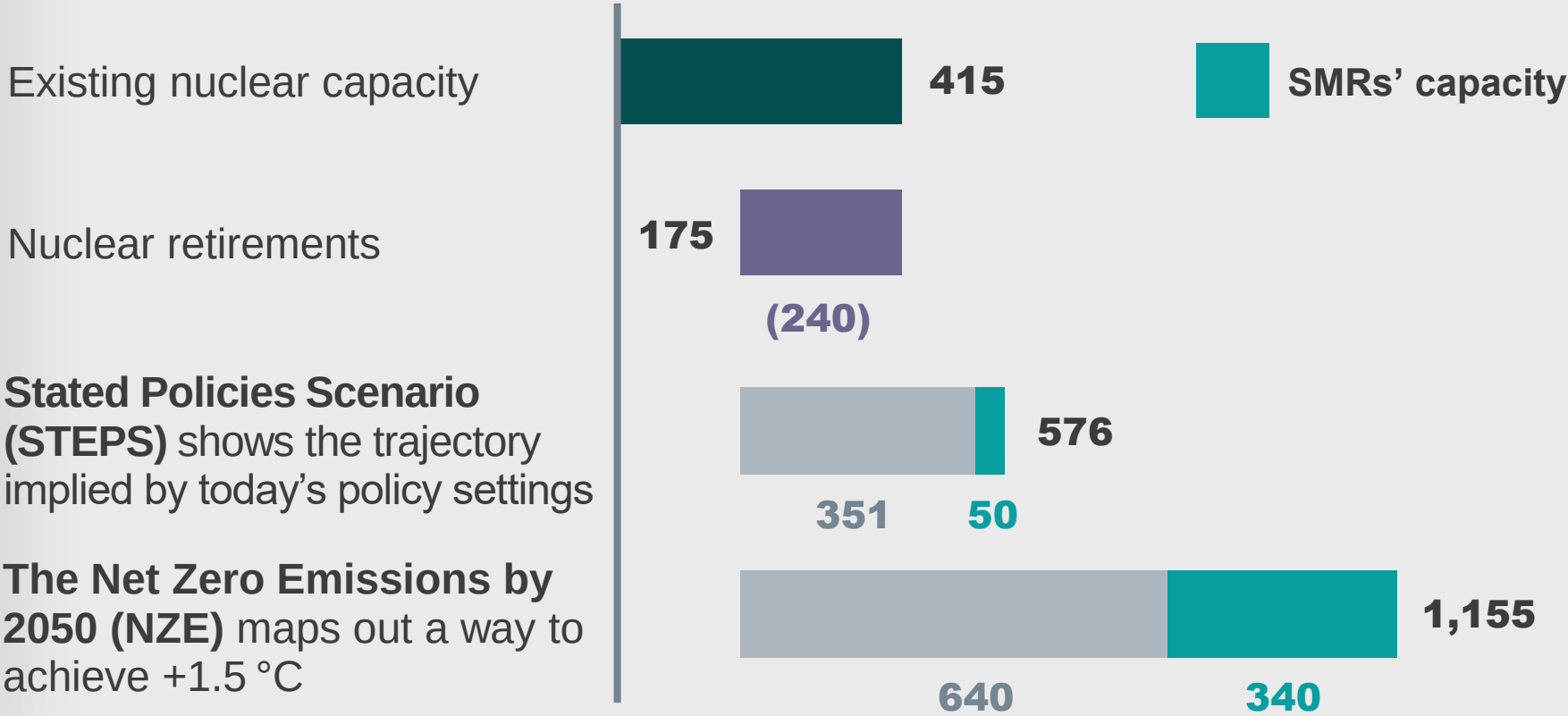
INSTALLED CAPACITY 2020



INSTALLED CAPACITY 2050

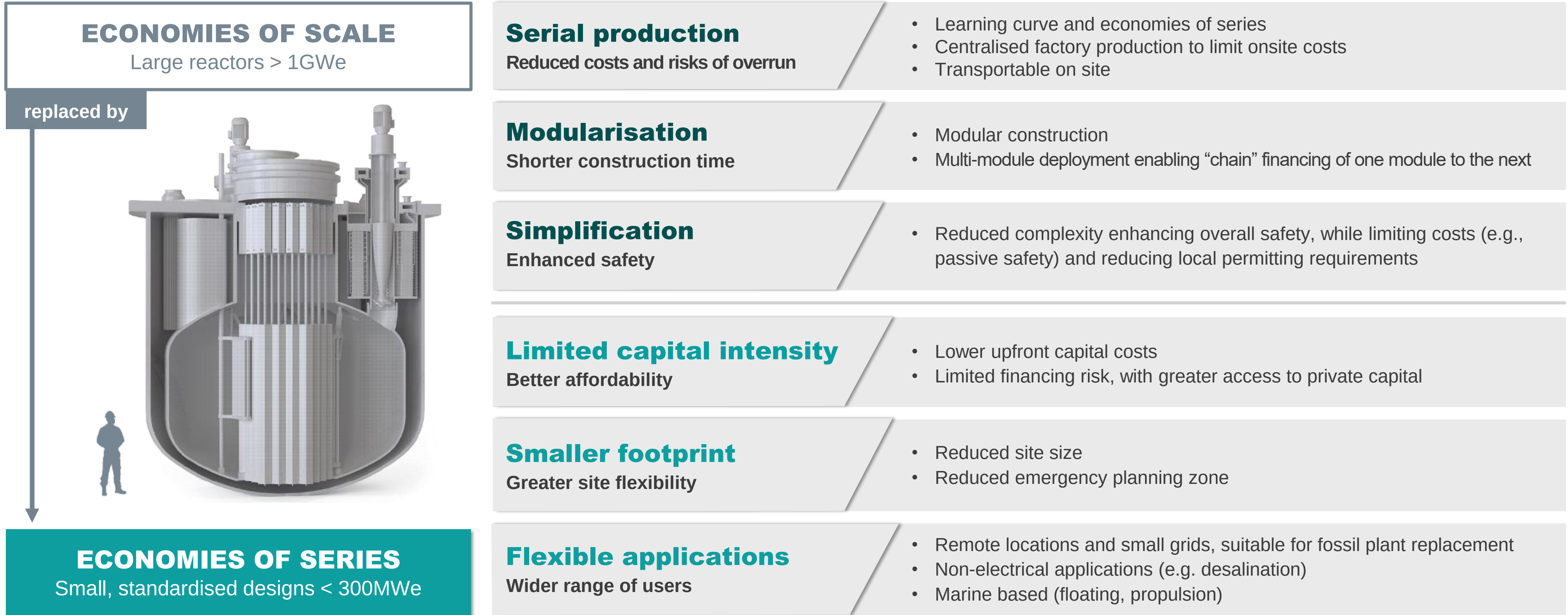


Nuclear installed capacity (GW) by 2050 as per IEA



# SMRs improve economics and flexibility in nuclear

Small Modular Reactors (SMRs) are nuclear fission reactors. Smaller than conventional nuclear reactors, they are designed to be manufactured at a plant and transported to a site for installation



# Advanced Nuclear Reactors: Generation IV (Gen-IV)

SMRs can use traditional technology (pressurised water and thermal neutrons) or can also be **Advanced Modular Reactors** (AMRs).

Since 2000, an international forum coordinated by the DOE has prioritised six **Generation IV** nuclear technology systems for development.

## Why LFRs amongst the GEN-IV technologies?

- Only Fast Reactors allow closing the fuel cycle, a sustainable use of nuclear energy
- LFRs can enable intrinsic safety in accident scenarios
- Lead does not interact chemically with water or air unlike sodium, working at atmospheric pressure. Lead is an excellent shield for gamma radiation. **LFRs can be simplified and made more cost competitive** compared to other Advanced Nuclear Reactor designs

### Gen-IV categories:

Gas-cooled Fast Reactor (**GFR**)

Lead-cooled Fast Reactor (**LFR**)

Molten Salt Reactor (**MSR**)

Supercritical-water-cooled Reactor (**SCWR**)

Sodium-cooled Fast Reactor (**SFR**)

Very-high-temperature Reactor (**VHTR**)

# newcleo relies on 25+ years of international research efforts



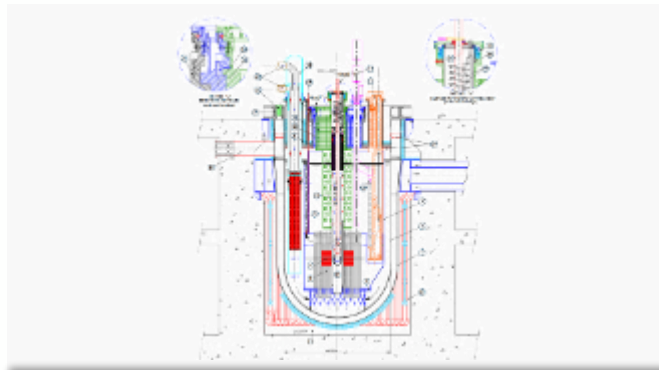
The concept of the **Accelerator Driven System** was first introduced at **CERN** by Nobel Laureate and Director General Carlo Rubbia as 'Energy Amplifier'

1993



First contacts with Russian scientists who designed the Alpha class nuclear Pb-Bi **submarines**. V.Orlof presents at CERN the conceptual project of his BREST reactor (now under construction)

1995



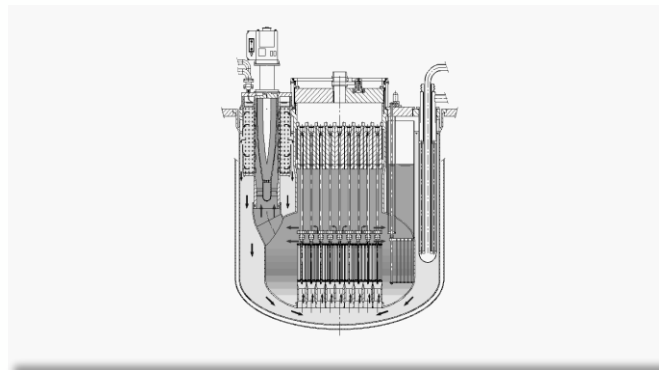
Italian Government funding an industrial project producing a reference configuration of the **ADS Experimental Facility (XADS)** with Luciano Cinotti as technical project manager

1999



Design and realisation of the large-scale liquid lead test facility CIRCE at ENEA-Brasimone, today the most relevant R&D infrastructure for LFR development

2002



**Hydromine Nuclear Energy** incorporated to design the **AS-200 and TL-X**, today part of the Gen-IV projects listed by the International Atomic Energy Agency (IAEA)

2013

**1994**

**FEAT** (First Energy Amplifier Test) run at CERN to demonstrate the ADS **feasibility** for energy production



**1996**

**TARC** (Test of Adiabatic Resonance Crossing) experiment at CERN to demonstrate **neutrons phenomenology in pure lead**



**2000**

LFR chosen as one of the **six leading technologies** developed by the **GIF** (Generation IV International Forum)



**2003**

The EU, through the **5<sup>th</sup> Framework Program**, launched a broad R&D program (~50 academic and industrial organisations) on lead-based ADS technologies



**2021**

**newcleo** incorporation and acquisition of Hydromine Nuclear Energy with its set of international patents  
Capital raise: **€100m**



# Heavy Liquid Metal: Lead-cooled Fast Reactors



Lead properties enable design simplification (hence **economic benefits**) and a high degree of inherent safety:

- Operating at atmospheric pressure, hence **thick forging not needed**
- No significant energy release in case of vessel failure, hence **high pressure-resistant containment not needed**
- Favourable chemical properties, hence **extra safety provisions can be avoided, no intermediate loop, possible use of low-cost water or air loops for DHR**
- Coolant boiling practically eliminated, hence **safety injection systems not needed**
- Significant thermal inertia in case of a loss of heat sink
- Lead fission product retention capability, gamma radiation shielding
- **High plant efficiency (40-50%)**
- **High operating temperature enables non-electrical uses**

## Unique properties for fast reactors design

| Absorption cross-section                       | Boiling Point | Heat transfer properties                  | Density @400°C             |
|------------------------------------------------|---------------|-------------------------------------------|----------------------------|
| Low                                            | 1737 °C       | Good                                      | 10580 kg/m3                |
| Large fuel pin lattice, low core pressure loss |               | Reduced risk of fuel cladding overheating | No risk of core compaction |

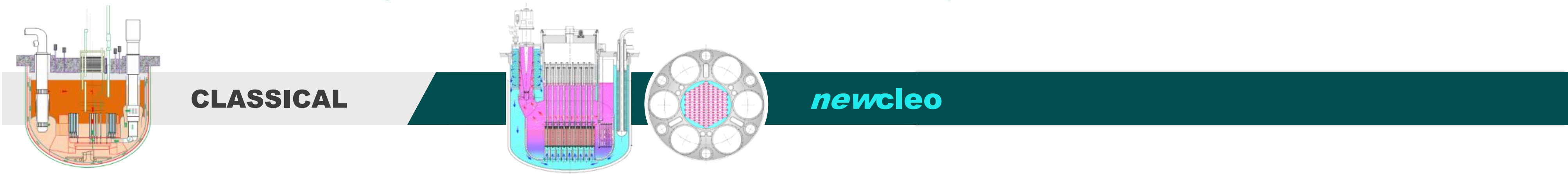
## But it also has properties that discouraged some designers, solved by *newcleo*

| Density @400°C          | Melting Point | Opacity | Compatibility with structural materials |
|-------------------------|---------------|---------|-----------------------------------------|
| 10580 kg/m <sup>3</sup> | 327 °C        | Yes     | Corrosive                               |

80 effective reactor-years of Lead Bismuth Eutectic reactors: 15 among land-based and submarines in Russia starting in the 1950s

Construction started in Jun-2021 for an LFR

# newcleo's design: simplification is key



|                                  |                                                           |
|----------------------------------|-----------------------------------------------------------|
| Pump in the cold                 | hot collector                                             |
| Primary fluid inlet in the upper | lower part of the heat exchanger                          |
| Vertical                         | Radial flow of the primary coolant in the steam generator |
| Fuel element fully immersed in   | with heads out of the primary coolant                     |
| Fuel element fixed at the bottom | top                                                       |
| Primary pumps between            | inside the steam generators                               |
| Control rods inside              | outside the core                                          |
| Inner vessel larger at the top   | bottom                                                    |

**INNOVATIVE COMPONENTS/SYSTEM**  
**STEAM GENERATOR, REFUELLING SYSTEM, DHR SYSTEM, CONTROL RODS, FUEL ELEMENT**

**Compact and dense primary system**  

|                           |                                  |
|---------------------------|----------------------------------|
| ~4x less than Superphenix | Short reactor vessel: only 6.2 m |
|---------------------------|----------------------------------|

**Compact reactor building**  

|                       |                        |                 |
|-----------------------|------------------------|-----------------|
| No intermediate loops | Compact primary system | No risk of LOCA |
|-----------------------|------------------------|-----------------|

newcleo identified technical solutions to minimise the impact of lead's unfavourable characteristics and in some cases has also drawn design advantages. We innovate by reimagining the classical solution, resulting also in the elimination of several components no longer needed

# Evolution of Fast Reactors

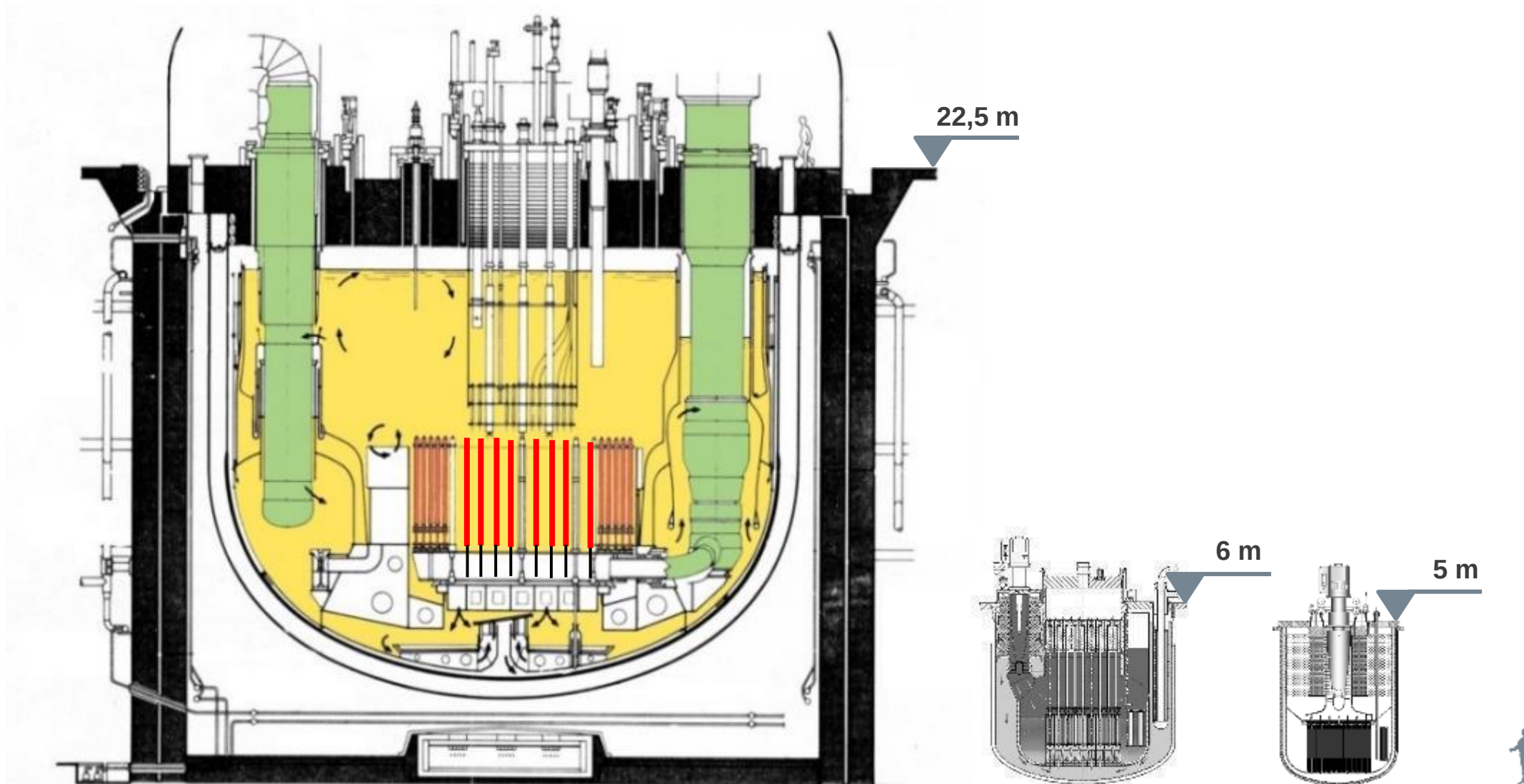
From old-generation SFRs to a new generation of small, modular LFRs

Among the Fast Reactors, there have been huge investments in the development of Sodium Fast Reactors (SFRs), but a very limited deployment. SFRs have turned out to be **expensive**

## Learning from the past

Fortunately, the **experience** acquired with SFRs can be almost entirely used for the development of LFRs. They use a similar fuel, functionally behave in a similar way, present similar thermal-hydraulic and mechanical aspects. But they are **more promising in terms of cost and safety**

50 years after the design of the old generation of nuclear, the strategy is now focusing on a significantly different approach: from huge projects to **Small Modular Reactors**



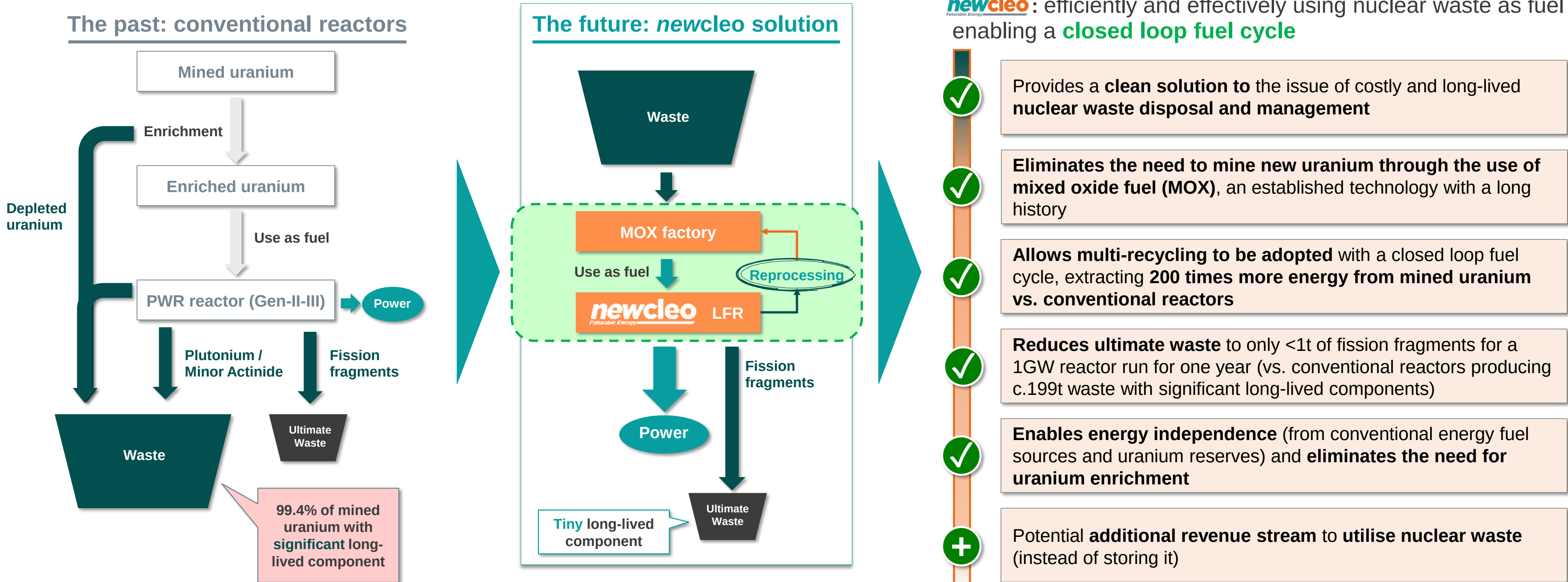
200 MWe

30 MWe

Superphenix (1974, 1240 MWe)

*newcleo* SMRs

# Newcleo's fuel technology approach solves the nuclear waste problem



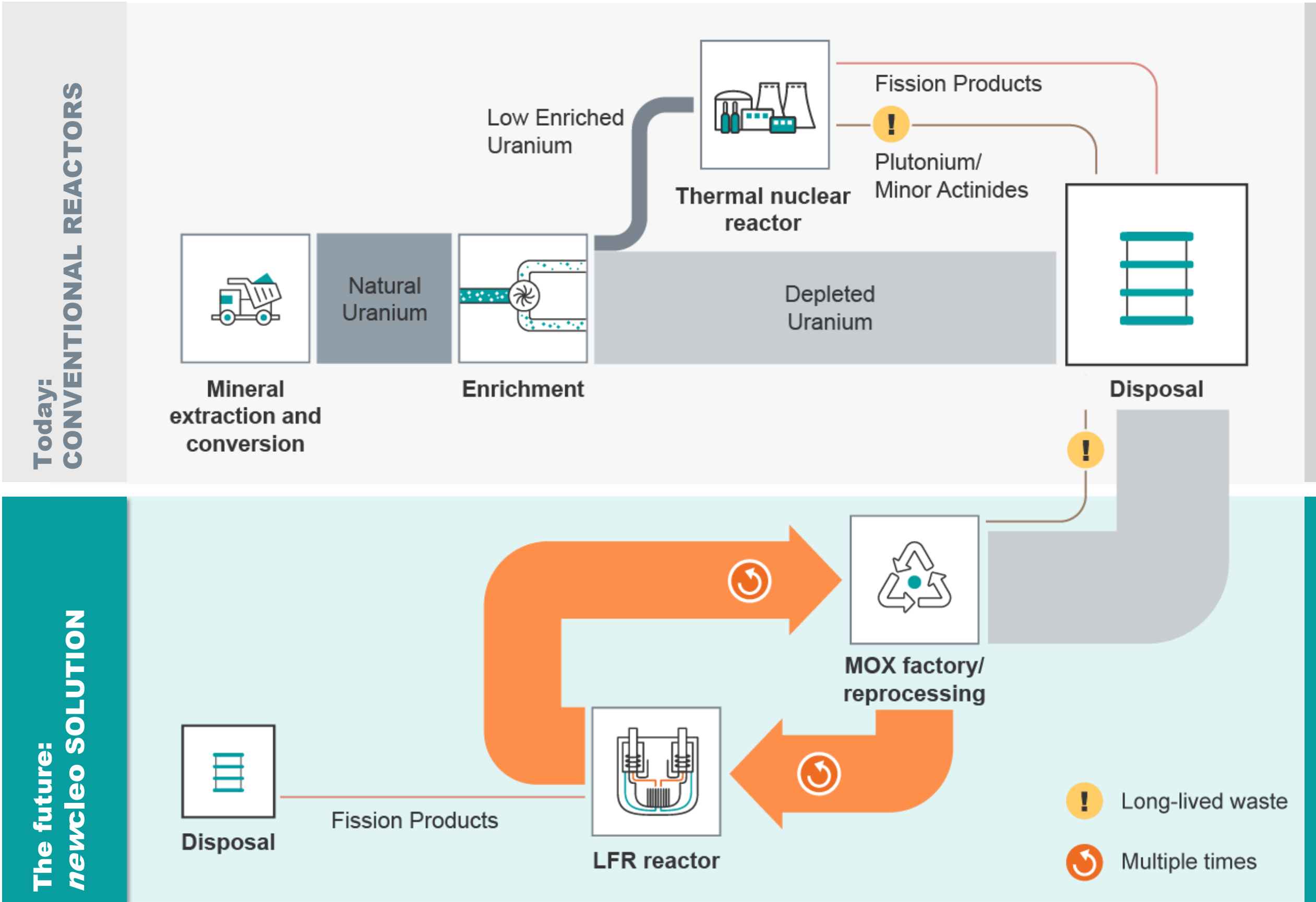


**newcleo's solution uses waste as fuel, reducing long-term waste by c.200x vs conventional nuclear;**  
**1GW from a newcleo LFR<sup>1</sup> would produce <1t of fission fragments per annum vs. c.199t of waste from conventional reactors**

Source: Company information; <sup>1</sup> Run for one year

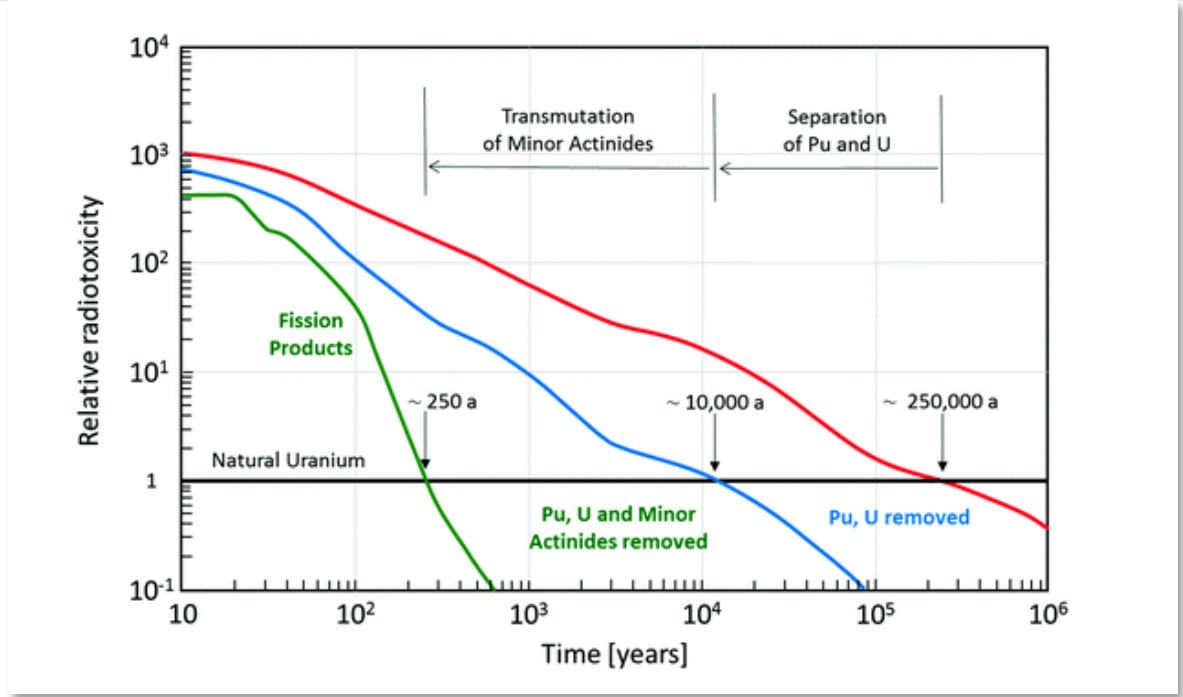
# Closing the fuel cycle: MOX

Including MOX (Mixed Pu-U Oxides) for cost effective, cleaner, and virtually inexhaustible production of nuclear energy, with no need of mining



Thermal fission reactors use a very small portion of the extracted uranium: an average 1GWe LWR uses every year 200t of mined uranium of which only 1t is fissioned (Fission Products), the rest is not used

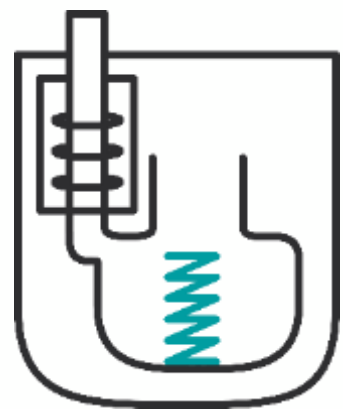
High-level waste has become an expensive liability



Today MOX for thermal reactors is used in a few countries, in a mono-recycling scheme. **Fast Reactors and fuel reprocessing** can extract energy from existing material and at the same time reduce radiotoxicity of residual waste to dispose: Fission Products return to value of the natural uranium ores after ~250 years

All artificial radioactivity created by reactors is virtually gone

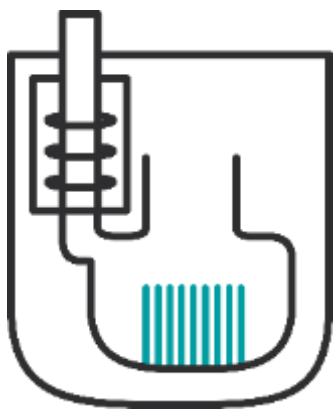
# newcleo's plan-to-market



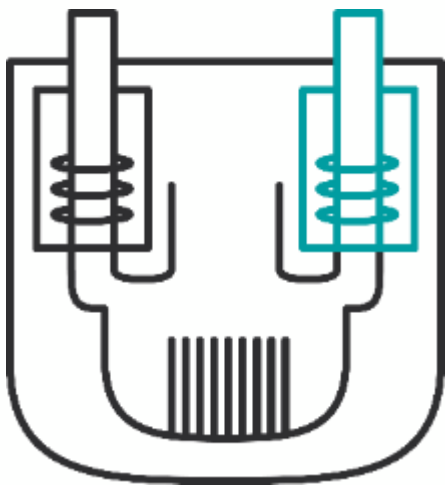
2026



2030



2031



2033

## R&D and Precursor

Several R&D facilities, and a **10 MW** non-nuclear facility with turbo-generator

Design, manufacturing and operation in progress

## MOX production

**FR-MOX production facility**, starting from available (separated) material in France

Basic Design and pre-licensing in progress: technical meetings with ASN and IRSN completed in June 2024

## LFR-AS-30

**30 MWe** nuclear irradiation reactor with core outlet at 440° and later 530°C

## LFR-AS-200

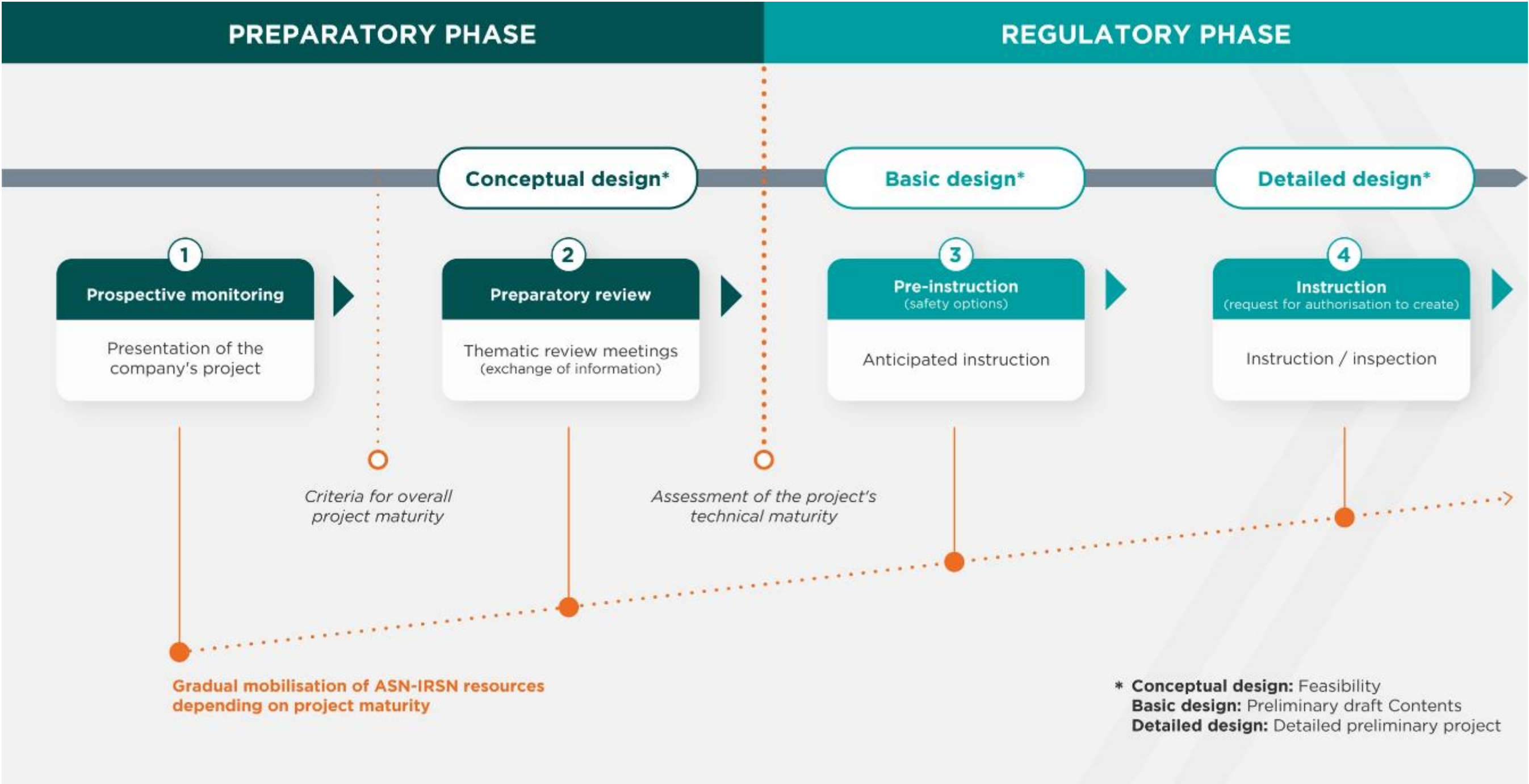
**200 MWe FOAK**, also for non-electrical uses (e.g. cogeneration and chemicals production)

Conceptual design in progress

# Licensing process in France

## Preparatory phase complete

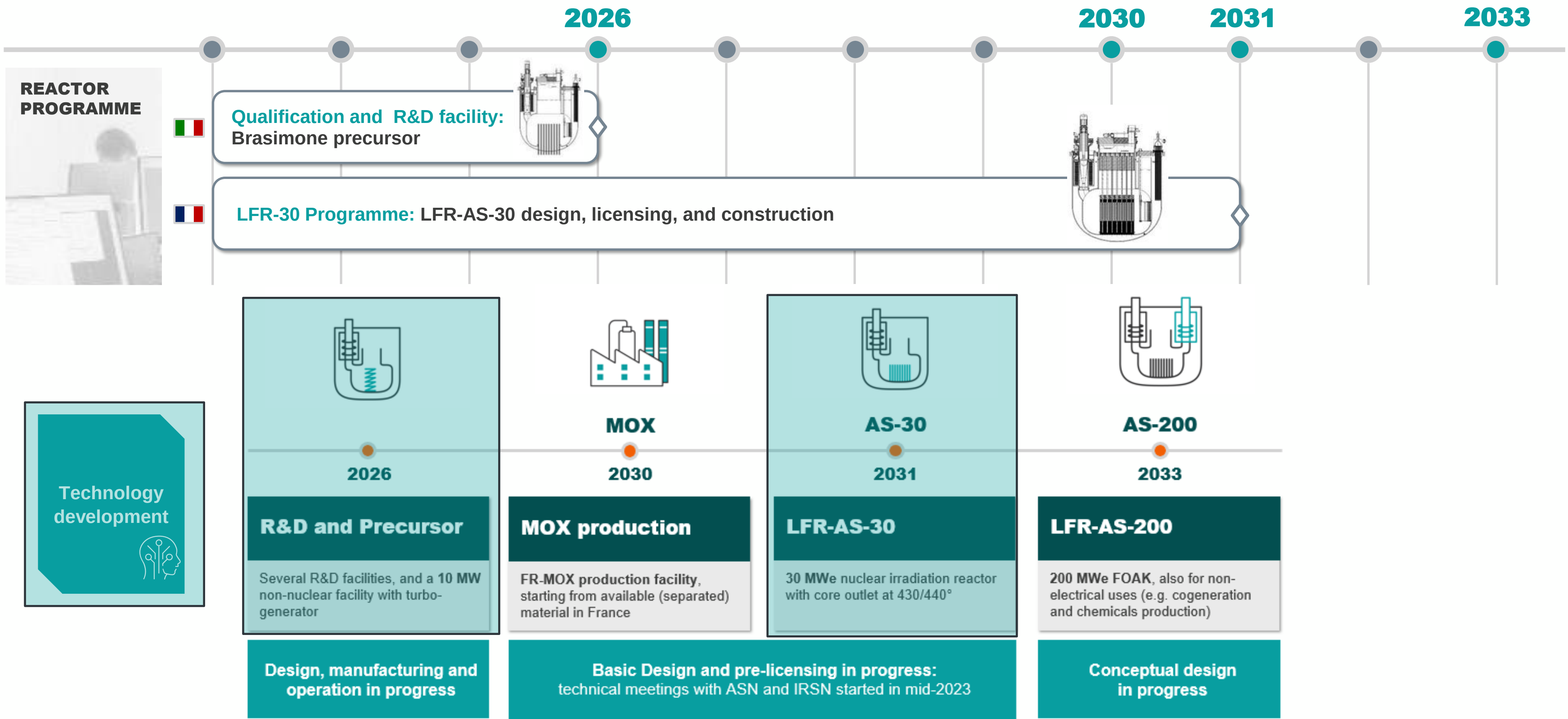
On **26 June 2024**, *newcleo* completed the "preparatory phase" set up by the French authorities for SMR developers, where they assessed the maturity of the project and discussed all safety options for our LFRs and the MOX plant, with a series of technical meetings and preparatory documents. *newcleo* will proceed submitting the official technical options, the French authorities will then establish a written advice which due consideration along with other derived from the preparatory phase discussions, will allow a faster process to grant the necessary authorisation.



# Our broad R&D programme

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# A well-defined roadmap to achieve tangible development goals



# R&D is at the core of *newcleo*'s DNA

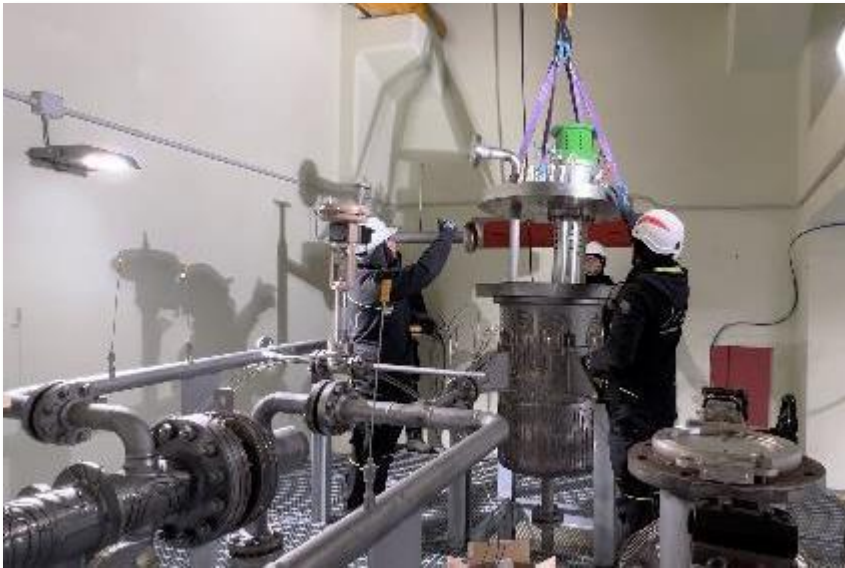
In parallel to engineering activities, *newcleo*'s R&D programme is progressing fast: findings are key in the completion of the reactors' design and licensing processes.

|                      |
|----------------------|
| UNDERSTANDING        |
| CHARACTERISATION     |
| QUALIFICATION        |
| VALIDATION           |
| ASSESSMENT           |
| OPERATION AND SAFETY |
| DEMONSTRATION        |

- Structural materials and coatings
- Fuel and fuel integrity
- Primary coolant behaviour and chemistry
- Core integrity
- Primary system integrity
- Instrumentation and Control (I&C)
- Reactor physics / neutronics
- Components handling systems
- In-Service Inspection (ISI) and repair
- Balance of plant
- Plant operation and accident response

Close technological partnership with **ENEA** and notable contributions from **SRS** and **FUCINA**  
Collaborations with labs and universities  
Ongoing conversations with specialised companies

SIMULATION AND  
EXPERIMENTAL  
CAMPAIGNS



Large investments: **EUR90+ millions allocated**

# ENEA partnership

## A strong partnership on LFR technology

*newcleo* Brasimone site



**H:** main hall, **E:** electricity buildings  
**C:** chemistry lab, **O:** offices

*newcleo* and ENEA signed a framework agreement on March 2022, a few months after the incorporation of the company

The scope of the collaboration spans over many aspects of Lead technology and deals with both the LFR design and the R&D programme.

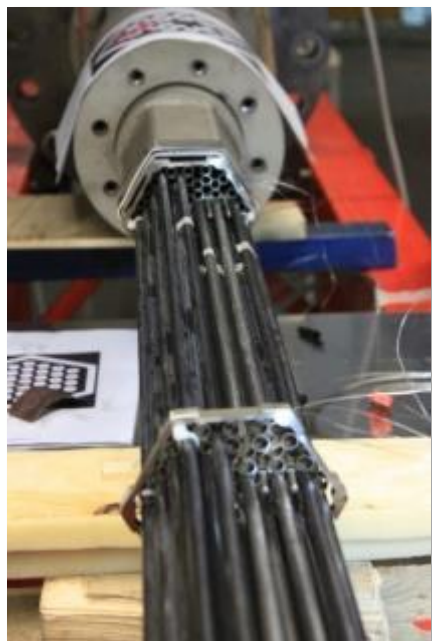
A close, crucial collaboration to fully exploit the skills on both sides and swiftly develop, design, install and operate non-nuclear experimental facilities.

At the ENEA-Brasimone centre *newcleo* is progressively restoring halls and installing new experimental facilities



# ENEA partnership – facilities

Lead technology for LFRs has been in development for over 20 years in Europe, including at ENEA



LIFUS-5 Separate Effect facility



LECOR Corrosion Loop



BIDONE Lead-Pool



CIRCE Large pool (90 tons LBE)



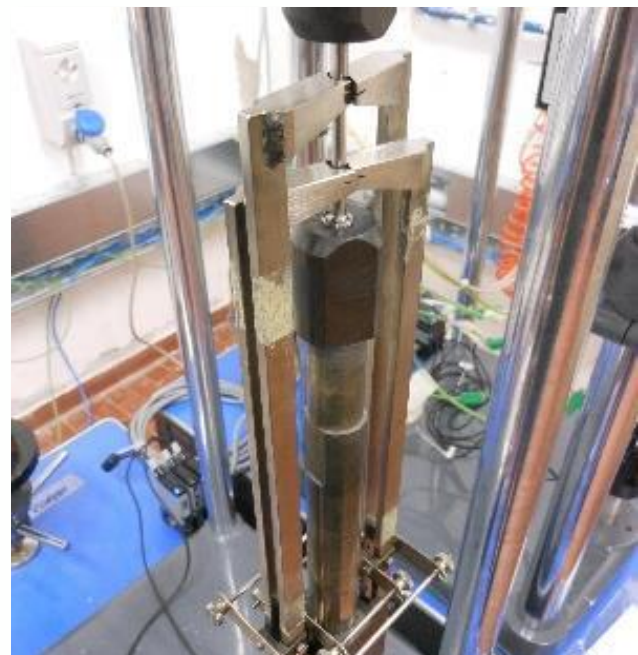
NACIE-UP loop



RACHELE (Coolant chemistry lab)



HELENA Lead Technology Loop



Lead Mechanical Laboratory

# SRS-Fucina expertise

## A strong addition to our skillset

SRS focuses on the design and engineering of nuclear systems and in recent years has further built its track record on nuclear technology applications: decommissioning of power plants; nuclear waste management, including conditioning and storage; new power plants: fusion and Gen-IV; nuclear fuel cycle systems



60

employees



Rome, Italy

Already involved in 24 LFR projects



Fucina has evolved from a high technology automation and steel and naval structures manufacturer to a leading company in the nuclear decommissioning, nuclear waste management and liquid lead systems.

A strong production platform benefitting from: 20,000 m2 production area, of which 9,000 m2 covered; 11,000 m2 additional available land, of which 6,000 m2 buildable land which will be a key production hub for newcleo

50

employees



Piombino (LI), Italy

Works closely with SRS



# Non-nuclear experimental campaigns and facilities

- CORROSION CAPSULES**  
operational
- CORE**  
200 kW  
commissioning in progress
- OTHELLO**  
2 MW  
detail design in progress
- PRECURSOR**  
10 MW  
basic design in progress
- MANUT**  
scope and detailed objectives defined
- CHEM-LAB**  
procurement in progress

Five modules filled with O<sub>2</sub>-controlled stagnant lead and argon, and with immersed specimens: corrosion tests of structural materials in molten lead.

New loop-type test facility for corrosion/erosion testing of structural materials in fluent lead.

New thermal-hydraulics loop test facility: performance testing of sub-assembly of Fuel Element and of the Steam Generator, validation experiments.

New pool-type large-scale test facility: broad-scope investigations on LFR system transient behaviour, component testing/qualification, etc.

Mechanical-type test facility: fuel handling systems and mechanisms (including rotating plugs) in air.

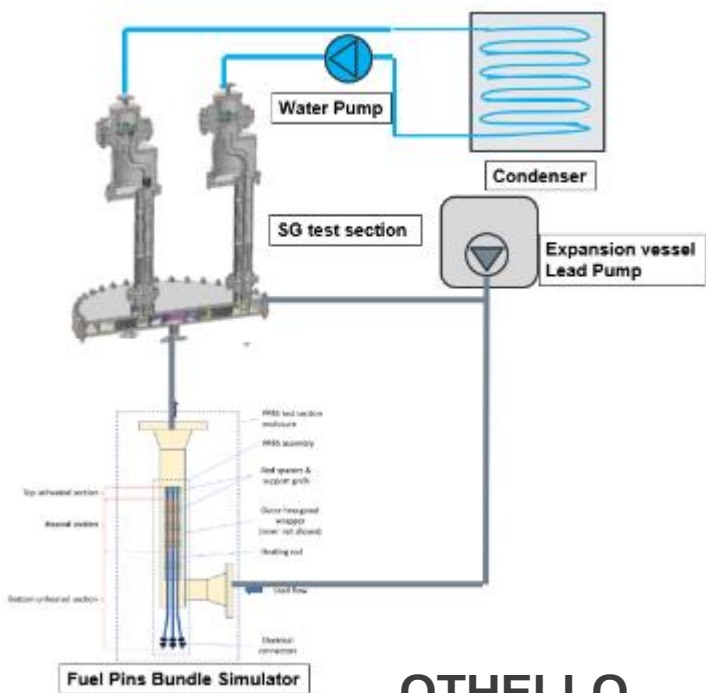
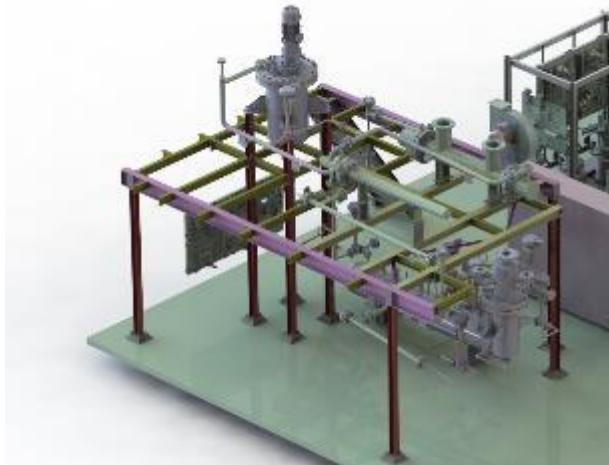
Chemical laboratory to support lead technology related investigations.



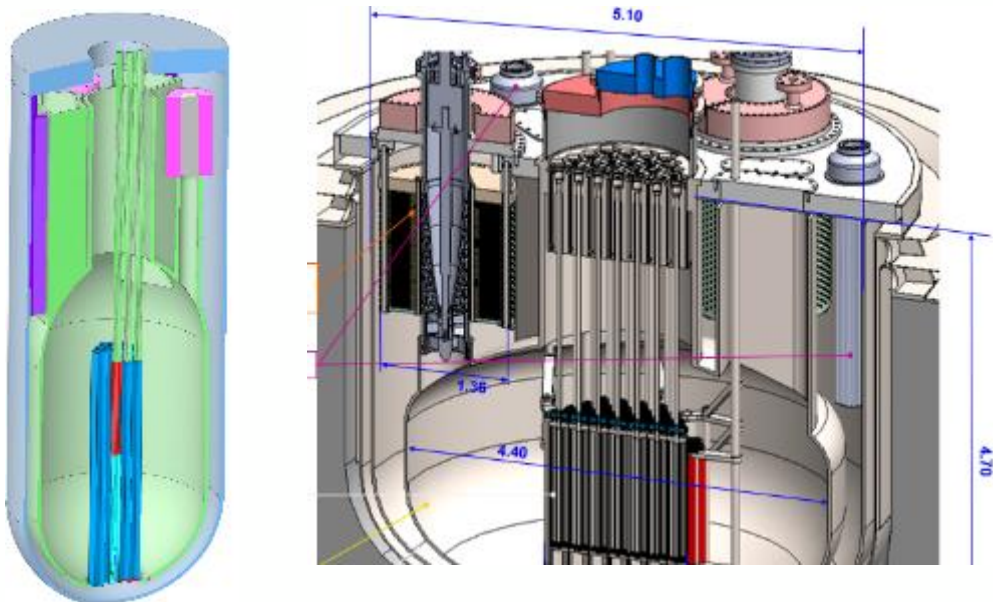
CAPSULE module



CORE

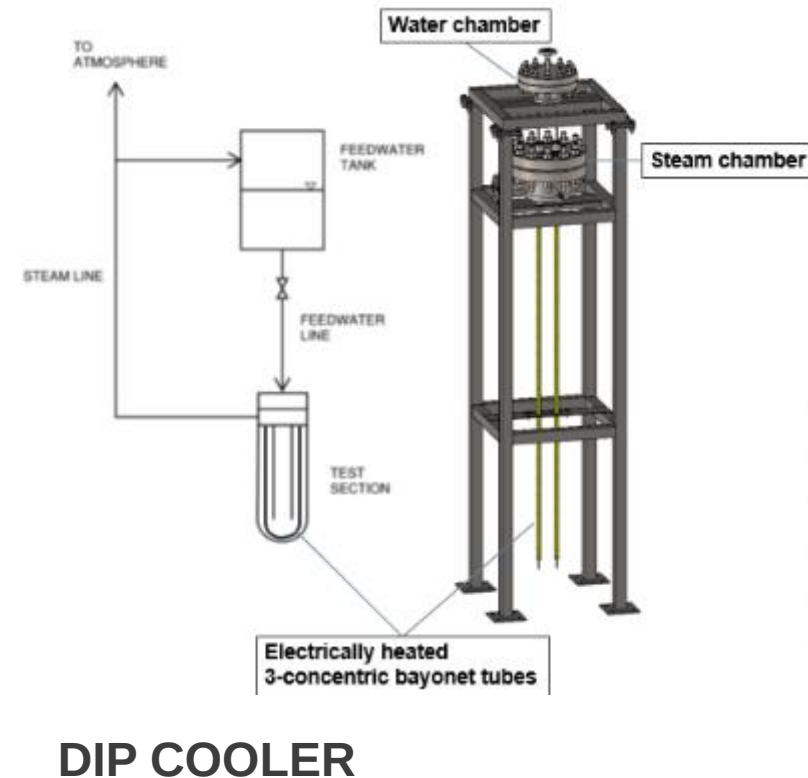
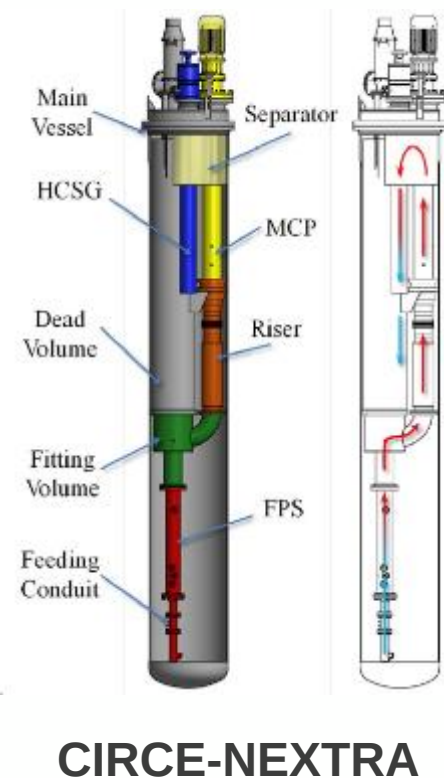
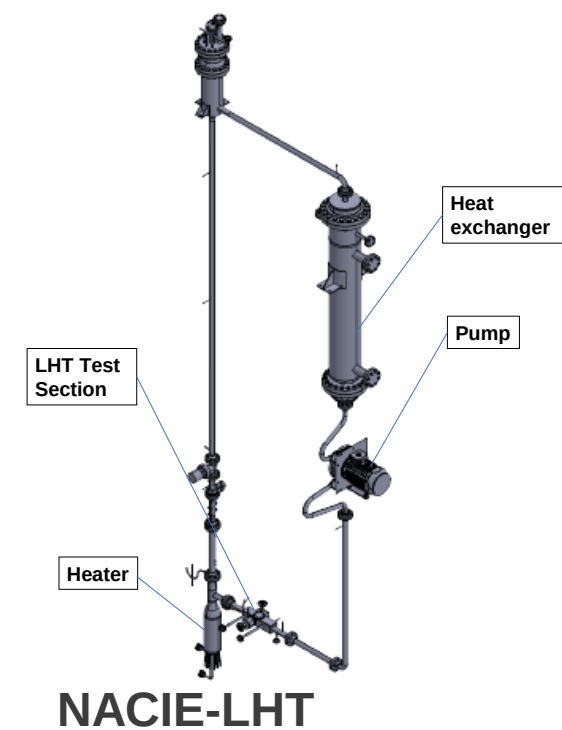


OTHELLO



PRECURSOR

# Non-nuclear experimental campaigns and facilities



● **NACIE-LHT**  
commissioning in progress

Test section at existing ENEA NACIE loop facility:  
lead cross flow heat transfer.

● **CIRCE-NEXTRA**  
with UniPi  
detailed objectives and scope  
defined

One or more test sections at existing ENEA-  
CIRCE: Component testing/qualification and  
thermal-hydraulics and fluid-structure-interaction  
phenomena involved in Steam Generator Tube  
Rupture (SGTR) scenarios in LFR.

○ **DIP COOLER**  
at PoliTo  
detailed design in progress

New test facility mimicking dip cooler based Decay  
Heat Removal system: performance and start-up  
issues.

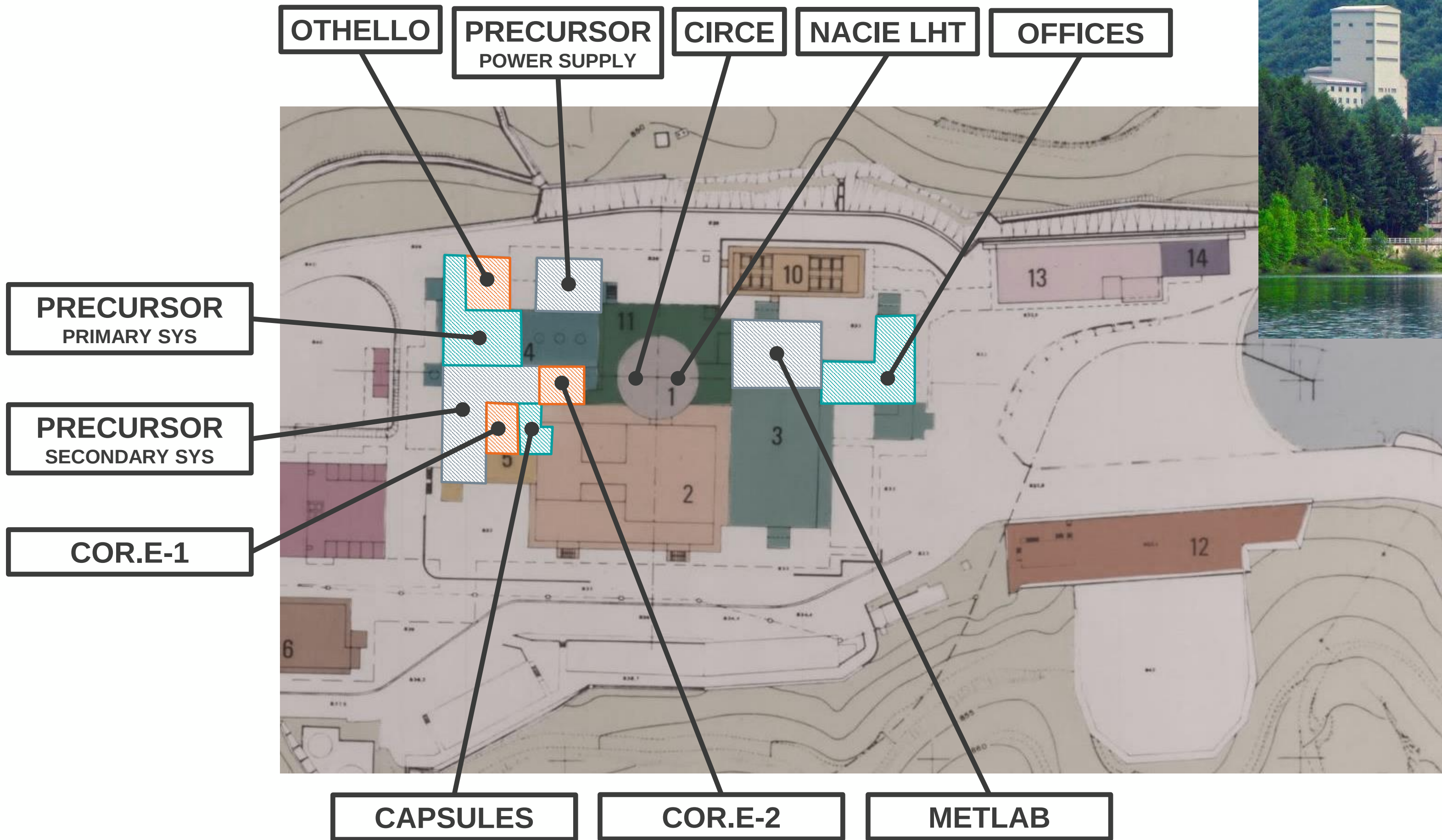
○ **POOL TYPE  
FACILITY**  
agreement underway

Campaigns at existing pool-type test facility with  
new test sections to be designed: thermal-  
hydraulics, lead chemistry control in large pools,  
SGTR tests with full-length tubes.

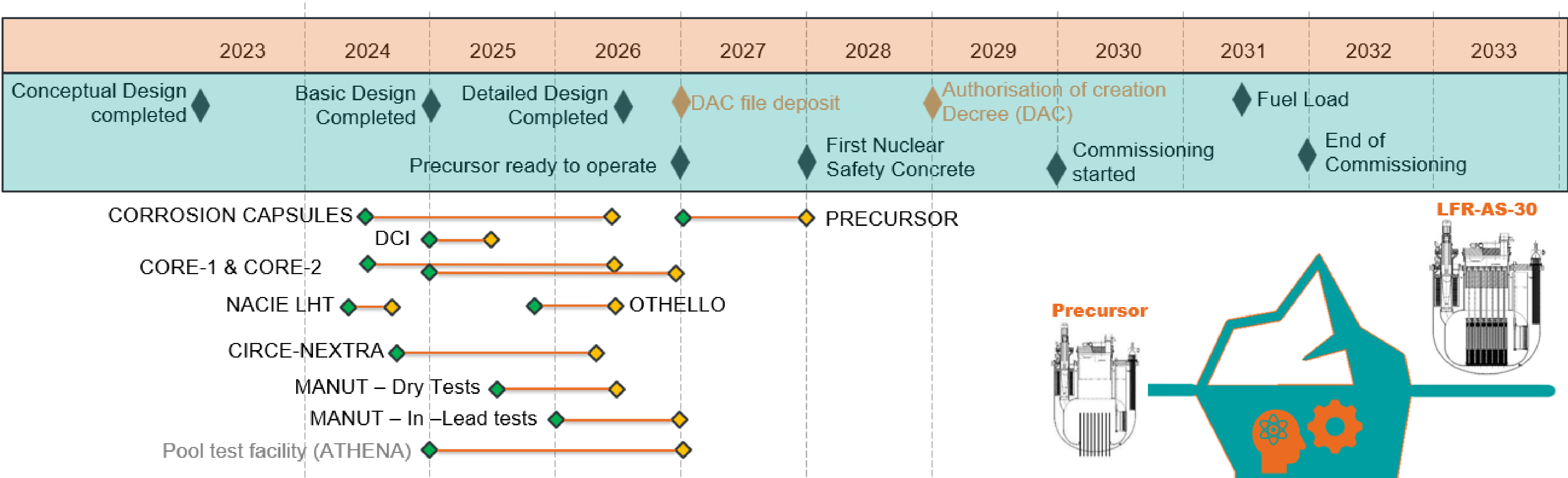
○ **MATERIALS LAB**  
Turin  
design in progress

Material laboratory, mechanical testing on structural  
materials.

# newcleo «Brasimone» FACILITIES

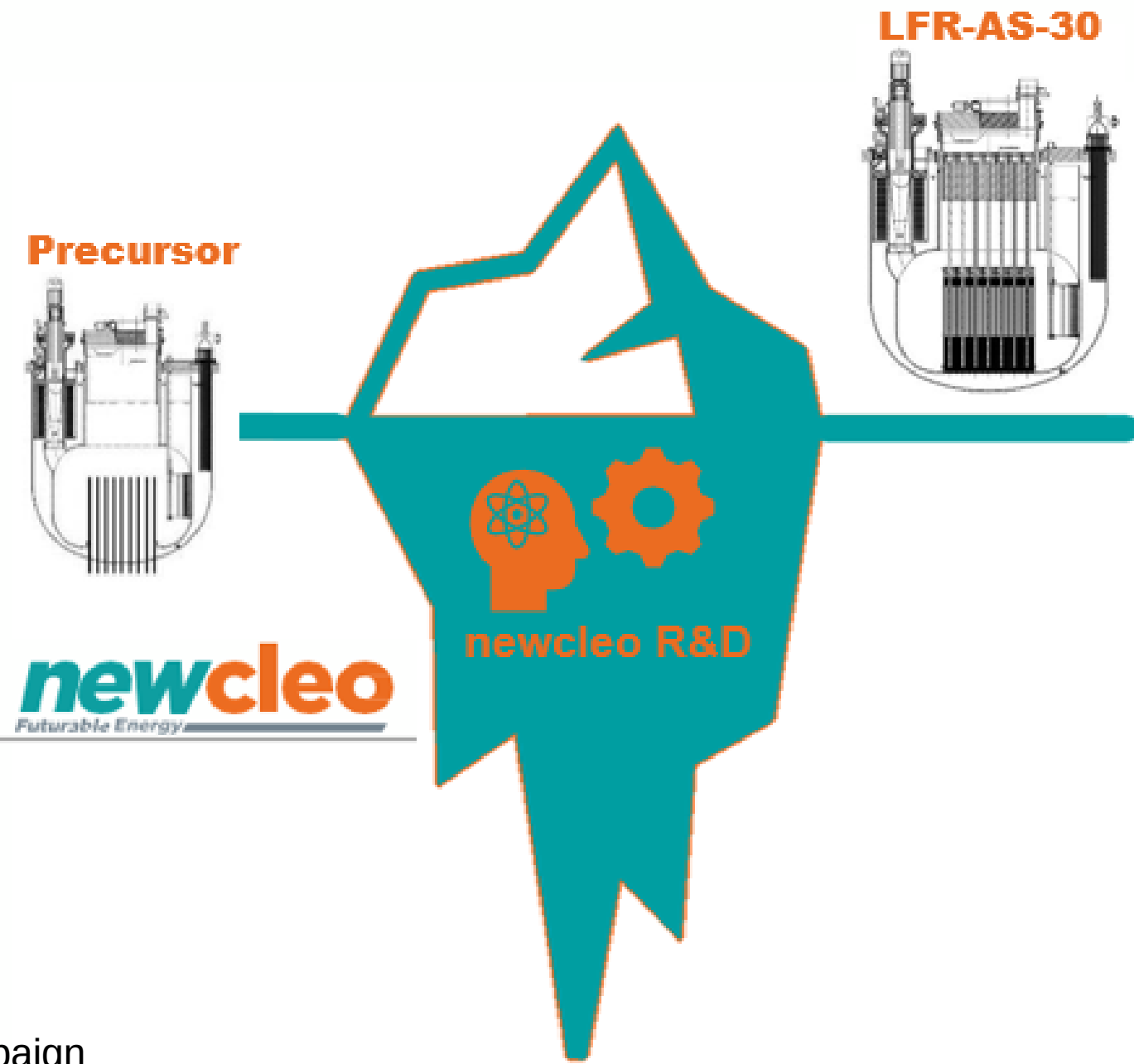


# newcleo's R&D Program Timeline Vs LFR-AS-30 Milestones



The current planning of most R&D infrastructures foresees the **completion of exp. campaigns within 2026** → **submission of the DAC file** for the construction of LFR-30/200 reactor for low temperature operations.

◆ Commissioning/  
start of experimental campaign



# newcleo's R&D programme: further considerations

- A **Steering Committee** oversees the newcleo R&D programme and starts new R&D initiatives as needed to meet LFR projects needs
- The R&D programme is closely linked to newcleo **equipment qualification** and **computer code validation** programmes
- Actively pursuing opportunities for **testing of materials under neutron irradiation**
  - Having conversations with JAEA JOYO; JRC Petten HFR; ÚJV Řež LVR-15
- newcleo R&D programme is also connected with **international research projects and initiatives**
  - EC-funded projects (see below)
  - CEN Workshop 064 Phase 3 PG 2 "Mechanics GEN IV and innovative reactors"

| Project title                                                                                                 | Call reference              | Coordinator | Duration                  |
|---------------------------------------------------------------------------------------------------------------|-----------------------------|-------------|---------------------------|
| 3: LESTO - LEad fast reactor<br>Safety design and Tools                                                       | HORIZON-EURATOM-2023-NRT-01 | ENEA        | 48M<br>from November 2024 |
| 4: CONNECT-NM - Coordination of the European Research<br>Community on Nuclear Materials for Energy Innovation | HORIZON-EURATOM-2023-NRT-01 | CIEMAT      | 60M<br>from October 2024  |

# Thank you



# ***Appendix***

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# Increasing numbers of partners and suppliers

Creating a global strategy supporting our delivery

## UK



## FRANCE



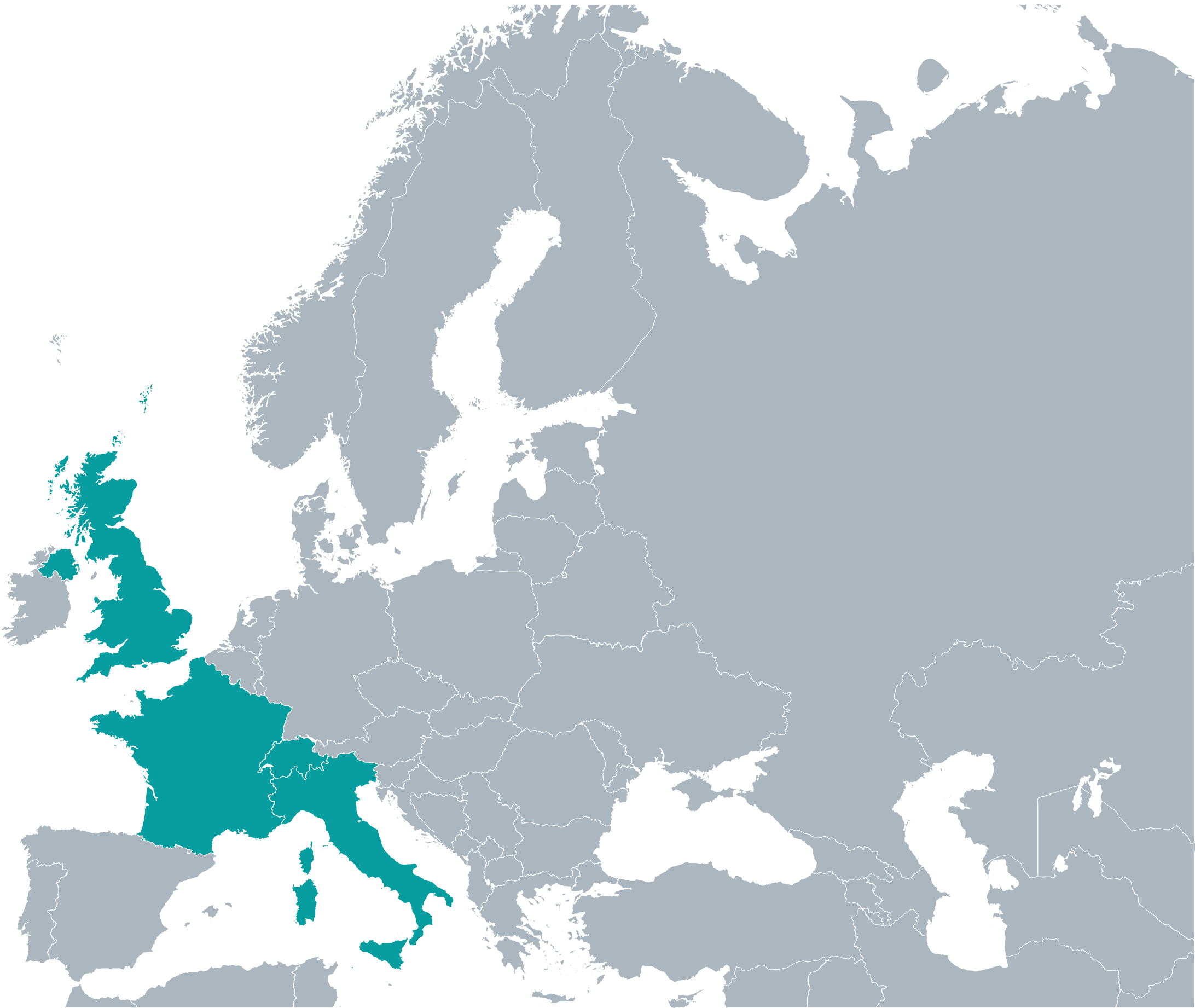
## ITALY



## US

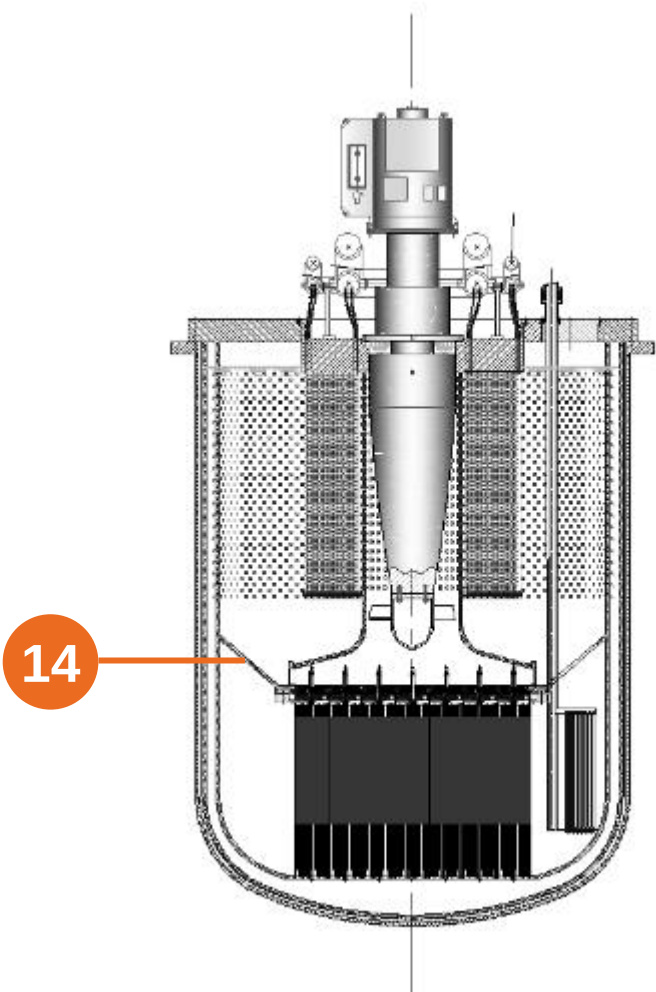
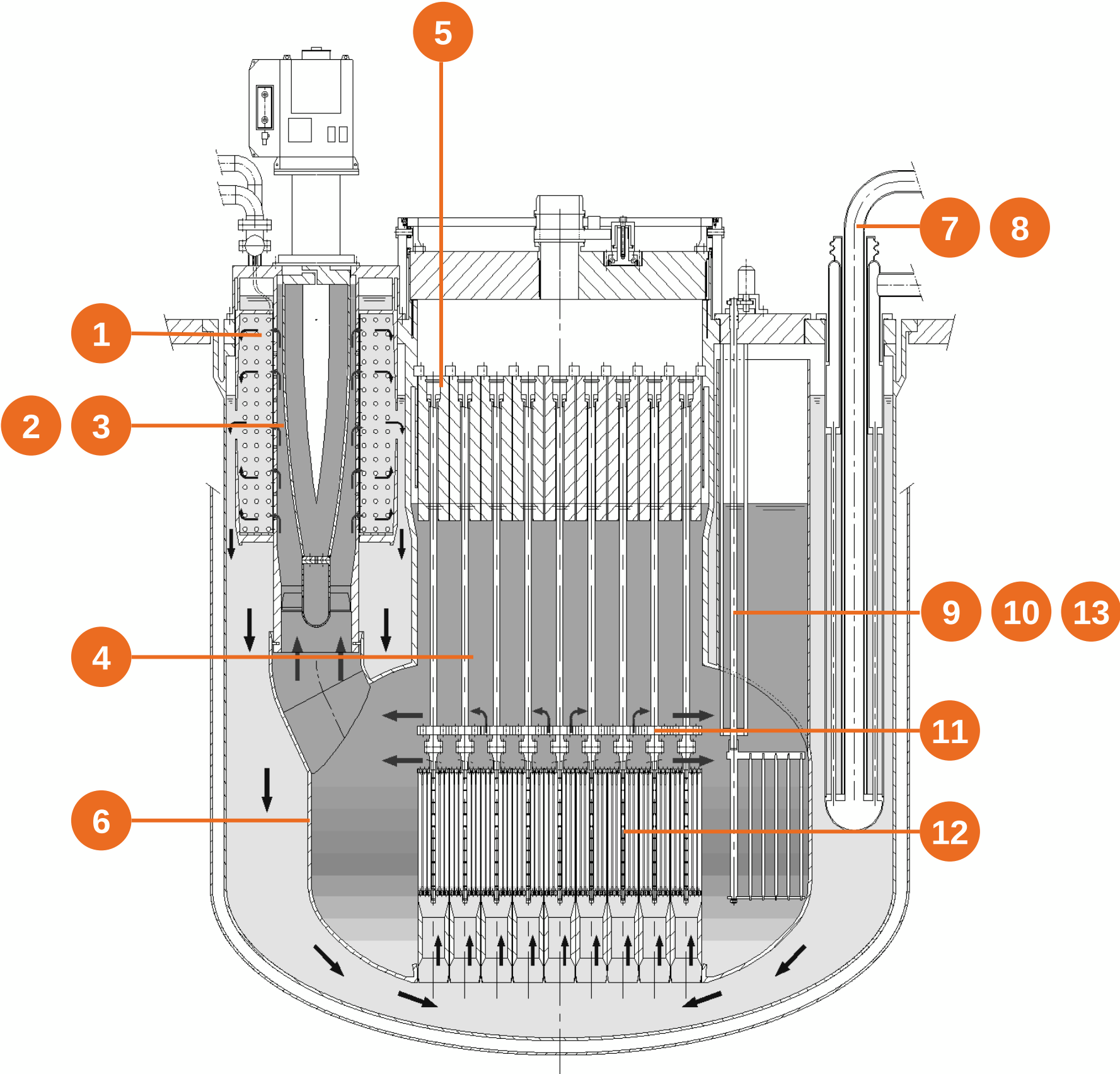


## GLOBAL



# International patents for our Gen-IV SMR designs

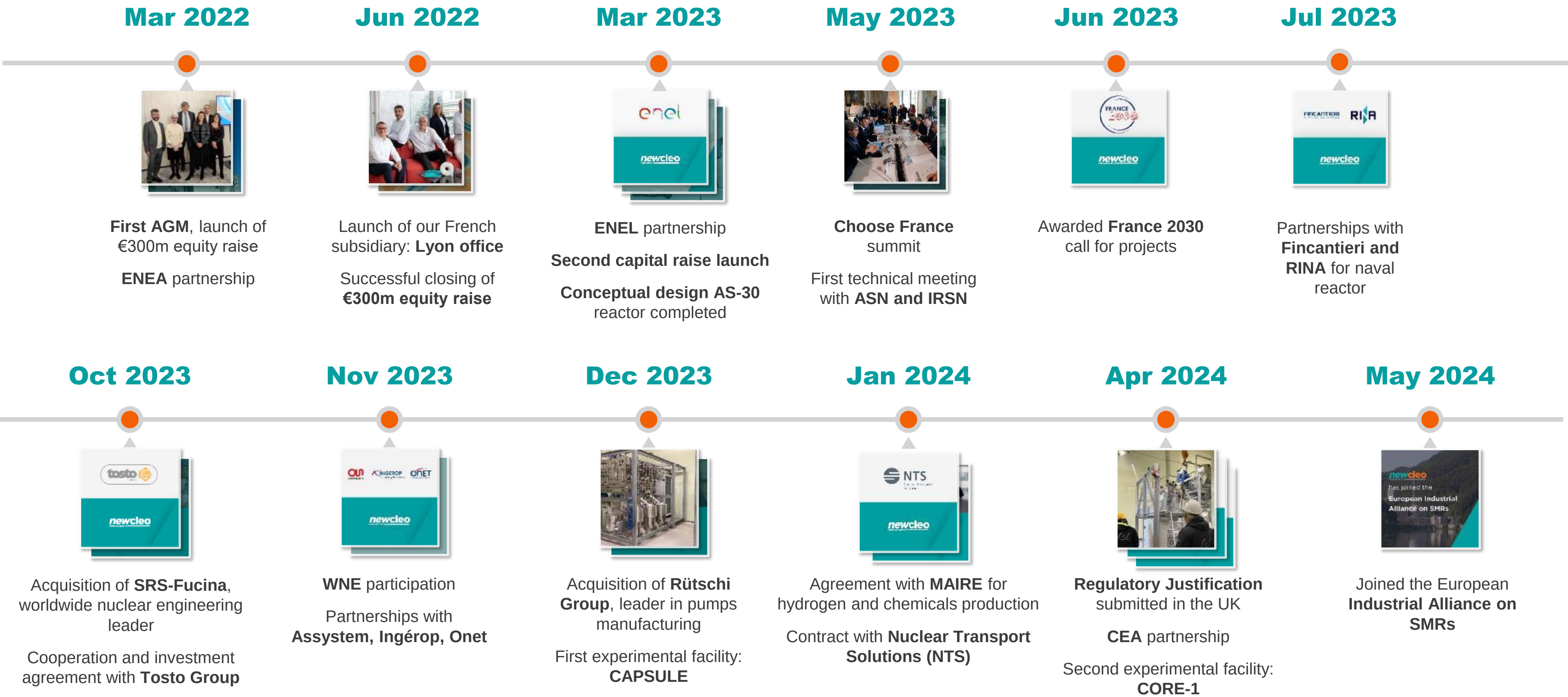
- [Patent 1](#)  
Spiral-tube Steam Generator 1
- [Patent 2](#) and [Patent 3](#)  
Pump/heat exchanger assembly 2 3
- [Patent 4](#)  
Extended stem FA 4
- [Patent 5](#)  
Self-supporting core 5
- [Patent 6](#)  
Amphora Shaped Inner Vessel 6
- [Patent 7](#) and [Patent 8](#)  
DHR passive systems 7 8
- [Patent 9](#), [10](#) and [13](#)  
Control and shut down rods 9 10 13
- [Patent 11](#)  
Expanders 11
- [Patent 12](#)  
FA with cooling ducts 12



**Patent 14**  
Support system of the core  
of a nuclear reactor  
*Filed 13-06-2022*

*Five additional patents  
filed in 2023*

# A strong track record



# Key partnerships are already in place to support roadmap and de-risk the business development



**newcleo**  
Futurable Energy

**26 April 2024:** newcleo has received an RfI for a possible LFR projects in Slovakia



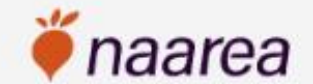
**newcleo**  
Futurable Energy

**9 April 2024:** newcleo has signed a partnership agreement with the CEA, a French public research organisation at the forefront of technological innovation



**newcleo**  
Futurable Energy

**17 January 2024:** newcleo signs contract with Nuclear Transport Solutions for the development of materials for the fuel cycle



**newcleo**  
Futurable Energy

**11 January 2024:** newcleo and NAAREA announce the creation of a strategic and industrial partnership



**newcleo**  
Futurable Energy

**10 January 2024:** newcleo signs agreement with MAIRE to study application of Gen-IV nuclear technologies for hydrogen and sustainable chemicals production



**newcleo**  
Futurable Energy

**28 November 2023:** newcleo announces the signature of three partnerships with Assystem, Ingérop and Onet for the development of the reactor and fuel manufacturing facility



**newcleo**  
Futurable Energy

**23 October 2023:** newcleo and LSE announce a partnership to support energy economics and policy research



**newcleo**  
Futurable Energy

**18 October 2023:** newcleo signs MOU with UK-based Nuclear Advanced Manufacturing Research Centre to drive forward manufacturability, supply chain, and development studies for pioneering nuclear technologies

# Key partnerships are already in place to support the technology roadmap and de-risk the business development



**11 October 2023:** newcleo and the Tosto Group sign cooperation and investment agreement to collaborate on several activities aimed at studying and perfecting manufacturing, fabrication and installation encompassing the whole reactor life



**15 September 2023:** newcleo and National Nuclear Laboratory (NNL) have signed a Memorandum of Understanding (MOU) outlining a framework for forthcoming collaborative activities on advanced nuclear research and development



**25 July 2023:** newcleo, Fincantieri and RINA in joint feasibility study for shipping industry reactor applications



**13 March 2023:** Enel and newcleo sign partnership to cooperate on Generation IV nuclear technology

# Presence across Europe

10+ locations and research centres

