newcleo
Futurable Energy

*new*cleo's Lead-cooled Fast Reactors for clean, safe and sustainable energy

Energy Fridays - 12 May 2023
University of Bologna – Faculty of Engineering

Ing. Roberto Spaggiari (*new*cleo) – Fuel cycle supervisor

1 - An overview

A fast growing company

*new*cleo was incorporated in September 2021 with **€100 million**, later in June 2022 raised an additional **€300 million** of seed funding, and has recently launched a capital raise up to **€1 billion**.

The company counts about **230 employees (of which 100+ scientists) in five offices**:

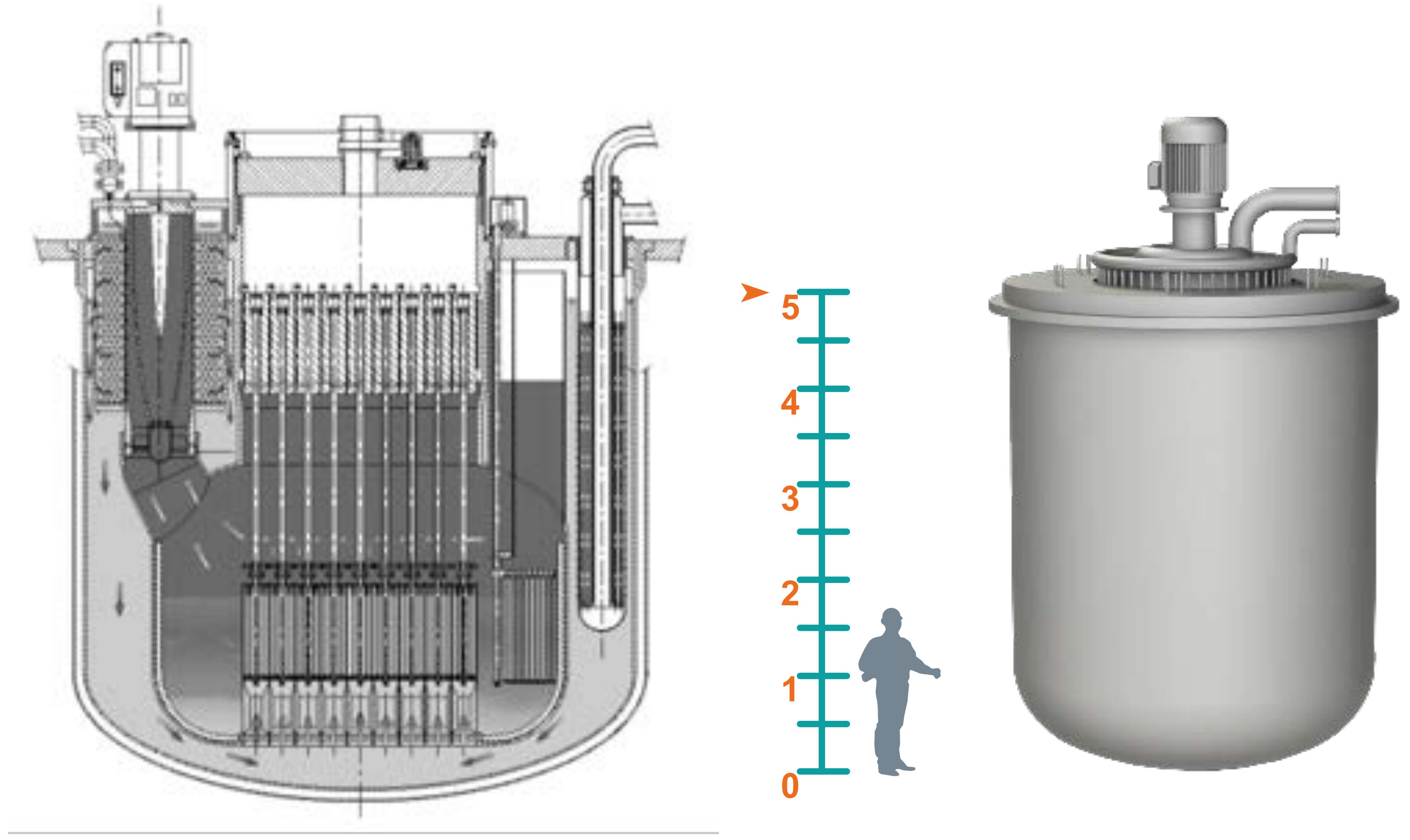
Growing to 500 by 2023

- **LONDON**
- **TURIN**
- **LYON**
- **BOLOGNA**
- **BRASIMONE**

*new*cleo, a new, innovative player in nuclear energy

Reactor technology: Lead-cooled Fast Reactors

- Lead intrinsic characteristics enhance safety, together with our design provisions
- Fast reactors allow for a more efficient use of fuel and enables using what today is considered waste
- Considered as the **most advanced and mature** fast reactor technology by GIF (Gen-IV International Forum)



Design: Small Modular Reactors

- Smaller than conventional nuclear reactors (<300 MWe)
- Designed to be manufactured at a plant and transported to a site for installation

Fuel: UO_2-PuO_2 Mixed OXides (MOX)

- *new*cleo is investing in MOX fuel manufacturing, which is obtained from "waste" of the current nuclear industry, creating a nuclear waste-to-energy solution

Designer, manufacturer of our own modular lead-cooled fast neutron reactors

Operators of our own modular lead-cooled fast neutron reactors

Independence and financial solidity ensured by a large panel of private investors

2 - Potential of *new*cleo's LFR

Lead has unique properties for developing a fast reactor

Atomic mass	Absorption cross-section	Boiling Point (°C)	Chemical Reactivity (w/Air and Water)	Risk of Hydrogen formation	Heat transfer properties	Retention of fission products	Density (Kg/m^3) @400°C
207	Low	1737	Inert	No	Good	High	10580
Fast neutron spectrum	Large fuel pin lattice Low core pressure loss	Primary system at atmospheric pressure	No intermediate loop Possible use of low-cost water or air loops for DHR	Reduced risk of plant damage	Reduced risk of fuel cladding overheating	Reduced source term during postulated accidents	No risk of core compaction

Melting Point (°C)	Opacity	Compatibility with structural materials
327	Yes	Corrosive
But it also has properties that have discouraged some designers		

*new*cleo has identified technical solutions to minimize the impact of the unfavourable characteristics of lead and in some cases has also drawn design advantages.

Heavy Liquid Metal Coolant for nuclear

Heavy Liquid Metal Coolant (HLMC) technology for nuclear application started in the **Soviet Union for submarine propulsion**:

2 submarine prototypes with 2 reactors each,

7 “Alpha Class” Submarines (155 MWt).

Total = 15 reactors including 3 land system reactors; plus one replacement reactor for submarines

The acquired experience base for HLMCs in the Soviet Union amounts to 80 reactor years

A LFR has never been built (only Russia has started the construction of BREST-OD-300 on June 8, 2021)

1951 Pb-Bi setup

1963 Prototype nuclear submarine Project 645

1971 Nuclear submarine-705 demo

1976 1996 Nuclear submarine-705 serial

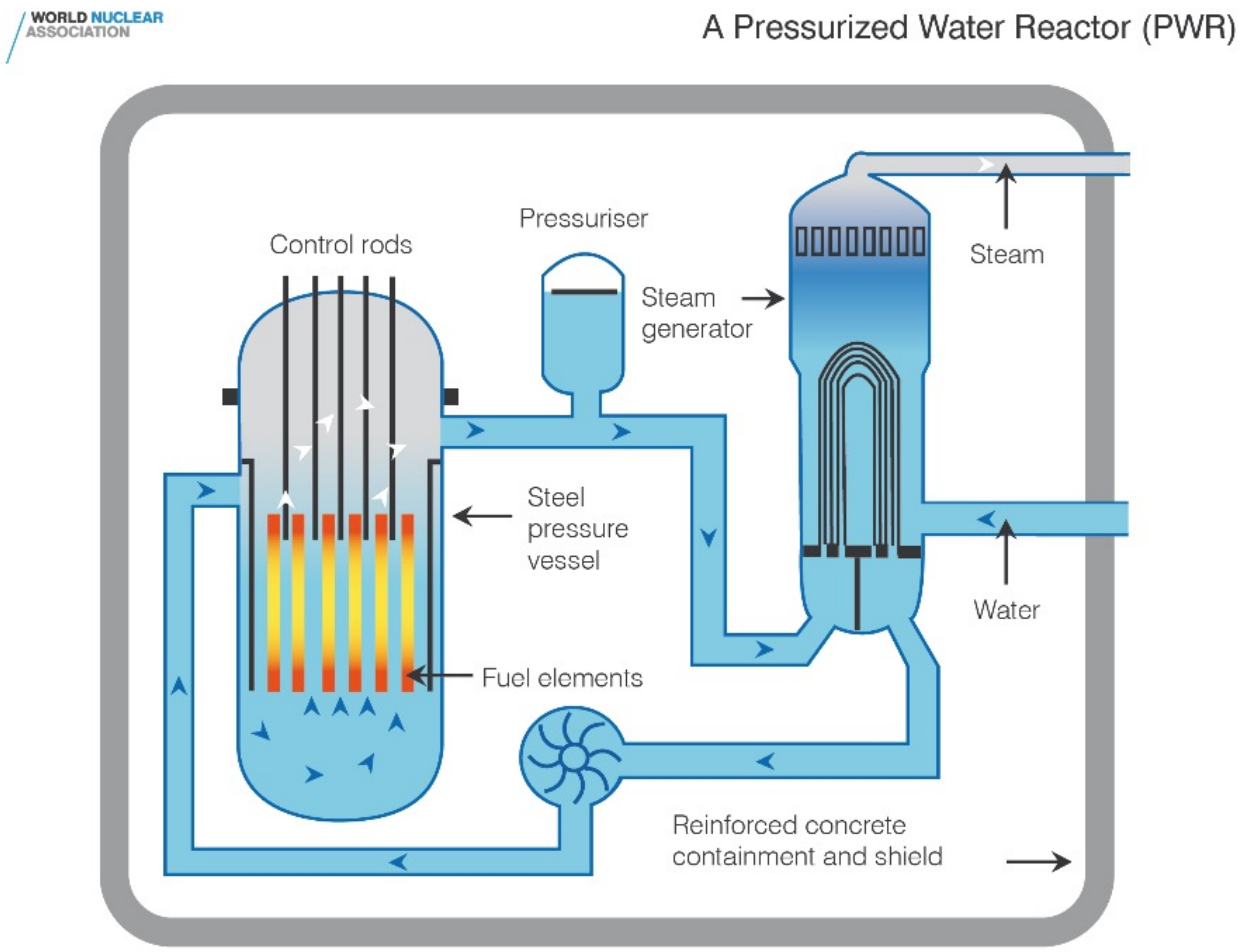
Reactors operating in the western countries are thermal reactors

Development of Light Water Reactors (LWRs) has been facilitated by:

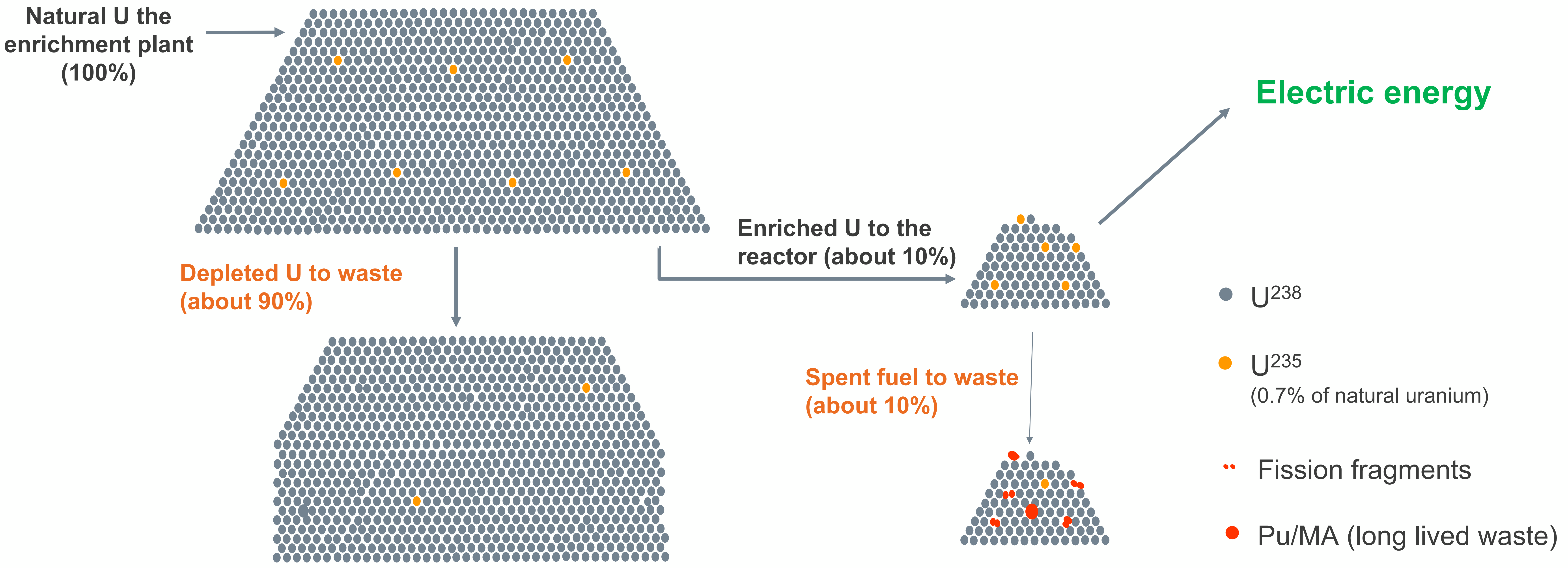
- well-known technology
- low cost of uranium
- technical progress on uranium enrichment
- scarce financing to innovation in the nuclear field

Drawbacks are:

- scarce use of natural resources
- production of long-lived waste

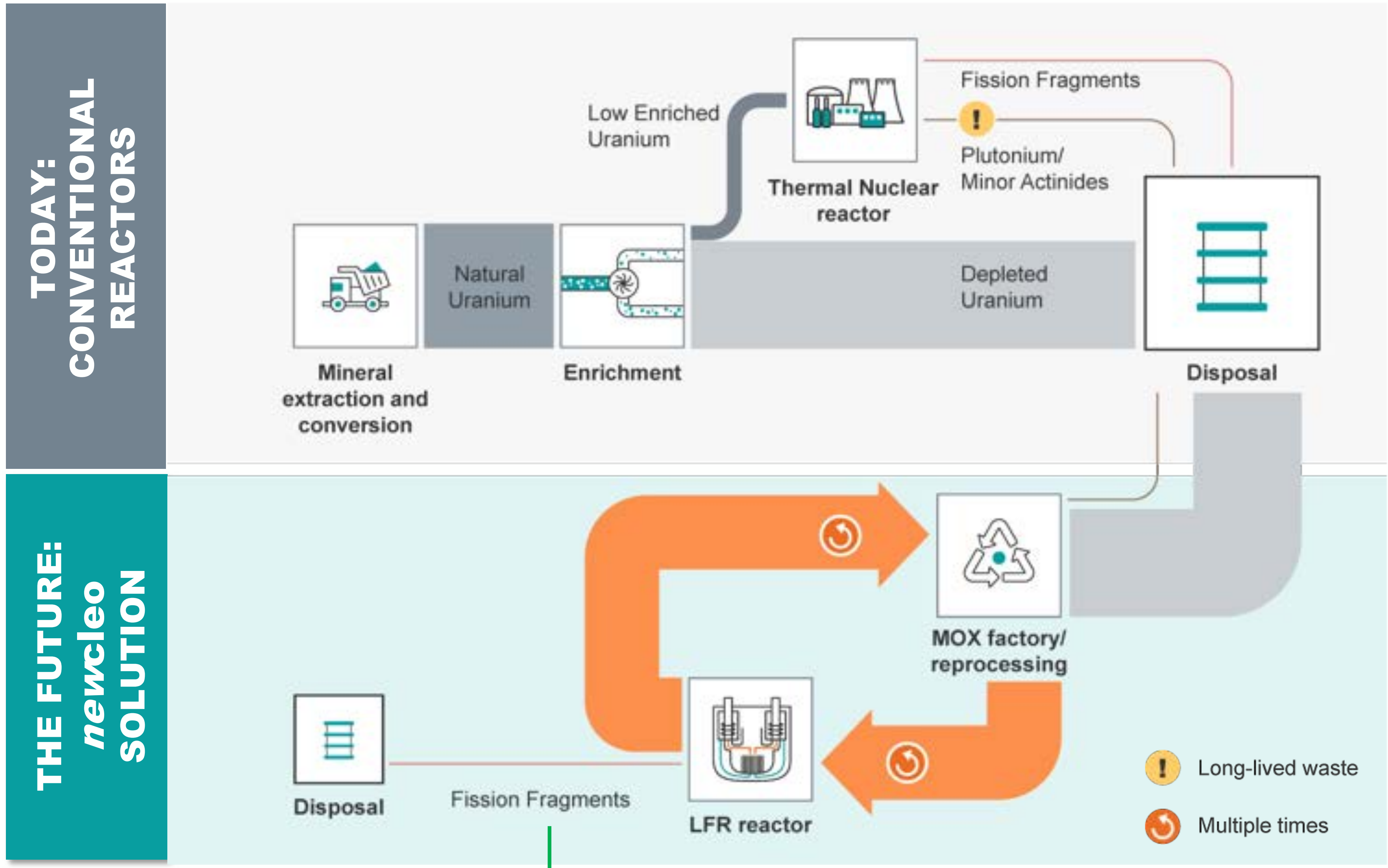


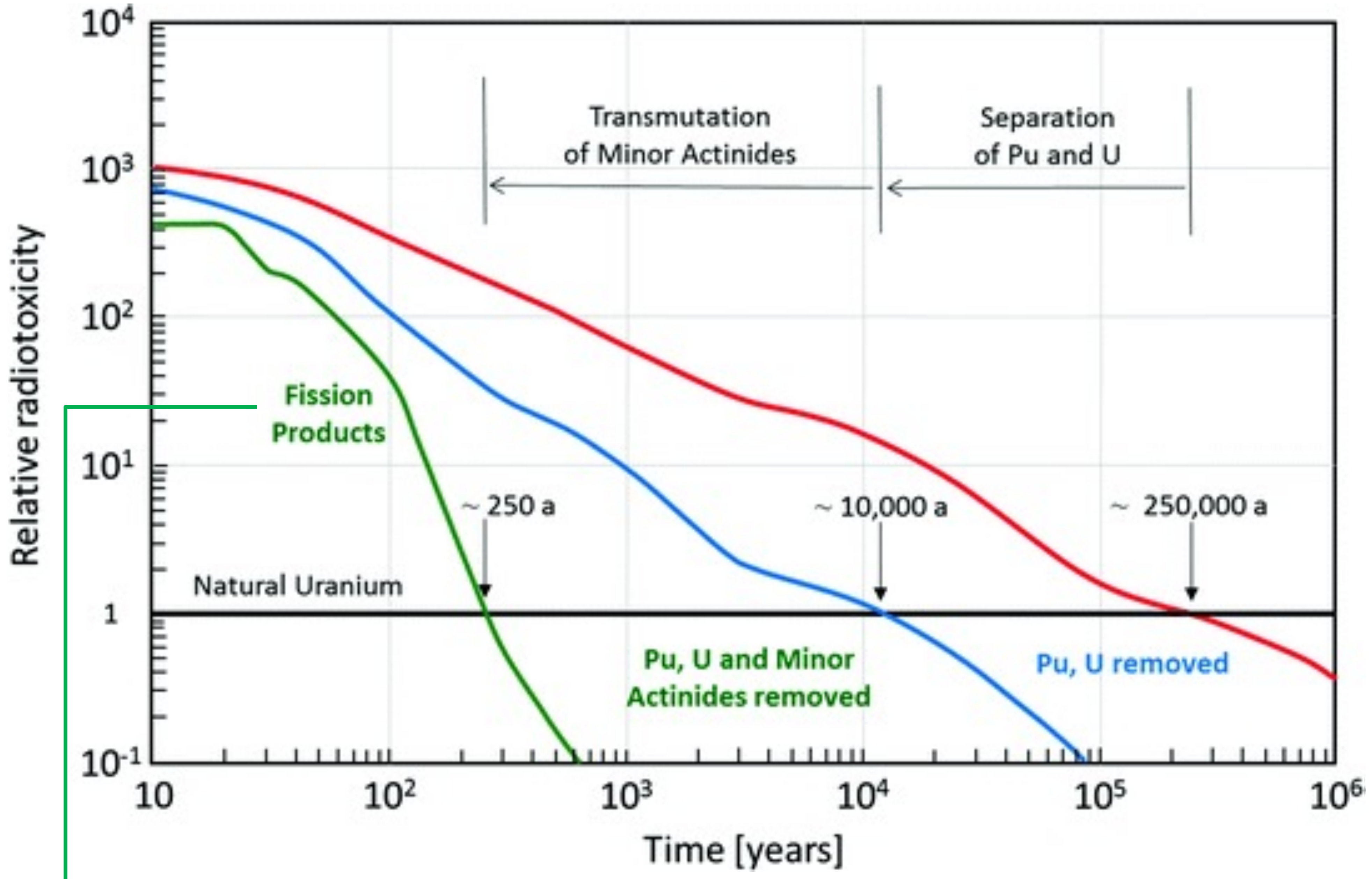
The LWRs fission only 0.5% of the natural uranium and produce long-lived waste



In an open fuel cycle, natural uranium is transformed in waste, but only its **0.5%** has contributed to the production of energy!

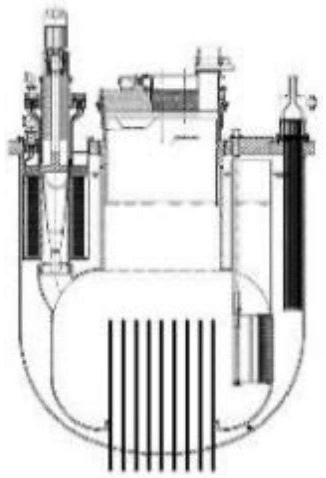
Closing the fuel cycle

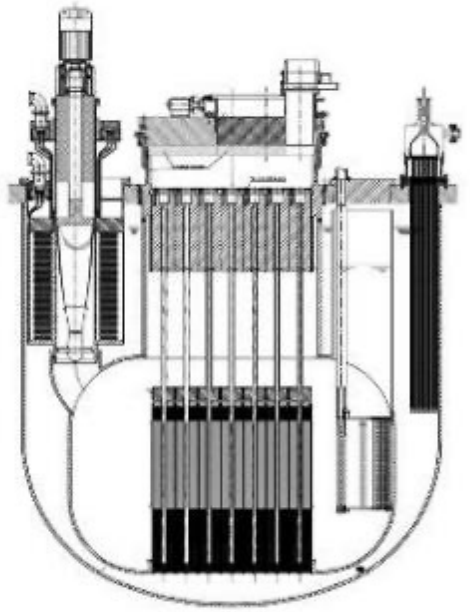




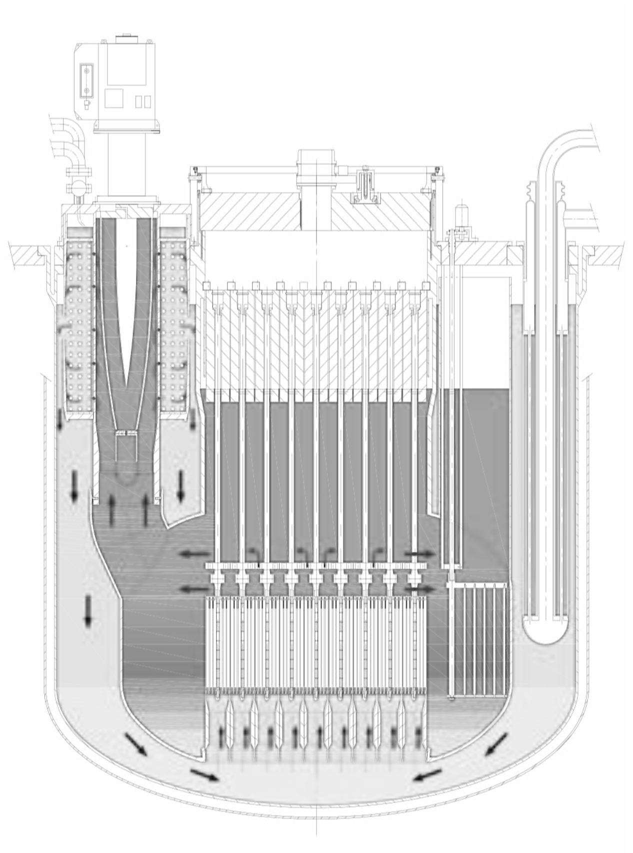
Fast Reactors and fuel reprocessing can extract energy from existing material and at the same time reduce radiotoxicity of residual waste to dispose: Fission Products return to value of the natural uranium ores after ~250 years

*new*cleo's plan-to-market

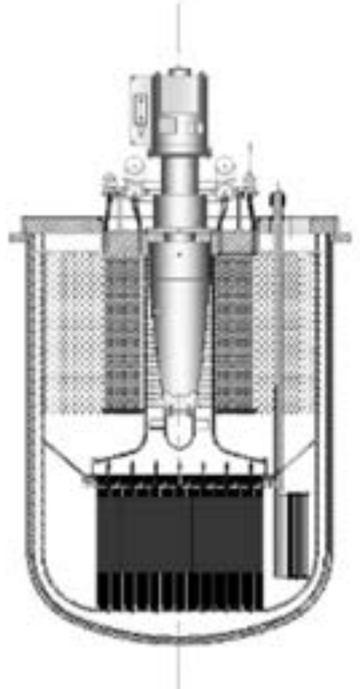




AS-30



AS-200



TL-30

2026

2030

2032

2032

Precursor

10 MW electrically heated/non-nuclear facility with turbogenerator

It reproduces scaled or full-scale components of the LFR-AS-30

LFR-AS-30 (30 MW)

30 MW demonstrator and test reactor with core outlet at 430/440° (later 530°), using MOX as fuel

LFR-AS-200 (200 MW)

200 MW nuclear waste-to-energy SMR, for stand-alone or fleet type configuration, using MOX as fuel

First-Of-A-Kind (FOAK) reactor

LFR-TL-30 (30 MW)

30 MW mini nuclear reactor for industrial and maritime applications

Working as a nuclear battery, with infrequent refuelling (>10 years)

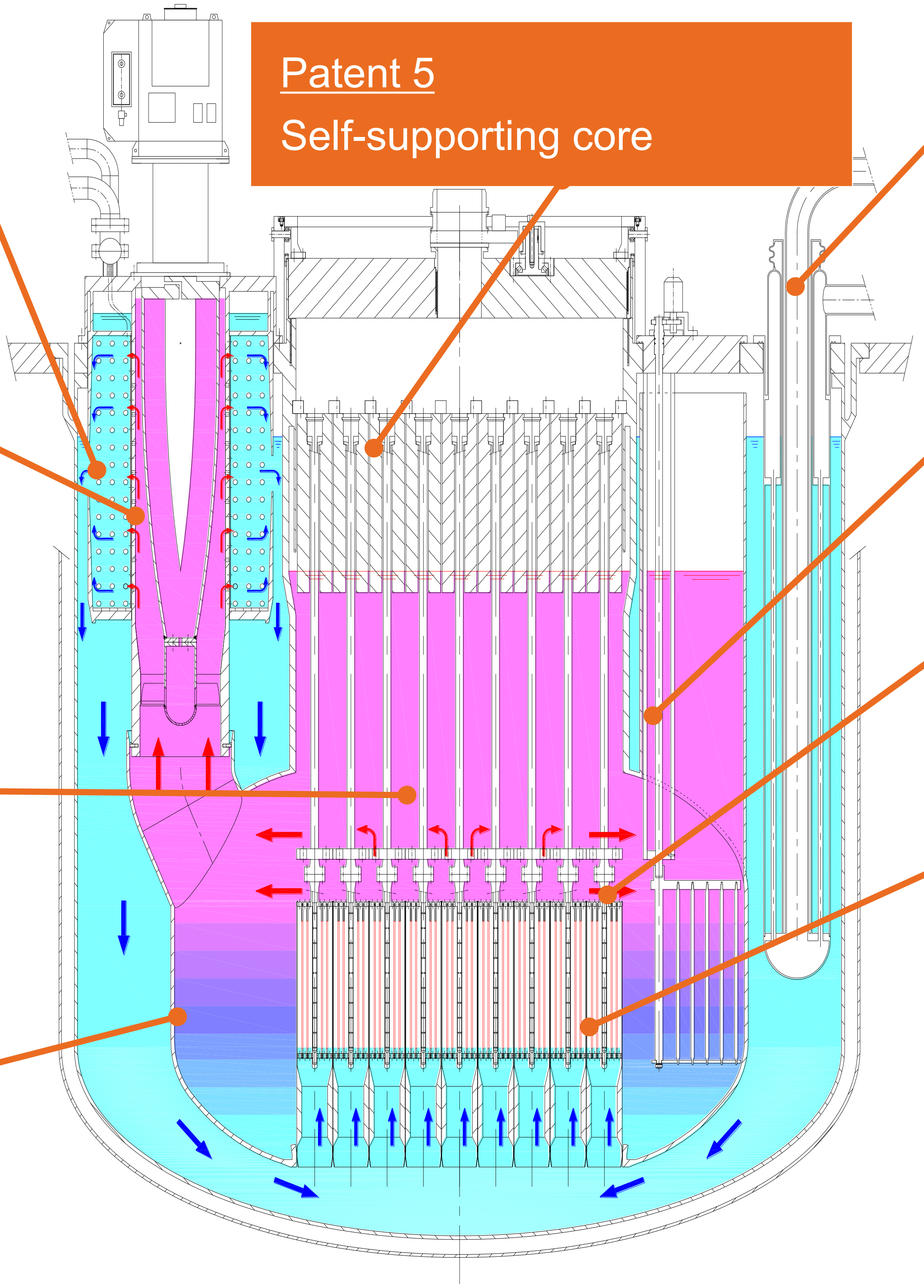
International patents for our Gen-IV SMR designs

Patent 1
Spiral-tube Steam Generator

Patent 2 and Patent 3
Pump/heat exchanger assembly

Patent 4
Extended stem FA

Patent 6
Amphora Shaped Inner Vessel



Patent 5
Self-supporting core

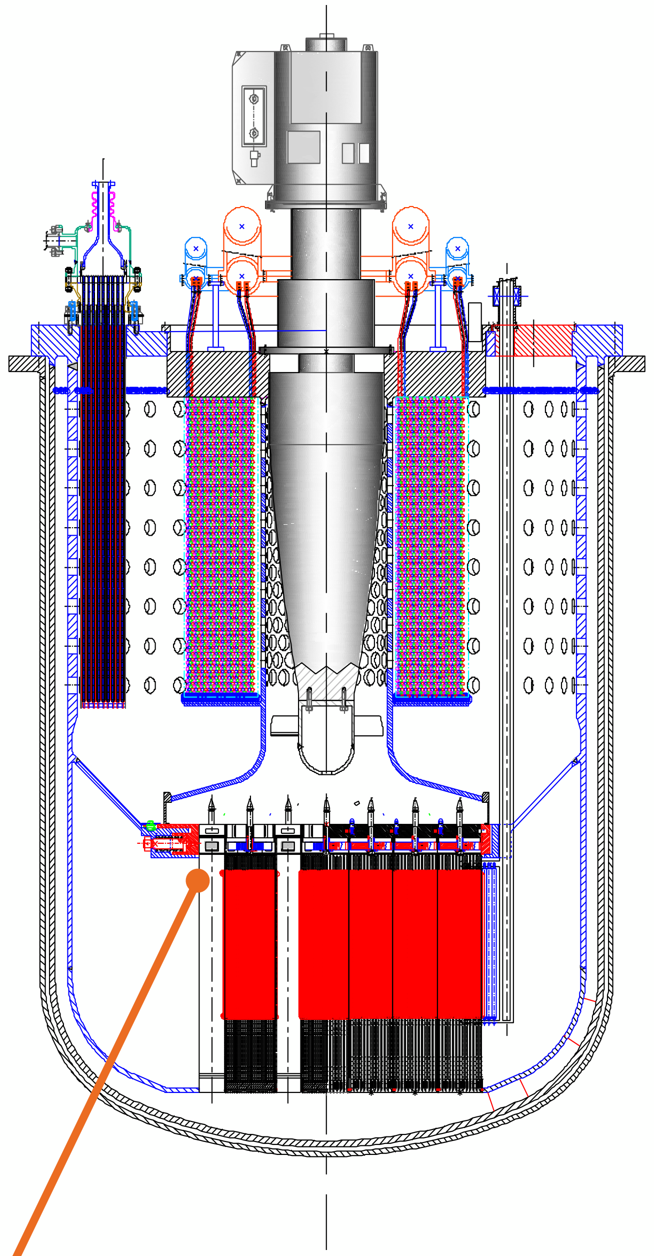
Patent 7 and Patent 8
DHR passive systems

Patent 9 and 10
Control and shut down rods

Patent 11
Expanders

Patent 12
FA with cooling ducts

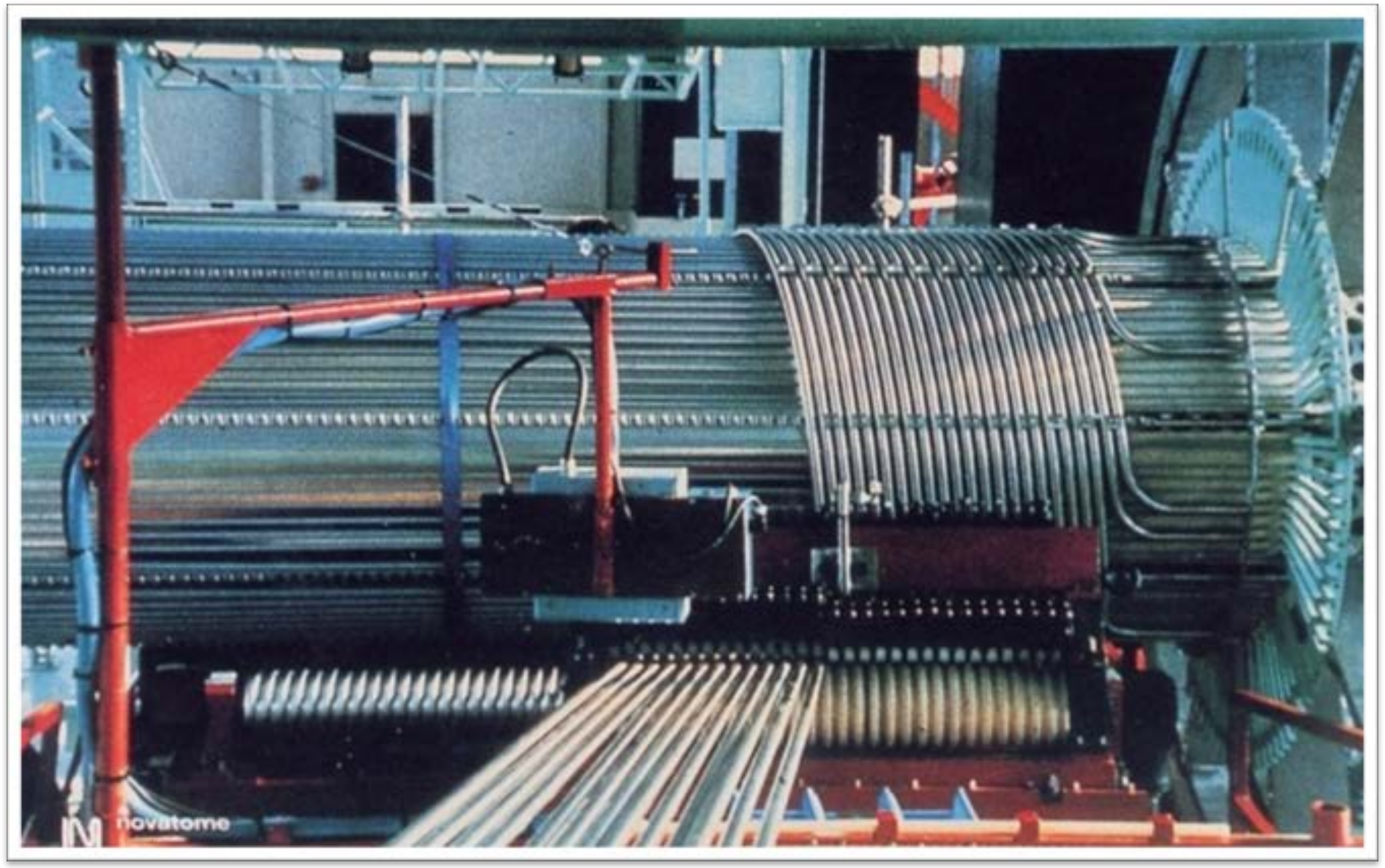
Patent 13
Active/passive shut down rods & protection vs. overpressure
Filed 06-12-2021



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

The Spiral-tube SG of the *new*cleo's LFR

The Spiral-tube SG (STSG) is mechanically forgiving as the Helical-tube SG (HTSG), but more compact and of easier manufacturing.



Manufacturing of the HTSG of SPX1


Mockup of a STSG after testing at Saluggia ENEA lab

R&D gap: uniform radial primary flow rate distribution in the bundle

Configuration of LFR-AS-200

Economics

Compact primary system < $1m^3$/MWe
(~ 4 times less than Superphenix-1, 2-3 times less than integrated PWRs, short reactor vessel: only **6,2 m**)

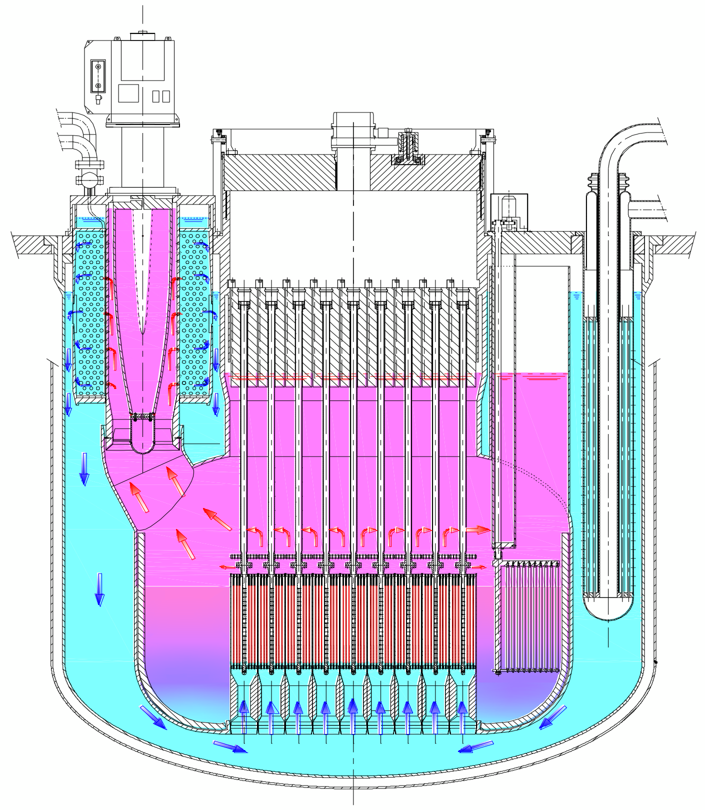
- Elimination of components no more needed
- Innovative components
- Reversal of traditional engineering solutions

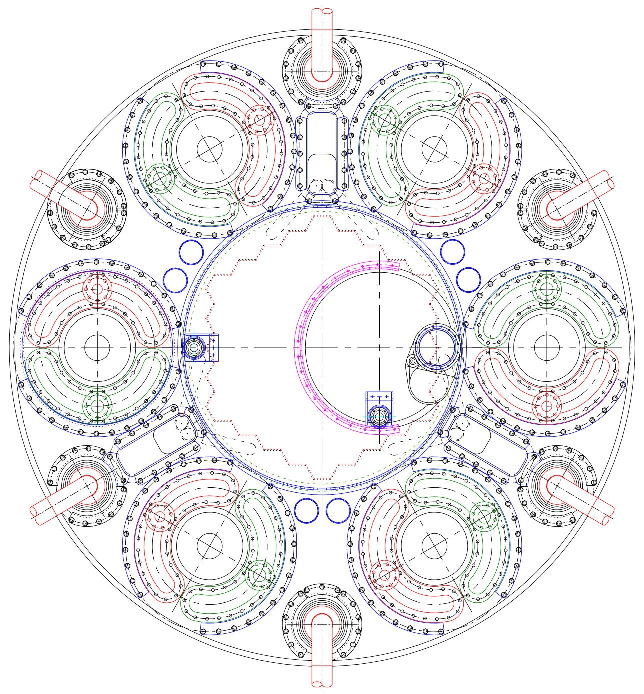
Compact reactor building

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

AS = Amphora Shaped

Main design parameters of LFR-AS-200	
Core power [MWth]	480
Electrical power [MWe]	200
Core inlet/outlet T [°C]	420/530
Primary loop pressure loss [bar]	1,3
Secondary cycle	Superheated steam
Turbine inlet pressure [bar]	180
Feed water/steam temperature [°C]	340/500





3 - Support Research & Development

ENEA partnership

- Agreement signed in March 2022, partnership to build a non-nuclear prototype of **first Generation-IV reactor in the world, the Precursor**
- ENEA brings **unique global know-how** in the field of liquid lead

***new*cleo Brasimone site**

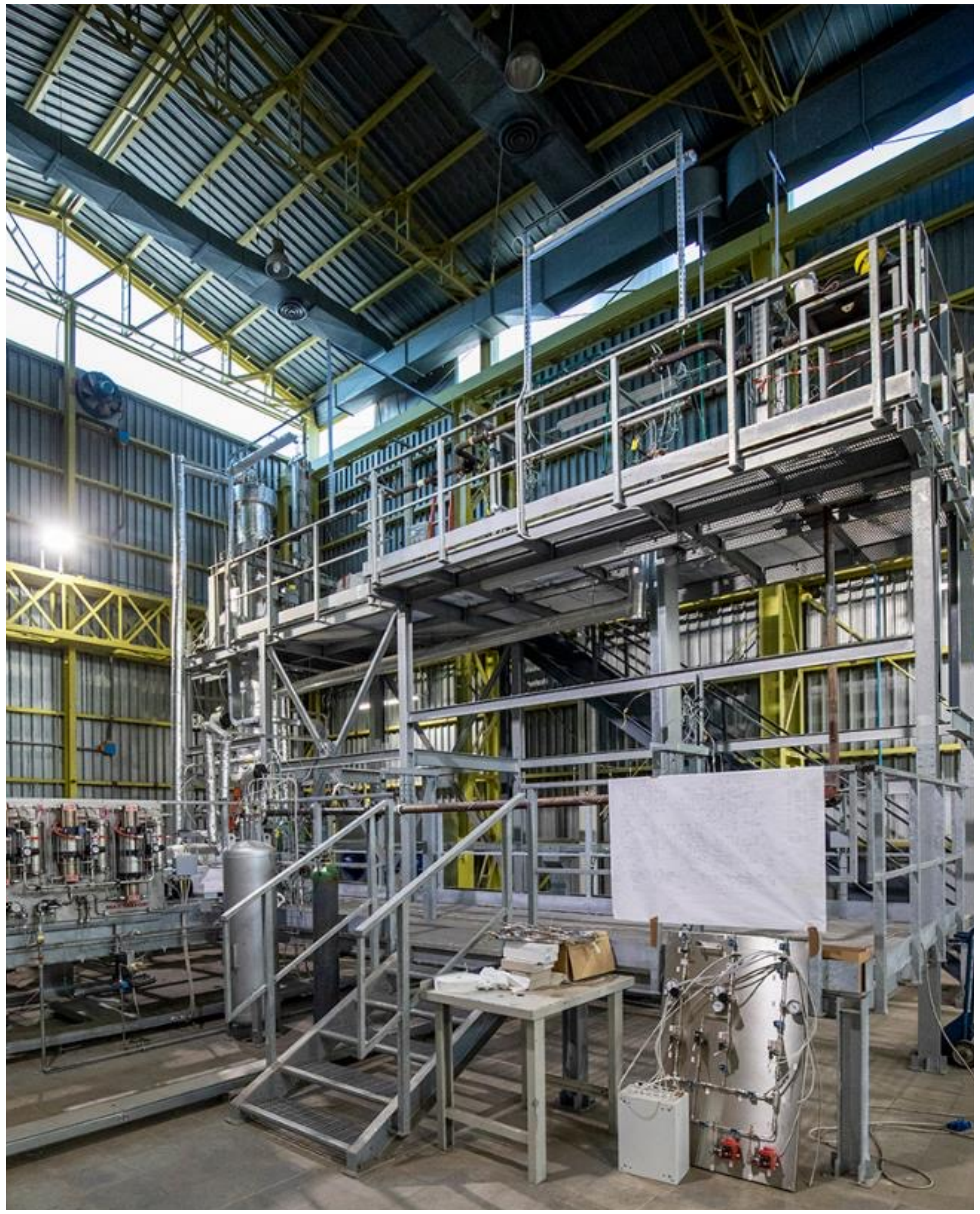
H: main hall, **E:** electricity buildings, **C:** chemistry lab, **O:** offices

ENEA partnership – Brasimone activities

The forecasted investment sums up to **EUR50+ millions in a 10-year period**, with **25 to 30 engineers** on site.

Non-nuclear facilities

Existing equipment	Using **NACIE-UP** in early 2023 for our Lead Heat Transfer (LHT) section reproducing *new*cleo steam generator conditions, soon starting on **HELENA**
COR-E	**Loop-type** facility to develop in 2023, with a forecasted **100 kW** power, dedicated exclusively to corrosion-erosion investigation
Performance	**Loop-type** molten lead test facility to deploy in 2024, forecasted power of **1.5 MW**, dedicated to topics like chemistry control and purification, thermohydraulic performance of core and primary system components, etc
Precursor	A **pool-type** integral test facility reproducing the LFR-AS-30 at a reduced scale, powered by electrical heaters up to **10MW**, to be operational in 2026



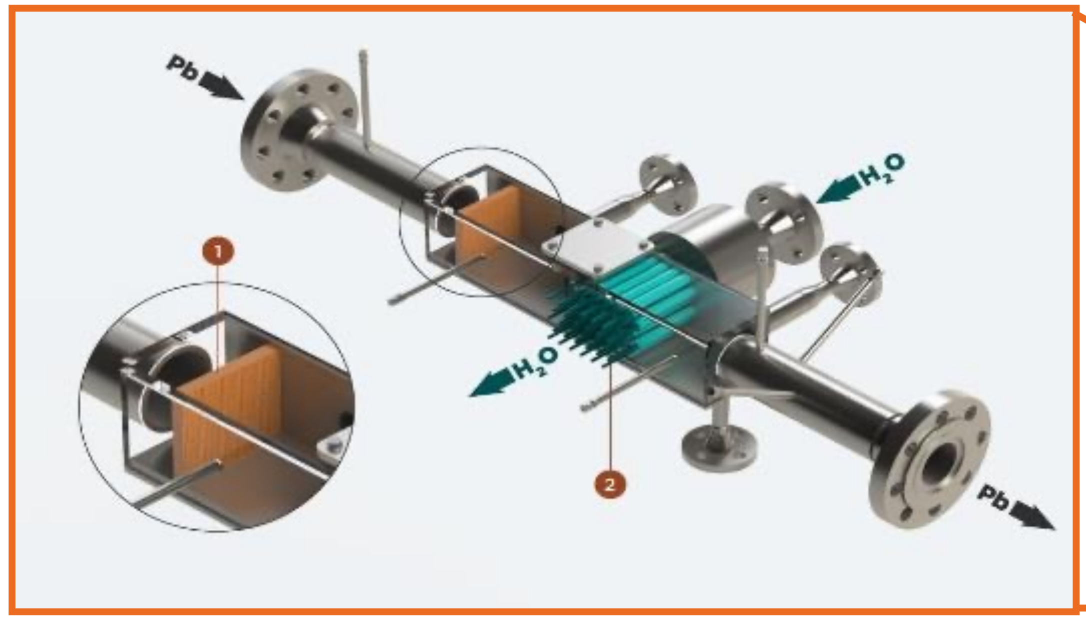
HELENA

Planned and ongoing activities in 2023

System design and code qualifications

Heat transfer (in lead cross flow) on the primary side of the steam generator

2023, ENEA NACIE-UP loop



Basic demonstration of the DHR bayonet dip cooler performance
2023, dedicated mock-up

TEST SECTION (replacing existing piping)

Qualification of steels and coatings

Screening of steels and coating to be used in lead up to 600°C *

newcleo COR-E Loop
Note: Available steels used in SPX1 allow operation in lead at peak temperature of 480°C (core outlet temperature of 440°C)

Creation of a metallurgical laboratory in Turin for the development and qualification of steels and coatings for use in lead environment

Thank you