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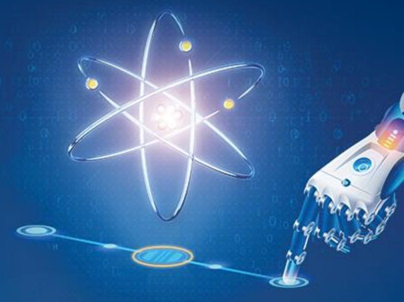

Lead-cooled Fast Reactors: an opportunity for closing the fuel cycle

Stefano BUONO

newcleo

newcleo
Futurable Energy

2023

*new*cleo was incorporated in September 2021 and since then raised €400 million, and is running a capital raise of up to €1 billion

The company has more than 450 employees across Europe, has completed 3 acquisitions and has several partnerships

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REACTOR TECHNOLOGY: GEN-IV LEAD-COOLED FAST REACTORS

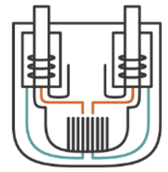
Fast reactors allow a more efficient use of fuel, and lead's intrinsic characteristics, together with our design provisions, enhance safety and reduce costs

DESIGN: SMALL MODULAR REACTORS

Designed to be manufactured at a plant and transported to a site for installation, economies of scale → economies of series

FUEL: MIXED OXIDE

*new*cleo is investing in MOX fuel manufacturing, using plutonium and depleted uranium from the current nuclear industry and allowing multi-recycling

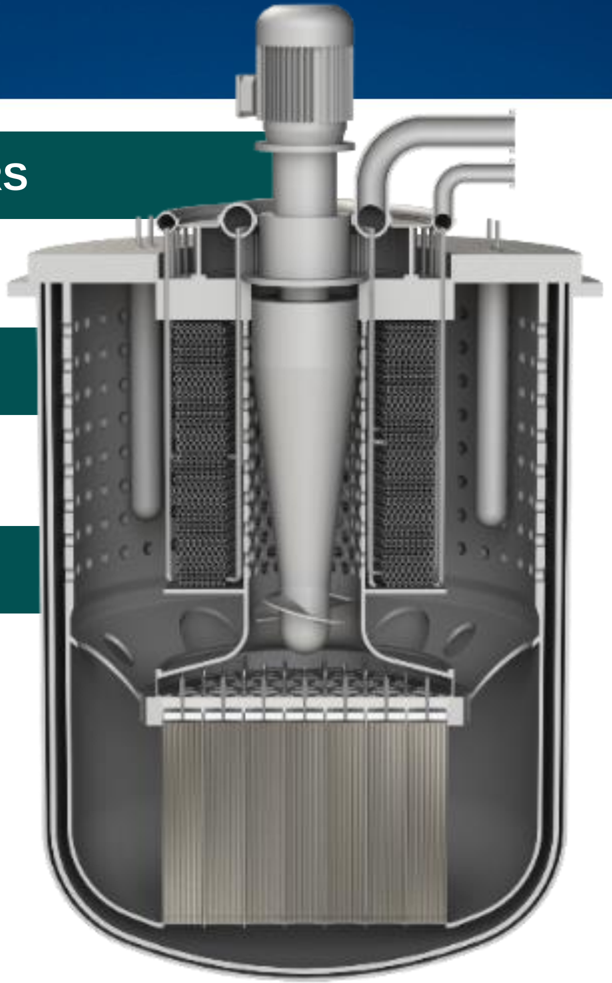


AS-200

200 MWe terrestrial module

TL-30

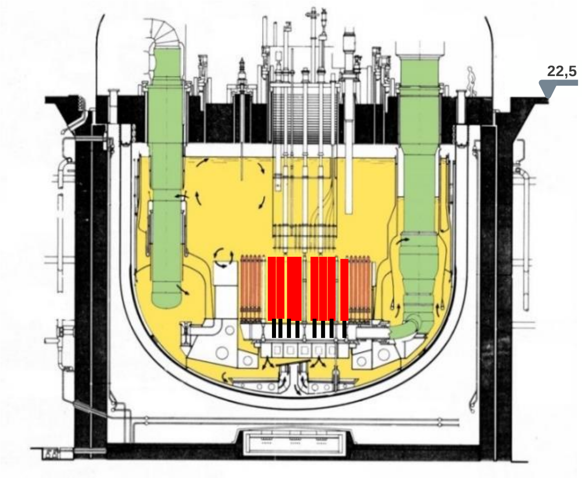
30 MWe battery, also for maritime



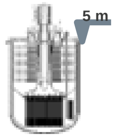
Learning from the past: the LFRs advantages

Similar concepts

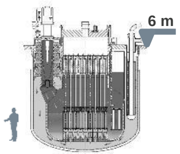
Liquid-metal fast reactors, same fuel, thermal-hydraulics and mechanical aspects, can be burners or self-breeders



Superphénix (1974, 1242 MWe)



30 MWe



200 MWe

newcleo SMRs

More promising in terms of cost and safety

- Lead doesn't react with air or water in an intense way like sodium, hence **no intermediate loop** needed and DHR systems can be simplified
- No shielding assemblies needed thanks to lead properties
- Favourable neutronics allow large pitch-to-diameter ratio, reducing pressure losses (despite the much higher density), enhancing **natural circulation** hence the safety performance
- Combined with the **high boiling temperature**, LFRs have an advantage in coping with severe accident initiators like ULOF, ULOHS, TLOP

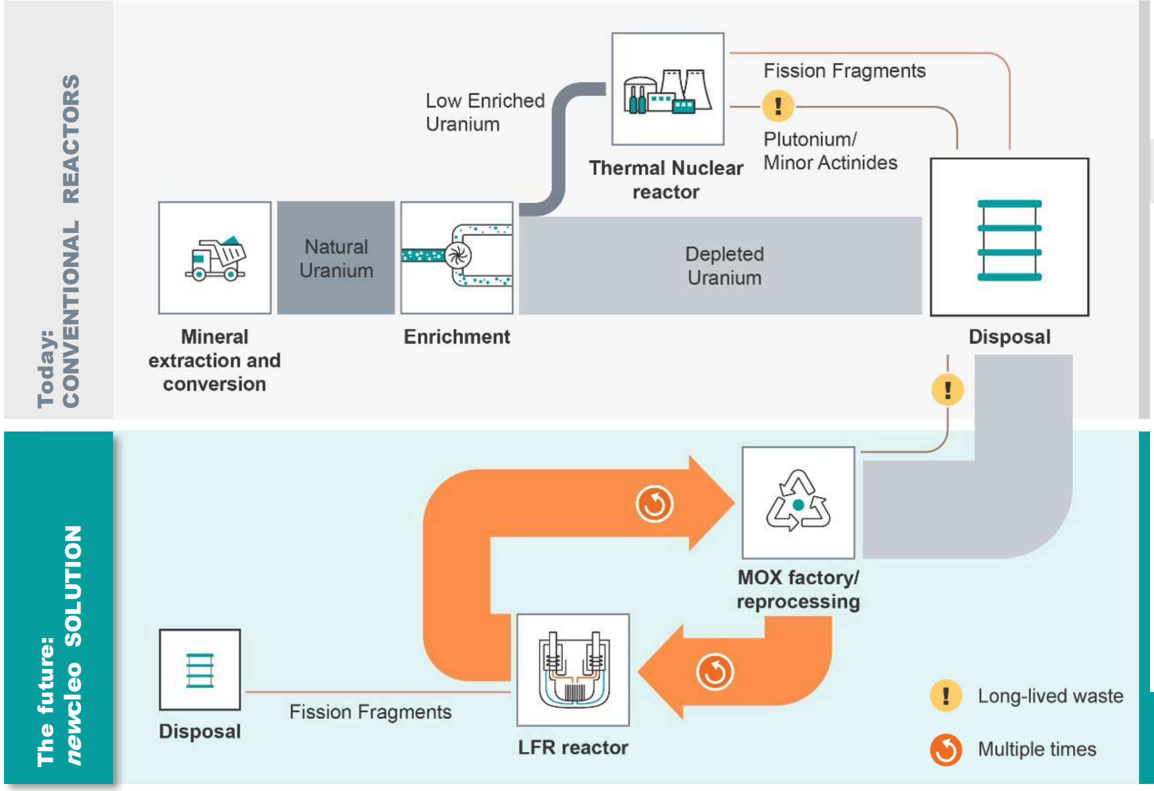
	Sodium	Lead
Density [g/cm3]	0.847	10.48
Melting temperature [K]	371	601
Boiling temperature [K]	1156	2023

Lead challenges

- High density impacts on seismic performance, need for a short vessel
- Erosion concerns limit coolant velocities
- Enhanced material are being studied to withstand corrosion at high temperature

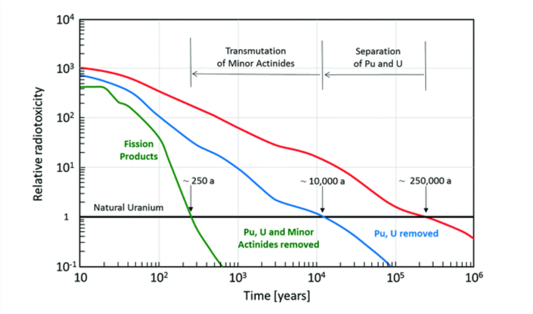
Technical solutions can be identified to maximise compactness and density of the primary system, up to 4x more than SPX1

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



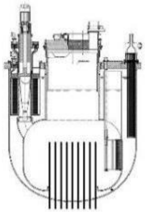
Thermal fission reactors use a very small portion of the extracted uranium: an average 1GWe LWR uses every year 200t of mined uranium of which only 1t is fissioned (Fission Products), the rest today goes to "*waste*"

High-level waste has become an expensive liability



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

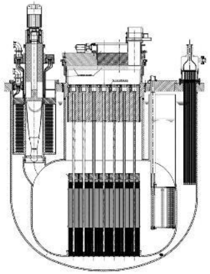


2026

Precursor

10 MW electrically heated/non-nuclear facility with turbogenerator

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



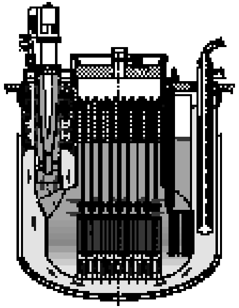
AS-30

2030

LFR-AS-30

30 MWe nuclear module with core outlet at 430/440° (later 530°), using MOX as fuel

Demonstrator and test reactor



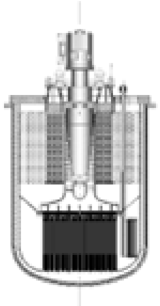
AS-200

2032

LFR-AS-200

200 MWe nuclear SMR, for stand-alone or multi-module configuration, using MOX as fuel

First-Of-A-Kind (FOAK) reactor



TL-30

2032

LFR-TL-30

30 MWe mini nuclear reactor for industrial and maritime applications

Working as a nuclear battery, with infrequent refuelling (10y +)

ENEA-Brasimone non-nuclear experimental facilities

CAPSULE
operational in February 2024

Facility to test various kinds of steel, bare and coated, in stagnant lead under oxygen-controlled concentration, essentially between 10^{-8} - 10^{-6} wt %; temperatures span between 450 - 750 °C

CORE
200 kW
operational in March 2024

Loop-type facility to test various kinds of steel, bare and coated, in fluent lead under oxygen-controlled concentration, essentially between 10^{-8} and 10^{-6} wt %; temperature in the corrosion test section 650 °C and velocity 1 m/s; in the erosion test section the temperature is 520 °C and the velocity 10 m/s.

It will also be used to test the effectiveness of cold traps and mechanical filters

OTHELLO
2 MW
operational in 2025

Loop-type facility with a Fuel Pin Bundle Simulator and a mock-up of *new*cleo Steam Generator with three full length tubes. It will be used to test a Fuel Pin Bundle Simulator to validate thermal-hydraulic computer codes, to appreciate the consequences of partial inter-pins obstructions

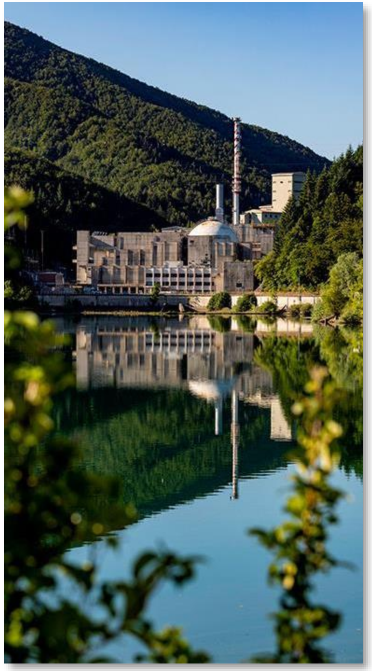
Also, to test the behaviour, both lead side and water/steam side, of the Steam Generator

PRECURSOR
10 MW
operational in 2026

Pool-type integral test facility with an electrical resistors bundle, and three Steam Generators at a thermal reduced scale, and the associated turbine-generator set. It will be used to test the global behavior of the plant in stationary and transient mode, the inset of lead flow both in hot and cold plenum and of possible stagnant zones, the effectiveness of the DHR system, test various mechanisms as the control rods

MANUT
conceptual phase

It is a "cold" facility to test the fuel hanging and handling systems as well as the rotating plugs operation during refueling campaign. This facility is just at a first conceptual draft.

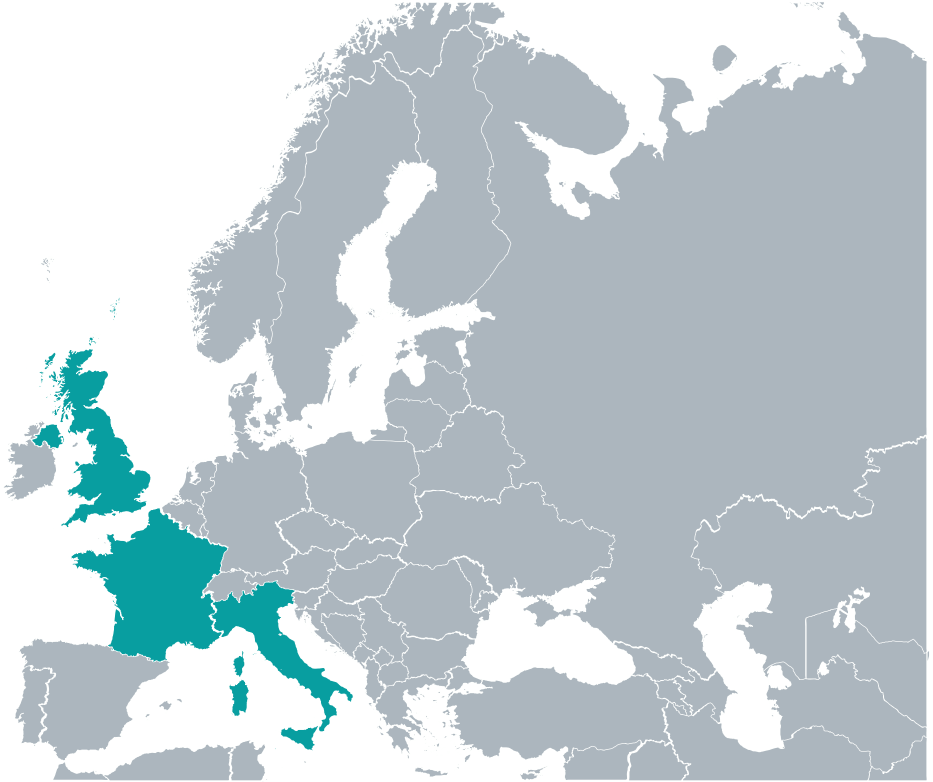


ENEA-Brasimone centre

HELENA facility

Partnership signed in March 2022: ENEA unique global know-how and *new*cleo 25-30 engineers and EUR50+ million for about 10 years. Renovation works started in June 2022

Increasing numbers of partners and suppliers



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Thank you

Stefano BUONO

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2023