newcleo’s Lead-cooled Fast Reactors for clean, safe and sustainable energy

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University of Bologna – Faculty of Engineering

Ing. Roberto Spaggiari (newcleo) – Fuel cycle supervisor
1 - An overview
**A fast growing company**

*newcleo* 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:

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

Growing to 500 by 2023
**newcleo, 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)**
- newcleo 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 newcleo’s LFR
**Lead has unique properties for developing a fast reactor**

<table>
<thead>
<tr>
<th>Atomic mass</th>
<th>Absorption cross-section</th>
<th>Boiling Point (°C)</th>
<th>Chemical Reactivity (w/Air and Water)</th>
<th>Risk of Hydrogen formation</th>
<th>Heat transfer properties</th>
<th>Retention of fission products</th>
<th>Density (Kg/m³) @400°C</th>
<th>Melting Point (°C)</th>
<th>Opacity</th>
<th>Compatibility with structural materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>207</td>
<td>Low</td>
<td>1737</td>
<td>Inert</td>
<td>No</td>
<td>Good</td>
<td>High</td>
<td>10580</td>
<td>327</td>
<td>Yes</td>
<td>Corrosive</td>
</tr>
</tbody>
</table>

**Fast neutron spectrum**<br>
- Large fuel pin lattice<br>- Low core pressure loss<br>- Primary system at atmospheric pressure<br>- No intermediate loop<br>- Possible use of low-cost water or air loops for DHR<br>- Reduced risk of plant damage<br>- Reduced risk of fuel cladding overheating<br>- Reduced source term during postulated accidents<br>- No risk of core compaction

**But it also has properties that have discouraged some designers**

*newcleo 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 (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 Nuclear submarine-705 serial
- 1996
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 into 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.
newcleo’s plan-to-market

**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 5**: Self-supporting core
- **Patent 6**: Amphora Shaped Inner Vessel
- **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 *newcleo’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 < 1m³/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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core power [MWth]</td>
<td>480</td>
</tr>
<tr>
<td>Electrical power [MWe]</td>
<td>200</td>
</tr>
<tr>
<td>Core inlet/outlet T [°C]</td>
<td>420/530</td>
</tr>
<tr>
<td>Primary loop pressure loss [bar]</td>
<td>1.3</td>
</tr>
<tr>
<td>Secondary cycle</td>
<td>Superheated steam</td>
</tr>
<tr>
<td>Turbine inlet pressure [bar]</td>
<td>180</td>
</tr>
<tr>
<td>Feed water/steam temperature [°C]</td>
<td>340/500</td>
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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
The forecasted investment sums up to **EUR50+ millions in a 10-year period**, with **25 to 30 engineers** on site.

### Non-nuclear facilities

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

**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

*TEST SECTION* (replacing existing piping)
Thank you

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