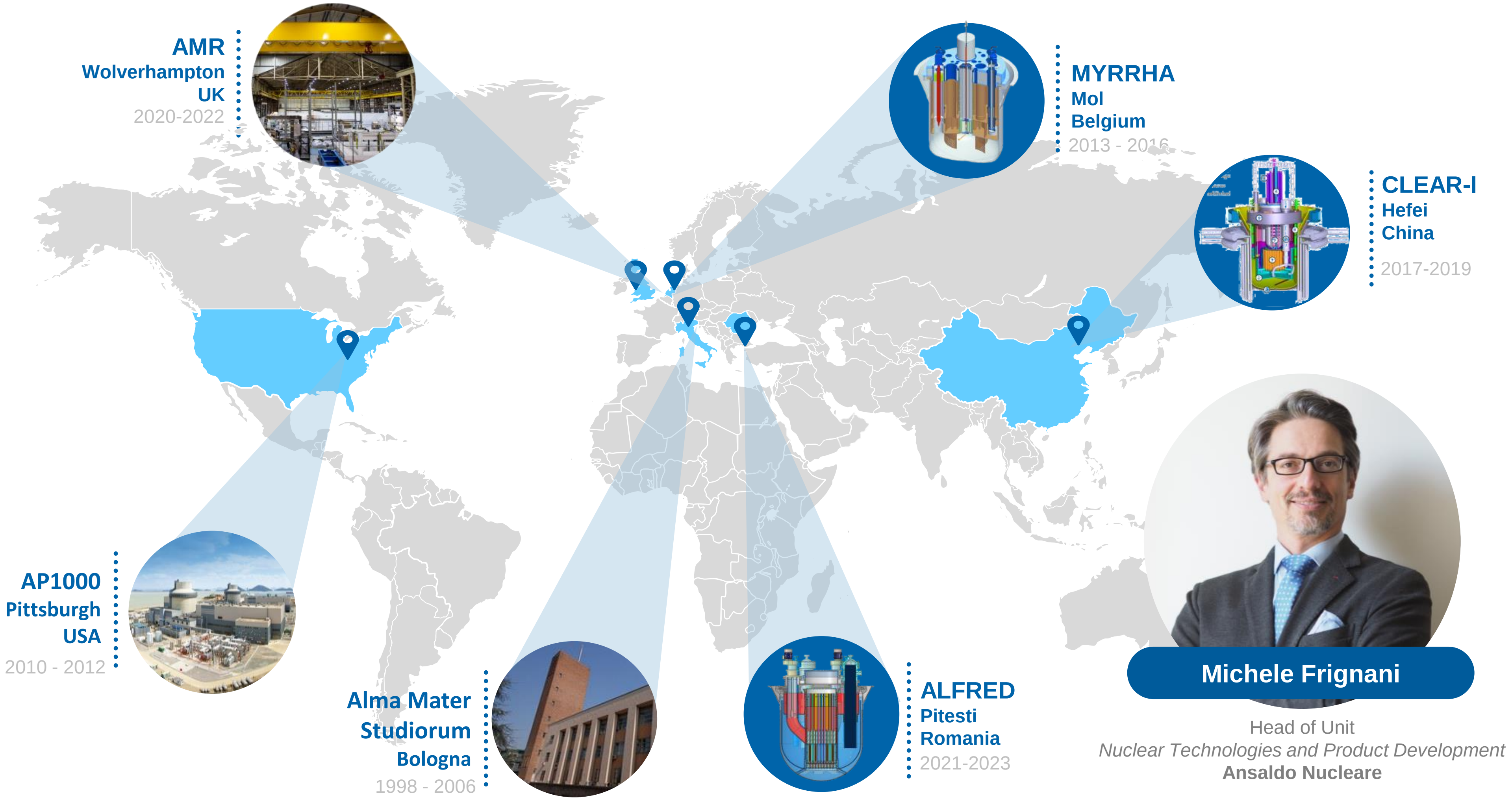
Leading a joint European roadmap towards a competitive LFR

Michele Frignani

Head of Nuclear Technologies and Product Development

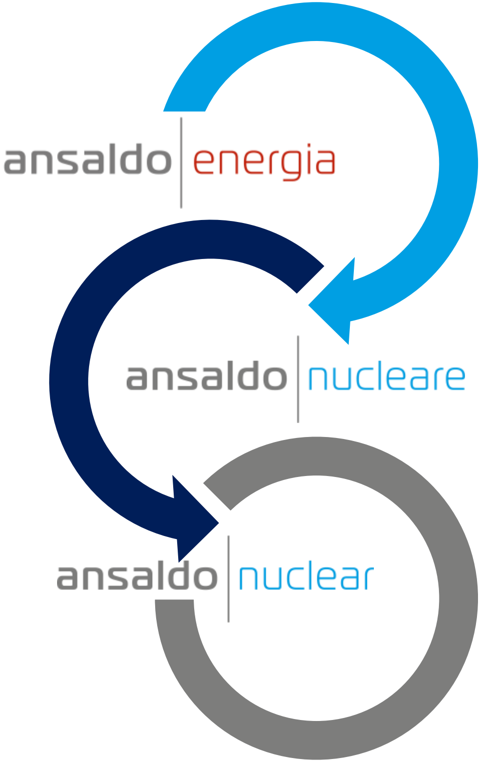
Member of FALCON Expert Board


AMR
Wolverhampton
UK
2020-2022
MYRRHA
Mol
Belgium
2013 - 2016
CLEAR-I
Hefei
China
2017-2019
AP1000
Pittsburgh
USA
2010 - 2012
Alma Mater
Studiorum
Bologna
1998 - 2006
ALFRED
Pitesti
Romania
2021-2023
Michele Frignani
Head of Unit
Nuclear Technologies and Product Development
Ansaldo Nucleare

Outline

- Ansaldo Nucleare’s roots in the LFR technology
- ALFRED: reference design and staged approach
- EU-SMR-LFR: a new joint development programme

Our Mission



Ansaldo Energia Group, owned by Cassa Depositi e Prestiti, is an international leader in the field of power generation (gas turbines, steam turbines, generators, turnkey plants, service solutions).

Ansaldo Nucleare S.p.A. and its subsidiary Ansaldo Nuclear Ltd (UK) operate together as **Ansaldo Nuclear**

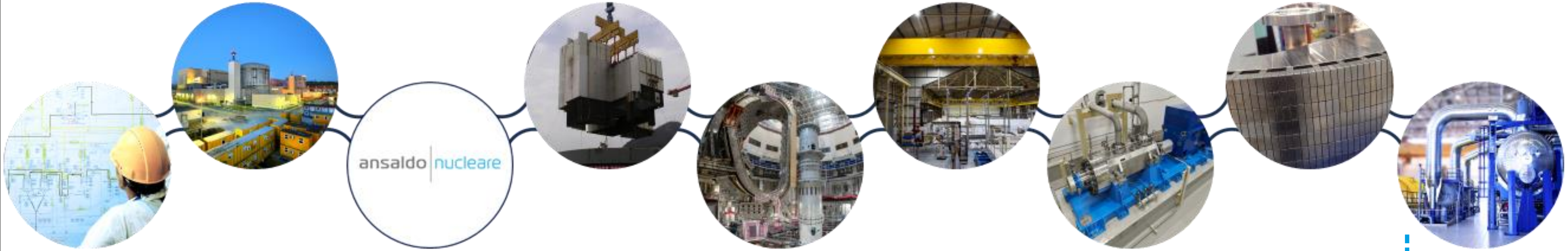
Ansaldo Nuclear is fully devoted to

- Exploiting engineering and manufacturing capabilities
- Exploring new technologies and developing products

440
Resources

80 € million
Revenues

Our History



1966
Ansaldo Nucleare Meccanico founded

1980-90's
Superphenix (France) and Cernavoda 1 (Romania) connected to the grid

2005
Ansaldo Nucleare established

2005-2010
AP1000 Design certification and Containment Vessel Contract Cernavoda connected to the grid

2010
ITER Vacuum Vessel Contract

2014
Aquisition of Ansaldo Nuclear Ltd

2018
KRSKO NPP, Safety Upgrade Program, PLEX Contract

2020
Main Contract in Nuclear Fusion (ITER, DEMO, DONES)

2023
Main contract: Cernavoda U1 ITER VVBR

Our portfolio

Ansaldo Nucleare provides **Integrated Delivery Model** for Nuclear Power Plant Products by matching, combining, complementing systems and components in the nuclear market

Our activities cover the full plant life-cycle, ranging from the design and construction of **new builds** and innovative reactors, to the production of **critical high-tech components**, from the **upgrade** of existing power plants to the waste management and decommissioning.

Ansaldo Nucleare in passive safety syems and LFR technology

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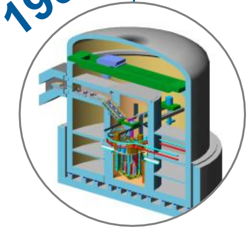
Advanced passive components prototypes

1980s

Co-development of Superphenix (LMFBR)

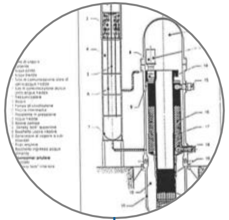
Support to AP600 licensing

1990s

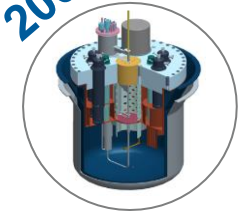


Early studies on Energy Amplifier by Nobel prize C. Rubbia

Early concepts of integrated SMRs



2000s



Long-lasting collaboration with SCK•CEN for the design of MYRRHA

Delivery of Passive Residual Heat Exchanger at Sanmen

2010s

ESNII
European Sustainable Nuclear Industrial Initiative

10+ EURATOM projects for the development of Gen-IV LFR technology

Design and Commissioning of AP1000 Containment Vessel at Sanmen 1

2016

2020s

Experimental facilities to support LFR technology

A European approach to Gen-IV LFRs: the original purpose of FALCON

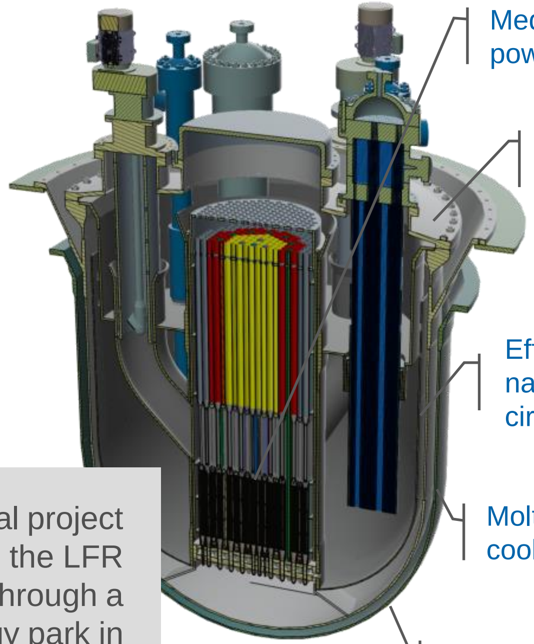
CESINA Partnership

FALCON

a long-term collaborative endeavour to promote the LFR technology in Europe, since 2013

ALFRED

An international project to speed up the LFR deployment through a technology park in Romania



Opportunities and Challenges of Lead Technology

Opportunities = Innovation in design approach

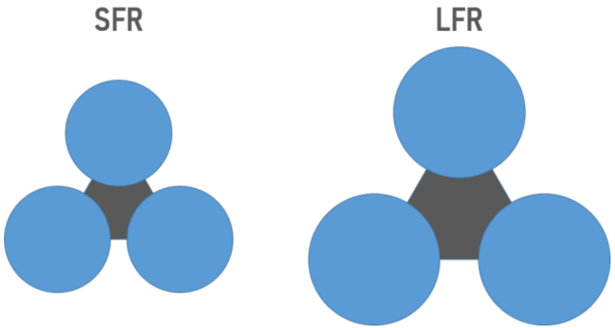
- Enhanced natural circulation
- Negative reactivity feedback
- Favourable breeding/transmutation
- Reduced pump head requirements
- No intermediate circuit
- Minimum stored energy in the system
- Fission products retention
- Simplified layout

Challenges = Innovation in design provisions

- Protective measures against corrosion
- Coolant chemistry and purification
- Self-regulating and anti-freezing DHR passive system
- Avoidance of steam drag into the core
- Seismic loads
- Maintenance, inspection and repair strategy

Lead-cooled Fast Reactors offer improved capabilities in terms of **passive safety** and **sustainability** that make them one of the most interesting candidates for the **Advanced Modular Reactor** segment

How coolant properties influence design choices

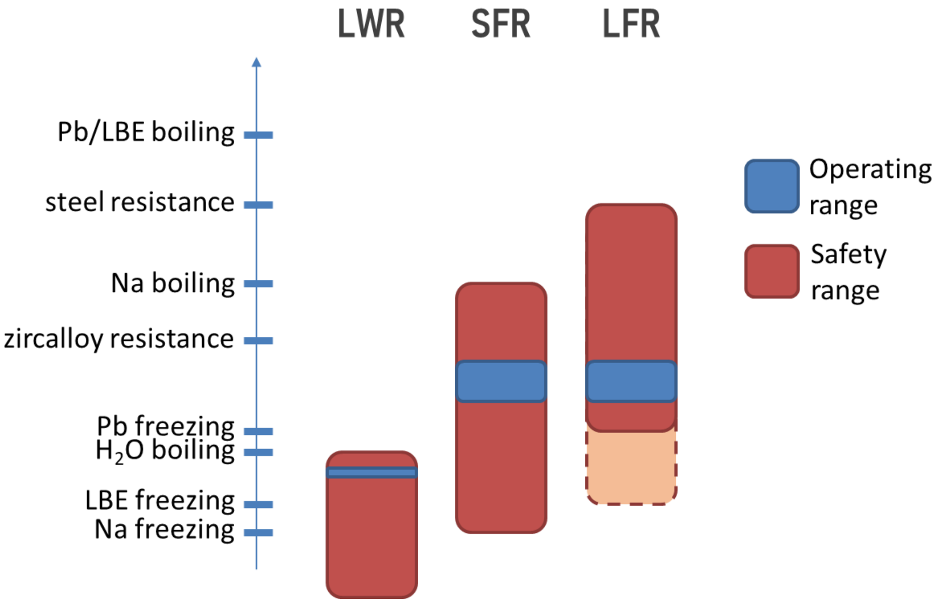


Superphénix:

p/d	= 1.152
<q'>	= 303 W/cm
$\Delta T_{coolant}$	= 150 °C
D_h	= 3.8 mm
$v_{coolant}$	≈ 6.0 m/s
Δp_{core}	= 4.7 bar
d_{pin}	= 8.5 mm
VF_{fuel}	= 36.6%
VF_{steel}	= 23.4%
$VF_{coolant}$	= 34.9%

ALFRED:

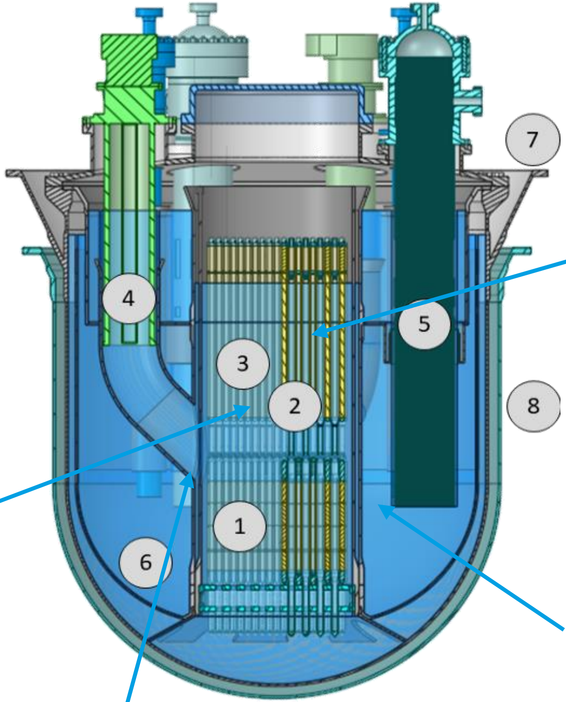
p/d	= 1.295
<q'>	= 219 W/cm
$\Delta T_{coolant}$	= 120 °C
D_h	= 8.5 mm
$v_{coolant}$	= 1.26 m/s
Δp_{core}	= 1.0 bar
d_{pin}	= 10.5 mm
VF_{fuel}	= 31.5%
VF_{steel}	= 17.8%
$VF_{coolant}$	= 46.4%



Courtesy of ENEA

Reactor Coolant System Arrangement

1. Core
2. Sub-Assemblies
3. Inner Vessel
4. Reactor Coolant Pump
5. Steam Generator
6. Internal Structure
7. Reactor Vessel
8. Safety Vessel



Fuel assemblies: MOX fuel, grid-spaced, hexagonal, wrapped, extended stem

Reactivity control: Two diverse and redundant systems, control and shut-down rods

Inner Vessel: safety-related, removable for out-of-vessel inspection

Internal Structure: not safety related, ensure pools separation and flow recirculation

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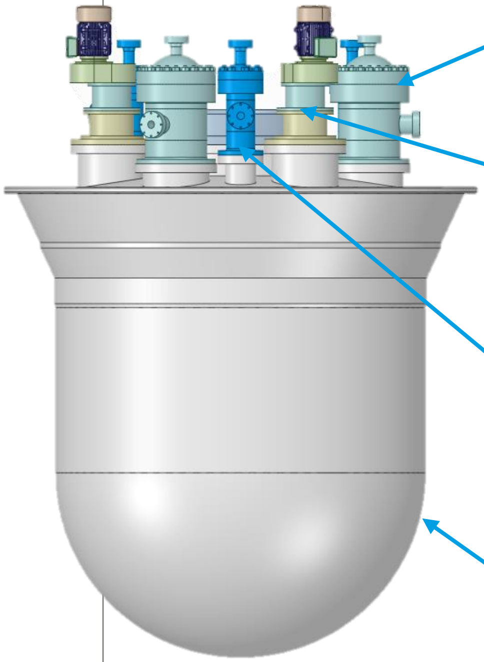
Main components features



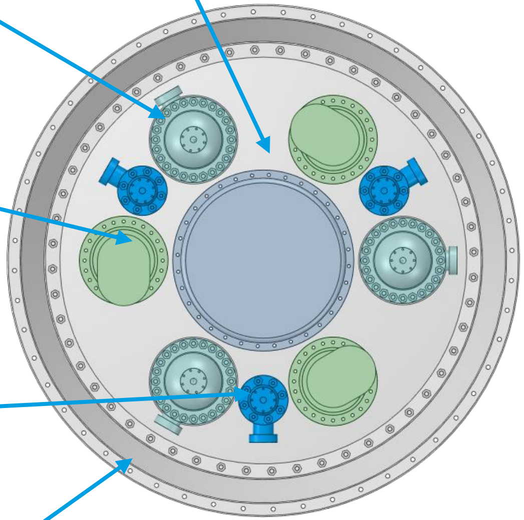
Steam Generator:
Single-wall bayonet tubes Steam generators connected to secondary system and to the isolation condenser of the DHR-2 system.

Primary Pump:
Pull-type axial pump connected in hot leg.

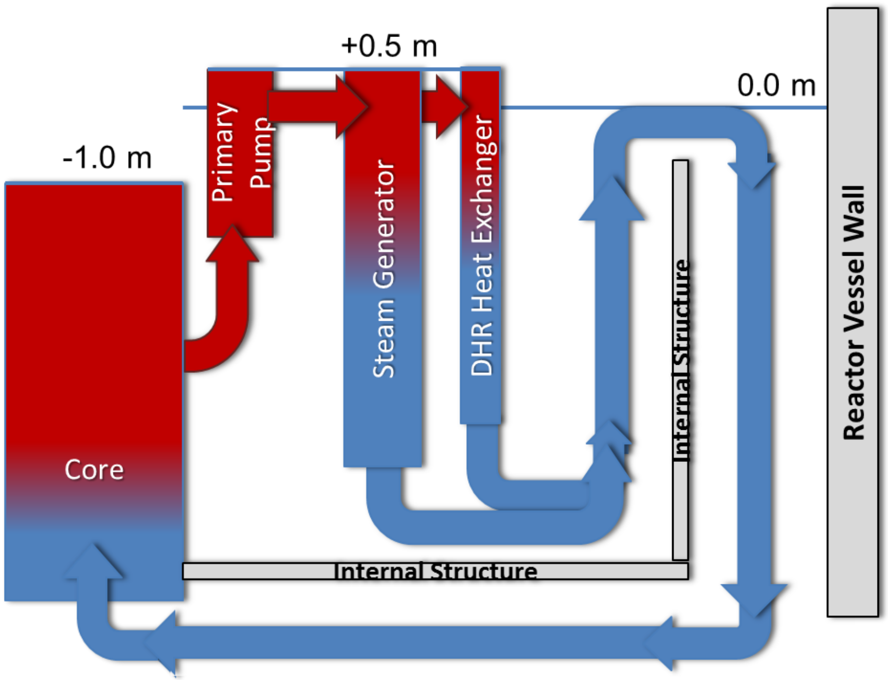
Dip Cooler:
bayonet tubes heat exchanger connected to isolation condenser of the diverse DHR-2 system.
In DBC1, the system shall maintain a state of stand-by condition in which the thermal power removed from the RCS is negligible.

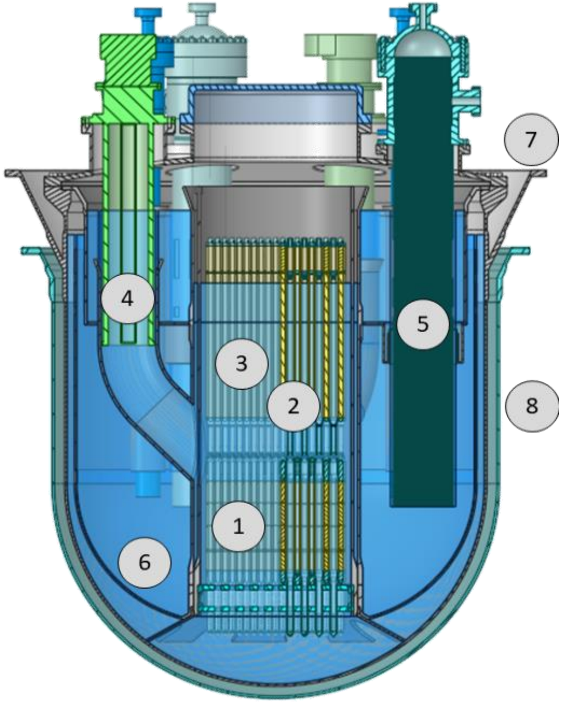
Reactor Vessel: Hemispherical head, Y-junction on the top and cone frustrum at the bottom

Reactor cover:
Hot design stainless steel reactor roof, standard flanged connections.
Design to ensure FA handling under lead during refueling operations.



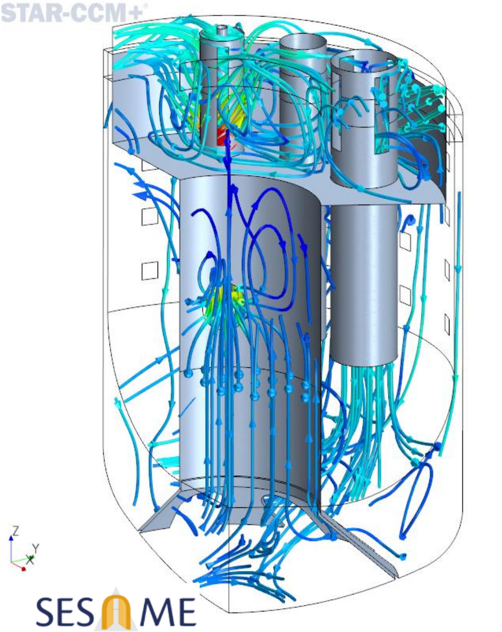
Notional view of coolant flowpath





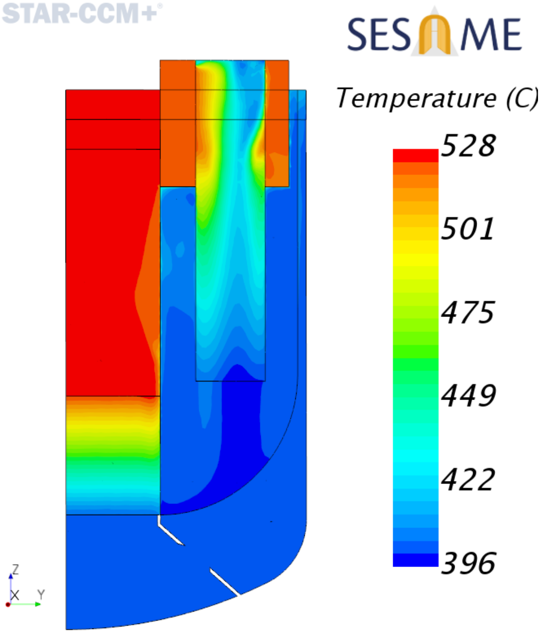
ALFRED configuration

Developed to address the thermal-hydraulic issues typical of fast reactors



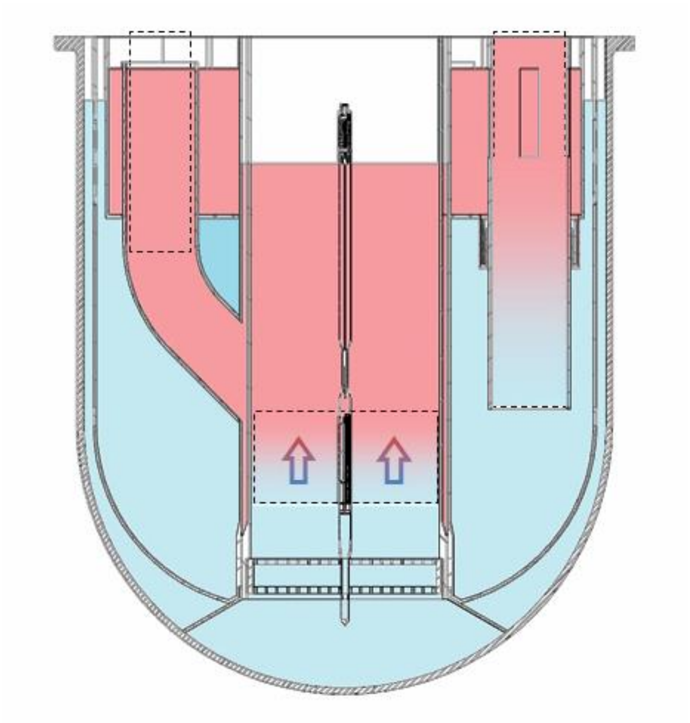
Courtesy of CRS4: SESAME, Task 3.1.2, D3.7, CFD Model of ALFRED Primary Loop

- No Pool Thermal Stratification
- No direct connection SGs – core to avoid steam entrainment in case of SGTR
- Hot Safety Vessel to mitigate Reactor Vessel break
- No intermediate circuit nor double wall SGs for higher performance
- Ensured Refueling operations with FA under lead
- Staged approach to by-pass technological limits



Courtesy of CRS4: SESAME, Task 3.1.2, D3.7, CFD Model of ALFRED Primary Loop

ALFRED relevant regions for component categorization



Hot spot:

- Heated region
- Clad region at highest temperature
- Accounting for uncertainties

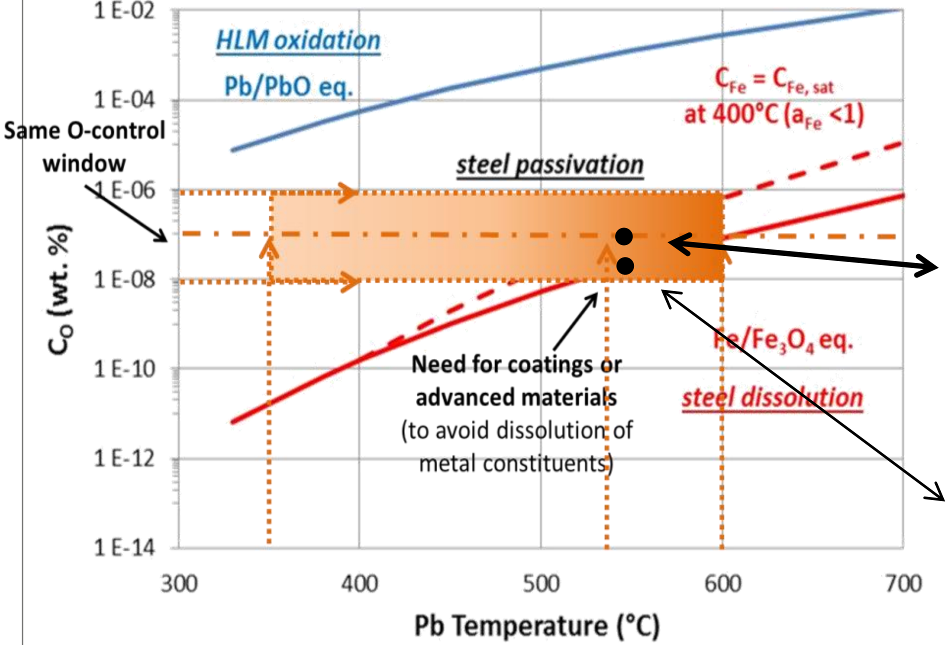
Hot pool:

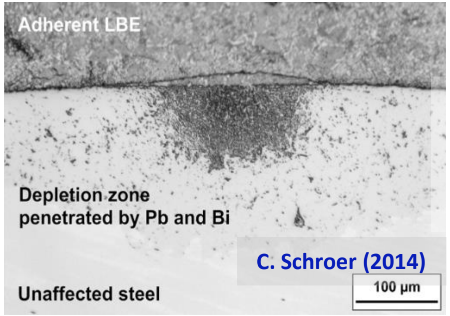
- Region at average core outlet temperature
- Affects also PPs and SGs inlet

Cold pool:

- Region at average core inlet temperature
- High thermal capacity

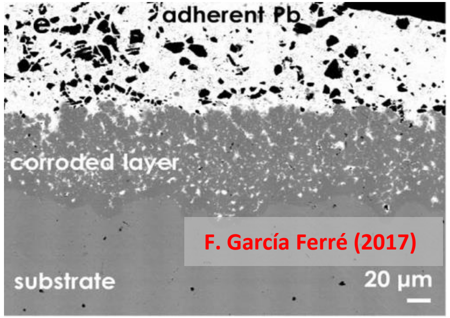
Structural Materials





Oxidation + Ni/Cr dissolution (γ Fe → α Fe), Pb penetration

316L steel in flowing LBE, 550◦C, high C_O, 7500 h.



15-15Ti steel in static Pb, 550◦C, low C_O, 4000 h.

Ni/Cr dissolution (γ Fe → α Fe), Pb penetration, no oxidation

Oxide film via Oxygen Control not effective for T > 450-480°C

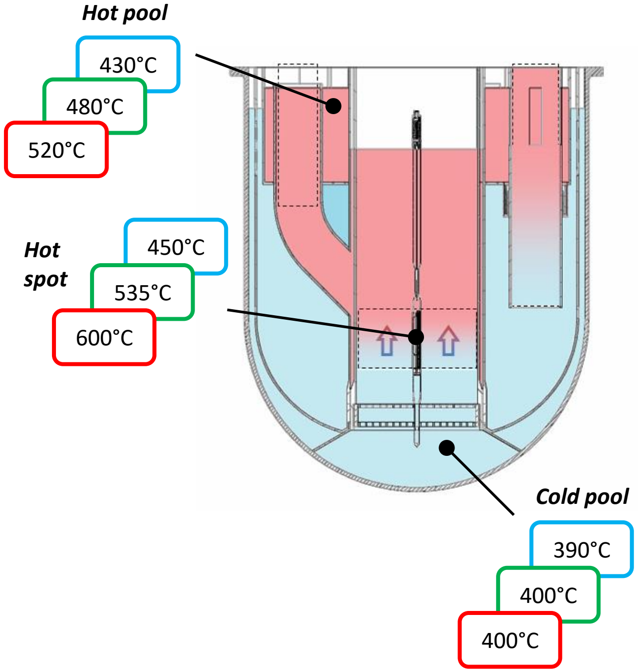
Need for coatings or advanced materials

ALFRED Staged Approach

- ALFRED will facilitate licensing readiness and operational readiness for western LFR commercial reactors.

Increase in reactor coolant temperature

- **STAGE 1**
  - Proven technology, proven materials, oxygen control, low temperature
  - Aimed at in-core qualification of PLD Al_2O_3 coating for cladding
- **STAGE 2**
  - Need for FA replacement
  - Aimed at in-core qualification at higher temperature
- **STAGE 3**
  - Replacement of main components (SGs, PPs, dip coolers, ...)
  - Representative of FOAK conditions for LFR deployment

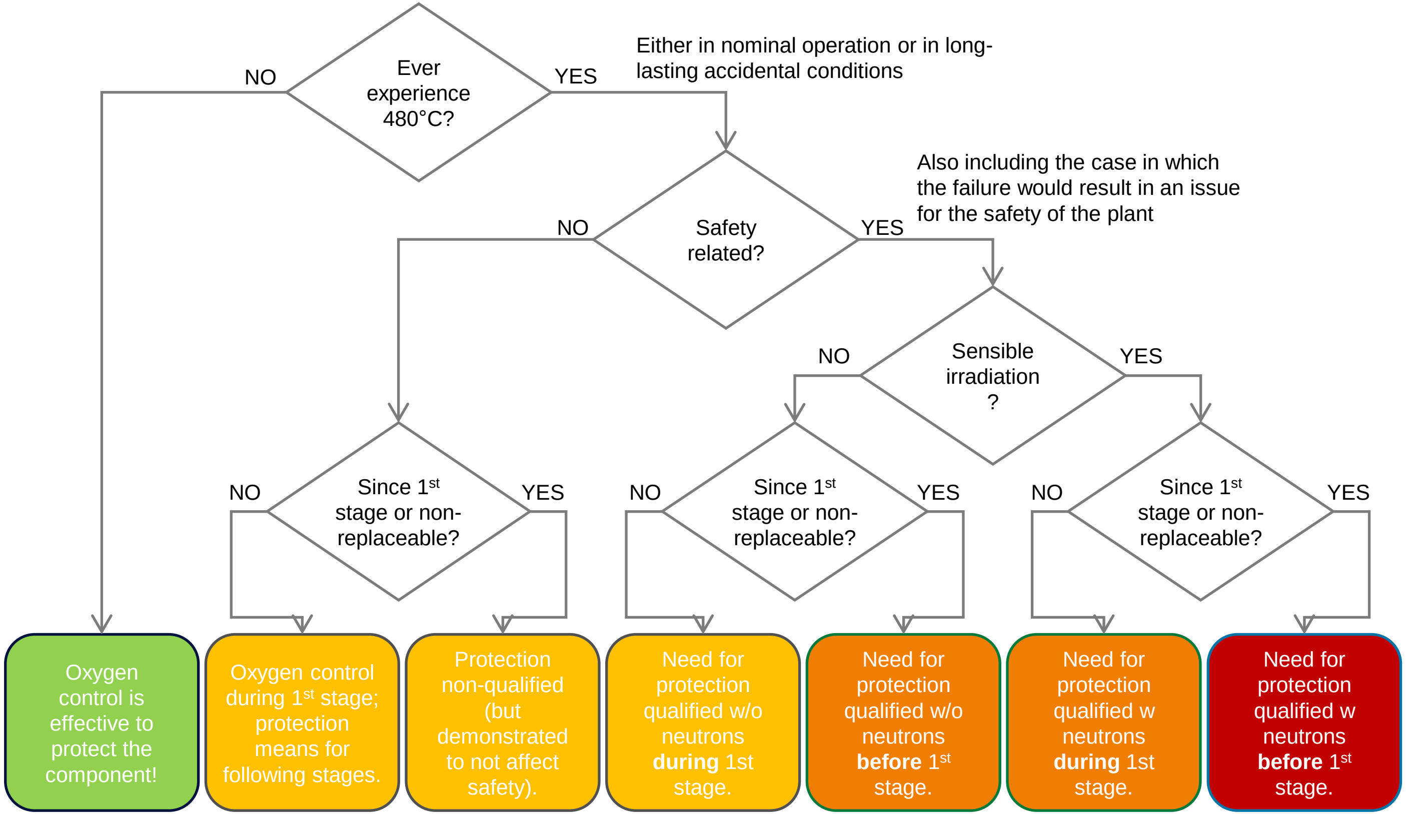


ALFRED Staged Approach

Selected temperature based on European experimental results on compatibility of proven materials with molten lead.

	Stage 0	Stage 1	Stage 2	Stage 3
	Commissioning	Low Temperature	Medium Temperature	SMR prototype
Core inlet temperature (°C)	390	390	400	400
Core outlet temperature (°C)	390	430	480	520
Core thermal power (MW)	**0**	**100**	**200**	**300**
Live steam pressure (bar)	/	170	175	180
Live steam temperature (°C)	/	420	435	450

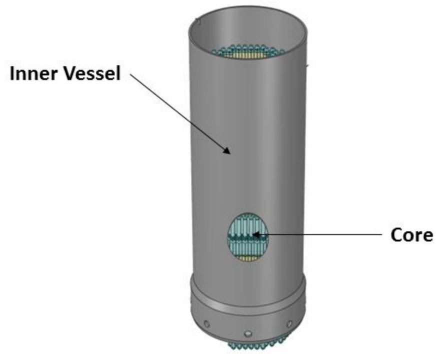
Logic for the selection of protective measures



Major mechanical equipment

- The main components of the RCS (and their stage's reference conditionas) are:

- Reactor Vessel (Stage 3)
- Reactor Cover (Stage 3)
- Inner Vessel (Stage 3)
- Internal Structure (Stage 3)
- Diagrid (Stage 3)
- Core Plug (Stage 3)
- Steam Generators (Stage 2)
- Reactor Coolant Pumps (Stage 2)
- Dip Coolers (Stage 2)
- Core (Stage 1)



Certification, qualification, industrialization

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NuScale SMR receives US design certification approval

01 September 2020

Share

The US Nuclear Regulatory Commission (NRC) has issued a final safety evaluation report (FSER) for NuScale's small modular reactor. This is the first-ever FSER to be issued by the NRC for an SMR, and represents the completion of the technical review and approval of the design.

SMR Design Certification approval

USD500 million for the Final Safety Evaluation Report (largely from DOE).
2+ million hours to develop information
14 Topical Reports.
2+ million pages of supporting information for NRC audits.

How a NuScale SMR plant could look (Image: NuScale)

world nuclear news

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Alloy clear for use in high-temperature reactors

06 May 2020

Share

Alloy 617 - a combination of nickel, chromium, cobalt and molybdenum - has been approved by the American Society of Mechanical Engineers (ASME) for inclusion in its *Boiler and Pressure Vessel Code*. This means the alloy, which was tested by Idaho National Laboratory (INL), can be used in proposed molten salt, high-temperature, gas-cooled or sodium reactors. It is the first new material to be added to the Code in 30 years.

Alloy-617 introduced in ASME for high-temperature reactors

First new material added **in 30 years**.
USD15 million (mostly from DOE).
12 years for testing.
3 years for the balloting process.

Alloy 617 was subjected to repeated fluctuations in temperature or physical stress to provide data for the ASME code case (Image: INL)

Enlarging the collaboration at European level

Italy

- Investing in LFR research since the 2000s.
- Discontinued national research program in 2018.
- But continued to support industrial research and Euratom projects.
- Now showing renewed interest in nuclear technologies.
- Very open to international collaboration.

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ENEA
Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Romania

- RATEN-ICN center involved in European projects on LFR since about 2010.
- Declared interest in hosting the first LFR demonstrator (ALFRED) in 2011.
- Joined the FALCON consortium in 2013.
- Embedded ALFRED and the associated research infrastructure in multiple national strategy documents.
- Financing the largest experimental lead facility in Europe (ATHENA).
- Investment of additional €100 million over the next 4-5 years.

RATEN
REGIA AUTONOMĂ TEHNOLOGII pentru ENERGIA NUCLEARĂ

Belgium

- Traditionally focused on ADS LBE cooled solutions.
- In 2022, LFR selected as the best technologies to meet national targets.
- Investment of 100 M€ over 4 years.
- SCK CEN is in charge of the research and demonstration activities.
- Experience in licensing process with FANC/Bel-V.
- Managing a fleet of experimental HLM-based infrastructures.
- Experience with MOX fuel.

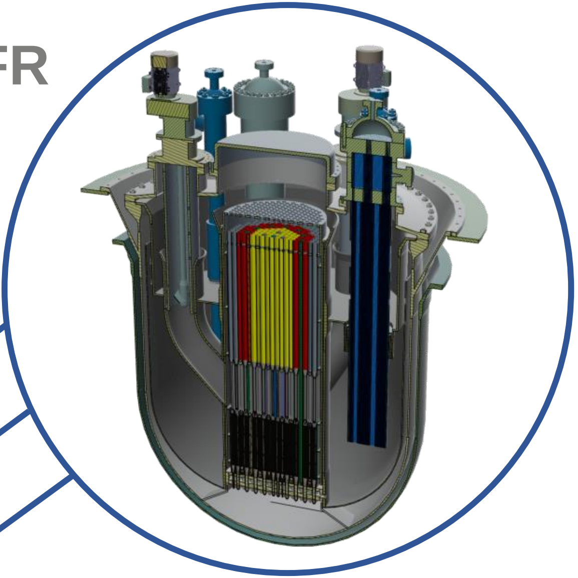
sck cen
Belgian Nuclear Research Centre

Partnership between nuclear national labs and industry leaders standing on a solid experience from the past and a shared vision for the future (MOU signed in Nov. 2023)

European Industrial Alliance on SMALL MODULAR REACTORS

- Competitive economics
- Proven passive safety features
- Sustainable closed fuel cycle
- High temperature heat
- Customers oriented
- Commercial fleet deployment by 2040

EU-SMR-LFR
(re-branding on-going)



Reference design
Simplified, robust, modular

Candidate sites
Mol-Belgium and Pitesti-Romania

Shared roadmap
Jointly owned IP

ansaldo nucleare — FALCON

ENEA — FALCON — Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

RATEN — FALCON — REGIA AUTONOMĂ TEHNOLOGII pentru ENERGIA NUCLEARĂ

sck cen — Belgian Nuclear Research Centre

Product key features

Time-to-market driven programme

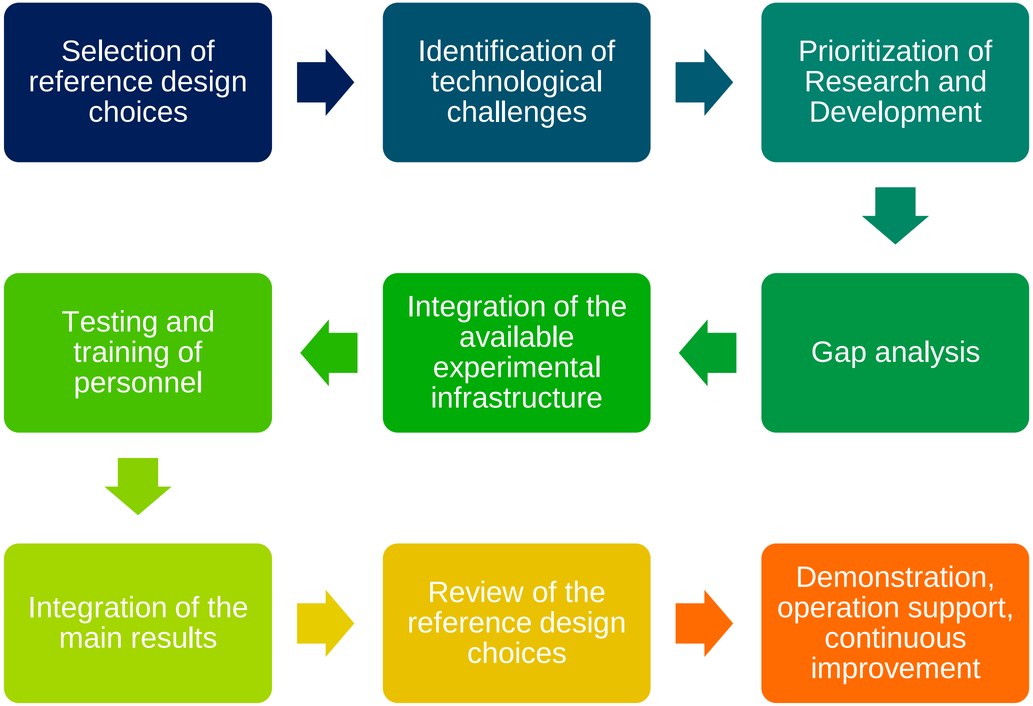
Balanced approach in the selection design options as a trade-off between marketability by performances and time required for their qualification.

Parameter	Ref. value
Reactor power	350 MWe
Primary/secondary coolant	Lead/Water
Reactor type	Pool
Safety approach	Passive safety
Fuel	MOX
Fuel cycle	Closed
Number of “loops”	3
Operating pressure (Prim./Sec.)	0.1 MPa / 18 MPa
Lead temperature (Min/Max)	370°C/520°C (>600°C)
Ultimate heat sink	Air (or water)
Load following	Thermal storage

- Economics and Marketability
  - LCOE competitive with future EU energy systems
  - Power selected for LCOE optimization
  - Size relevant for replacement of fossil fired power plants
  - Capability to assist the decarbonization of other sectors
  - Improved site-ability
- Safety and Security
  - Passive safety
  - No core meltdown
  - 72 hours minimum grace time
  - No EPZ (limited to site boundary)
  - Proliferation resistant
- Environment and Sustainability
  - Closed fuel cycle
  - Env. impact comparable or lower than RES
  - Minimization of rare raw material dependence
- Plant Operation
  - Minimize downtime due to inspection/maintenance in lead
  - All components replaceable

Logical definition of a roadmap

- Increased reference power for commercial LFR
- Increased reference operating temperature (improved efficiency, unlock other uses)
- Increased temperature difference across the core
- Accept higher dpa limits on supporting structures
- Passive safety shutdown (no unprotected transients)
- Reduced mass flow rate per unit power
- Reduced cross-sectional areas (assuming a maximum velocity to limit erosion)
- More effective steam generators (higher power density, lower pressure drops)
- Relocation of pump (more stringent material requirements due to temperature increase)
- Alternative DHR (passive category B)
- Alternative power conversion systems



Roadmap to commercial LFR

LEANDREA

Fast spectrum, technology viability demonstration and irradiation facility for qualification of materials/fuels

Objective: qualify fuel to be used in ALFRED

ALFRED

Representative of the commercial SMR-LFR, aiming to demonstrate capacity of operating over time while meeting expected availability

Objective: staged approach to ref. conditions

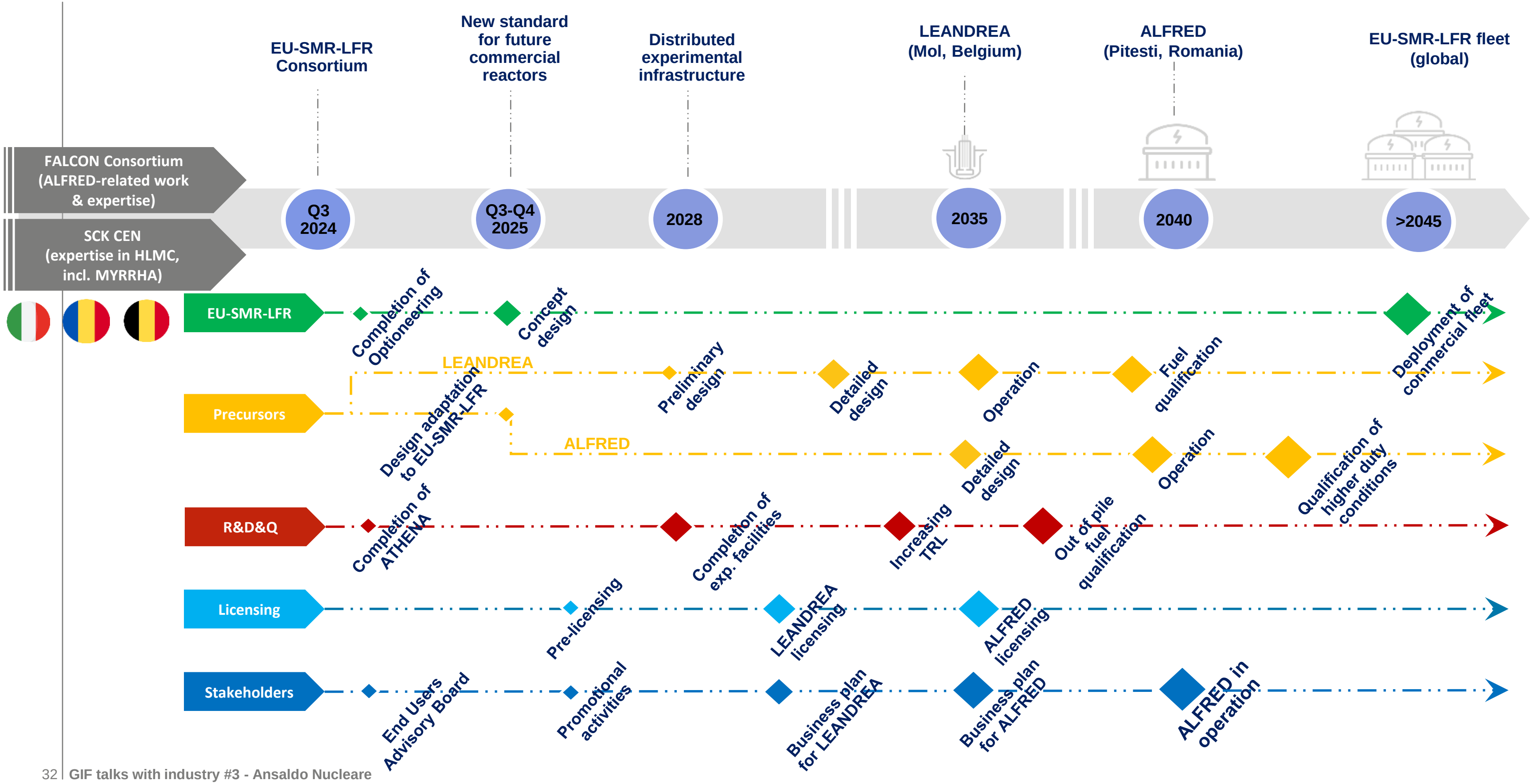
2 Precursors addressing the two fundamental steps of the Programme, developed largely in parallel, thanks to their specific goals

EU-SMR-LFR

European commercial of SMR-LFR fleet

Investment decisions for commercial reactors no later than 2040 based on ALFRED

Joint Programme



Licensing experience

SCK CEN has vast experience in interacting with the Belgian regulatory body, through a pre-licensing process, for the lead fast reactor technology.
For the EU-LFR-SMR precursor LEANDREA, preliminary interactions with the Belgian regulatory body were made

Ref.
S. Coenen et al., “Belgian Approach For Licensing New Innovative Reactors” (IAEA-CN-308, 2022).
I.G. Sanda et al., “3S Approach for Advanced SMR Designs in Belgium” (IAEA-CN-123/45, 2024).

In 2017, RATEN-ICN notified the Romanian Regulatory Body (CNCAN) about the intention to deploy ALFRED on the Mioveni platform, starting a preparatory phase to the authorization process. Building upon a licensing Basis Document (LBD), periodic meetings where held.

Ref.
G. Grasso et al., “Approach for ALFRED Licensing in Romania” (FR21, IAEA-CN-291/433).

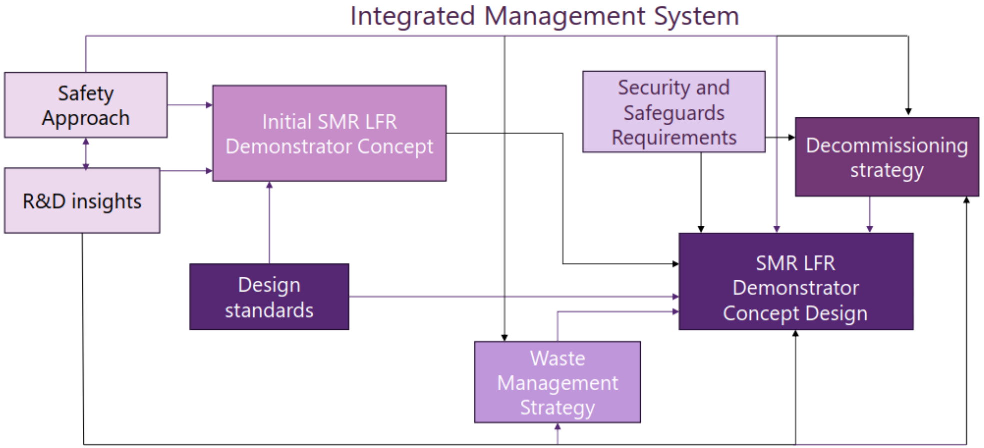
In 2018-2022, Ansaldo Nucleare and ENEA in collaboration with Westinghouse have been engaging with the UK regulatory body (ONR) and the national Environmental Agency, concerning the safety and licensing aspects of the LFR concept proposed under the BEIS funded feasibility and development studies.

Ref.
J. Liao et al., “Engagement Activities with the United Kingdom Regulators for the Westinghouse Lead Fast Reactor” (ICAPP-2024, accepted for publication).

Licensing harmonization process

- Start to set up a joint pre-licensing pilot process with FANC/Bel V and CNCAN, trough an IAEA extra-budgetary project funded by the consortium partners (pilot for NHSI regulatory track WG3)
- Safety Approach: alignment with safety standards and safety guides for a harmonized framework
  - Lists of Initiating Events to be analyzed as part the PSARs
  - Codes and Methodologies to be used for the Safety Analysis
- R&D Road Map: evidence-based safety claims and verification of numerical tools for safety analyses
- Design description
  - Design philosophy and options selection;
  - Design of systems and components;
  - Operation and Maintenance strategies
- Security and Safeguards Integral Approaches
  - Safeguard by design
  - Security by design
  - Cyber security
  - Integration of 3Ss into the designs

- Focus on pre-licensing for harmonization
- Multilateral pre-licensing project
- Integrated approach



Existing tangible and intangible assets

	Papers in peer-reviewed journals	Relevant patents	EURATOM funded projects	Experimental facilities
ansaldo nucleare	400	2	19; 3 m€	2
ENEA – Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile	1200	1	20; 14 m€	9
sck cen – Belgian Nuclear Research Centre	1000	1	22; 20 m€	15
RATEN – REGIA AUTONOMĂ TEHNOLOGII pentru ENERGIA NUCLEARĂ	350	-	15; 2.5 m€	1

+ computational tools and models validated experimental datasets.

Research infrastructure in Romania

- ATHENA & CHEMLAB (2020 – 2025)
  - Operational Programme Competitiveness + National co-financing
  - 22+ Million Euro
  - Under construction
  - Dec. 2024 – Completion
  - Dec. 2025 – Full power operation
  - **Largest lead test facility in the world**
- 4ALFRED Project (2025 – 2027)
  - Operational Programme for Smart Growth, Digitization and Financial Instruments (POCIDIF from ERDF)
  - Facilities construction and R&D activities
  - 100+ Million Euro
  - Dec. 2022, funding confirmation
  - Jun. 2023, ICN award expected

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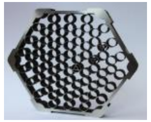
Status of experimental infrastructure in Romania

RATEN REGIA AUTONOMĂ TEHNOLOGII pentru ENERGIA NUCLEARĂ

- ATHENA and ChemLab, goes into operational stage in 2025
- HELENA2, ELF, Hands-On, Meltin'Pot - will start implementation in 2025; are planned to enter the operational stage in 2027.

Experimental park at ENEA Brasimone (Italy)



RACHEL Lab

BID-1

NACIE

CIRCE – Pool TH

LIFUS5

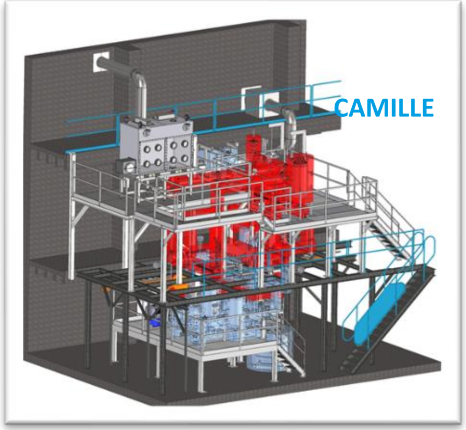
HELENA

CIRCE - SGTR

Overview of the next experimental installations

Focus on key liquid lead technologies

- **LFR-SMR Materials and Chemistry**
  - CAMILLE loop (**C**hemistry **A**nd **M**aterials **I**nvestigations in a **L**iquid **L**ead **E**nvironment)
    - Corrosion tests, oxygen control studies, fuel assembly integral tests
  - **HELIOS** (**HE**avy **Li**quid Metal **O**xygen control **S**etup)
    - Pool-type system behavior, including oxygen control strategy and technologies validation
- **LFR-SMR Full-Scale Component Testing**
  - **PULSAR** (**PU**mp faci**L**ity for **S**c**A**led expe**R**iment)
    - Full-scale investigation of LFR-SMR lead pump configurations
  - **HYDROBEAR** (**HYDRO**static **BEAR**ings test facility)
    - Full-scale investigation of LFR-SMR pump hydrostatic bearings
- **Mechanical testing**
  - **POLTERBEAR** → Small scale robotics and long-term bearing tests in lead
  - **LIMETS 5 and 6** → Tensile and fatigue tests in lead
  - **Erosion and creep set-ups** → liquid lead erosion and creep investigations/data acquirement



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SIRIO Test facility

Requirement: to remove decay heat passively

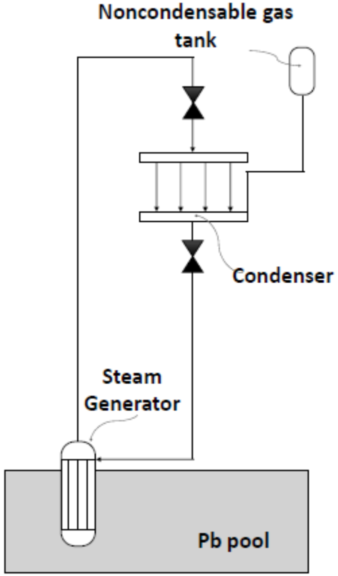
Challenge: lead freezes @ 327°C

Idea: self-refulating system

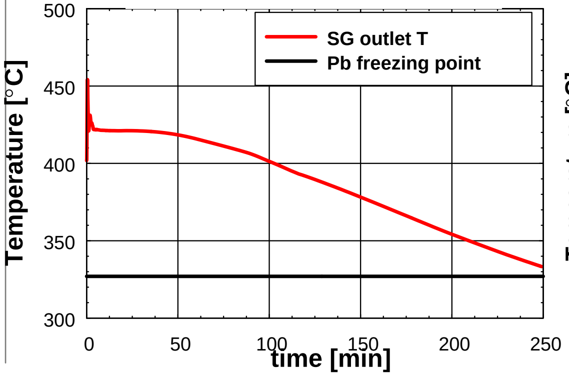
Solution: non-condensable gases

EURATOM funded PIACE Project: 3.2 M€, 2019-2022 (G#847715). In synergy with SIRIO facility at SIET funded by IT-Govt. (1.4 M€).

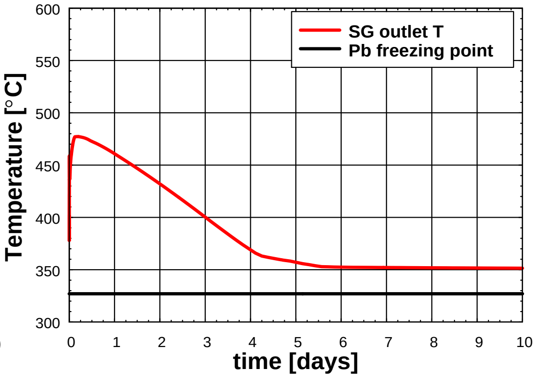
Passive power modulation by means of non-condensable gases against lead-freezing.



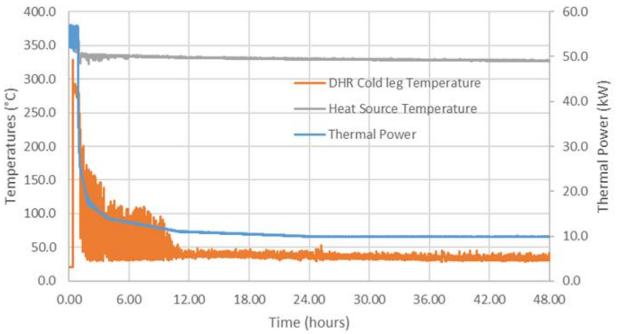
Without non-condensable tank



With non-condensable tank



Validaiton through experimental tests



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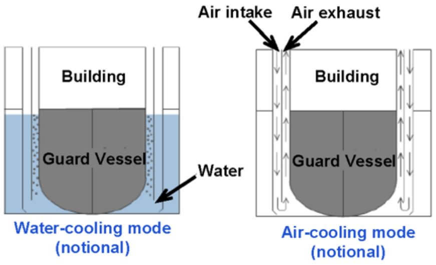
Category B PHRS demonstration

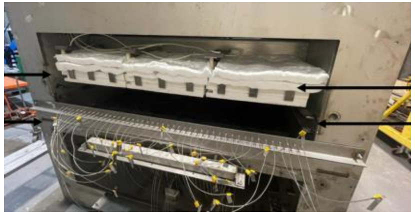
Requirement: to remove decay heat passively

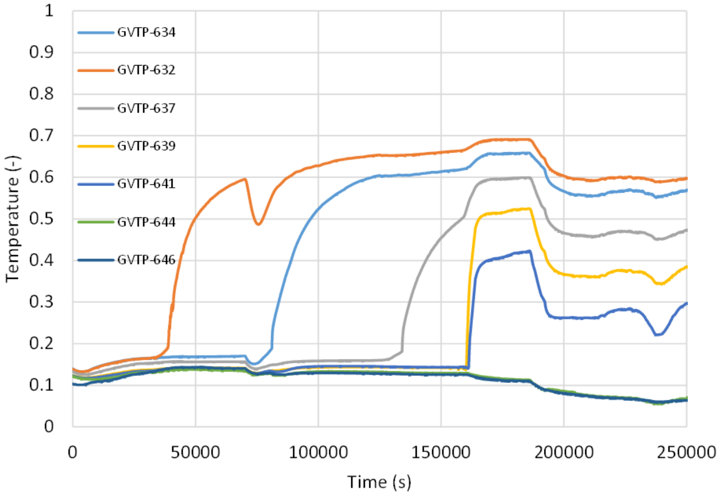
Challenge: lead freezes @ 327°C

Idea: Rely on thermal radiation

Solution: External system







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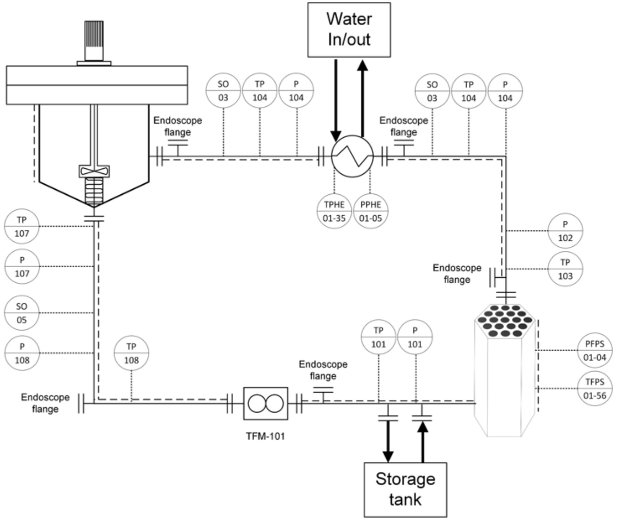
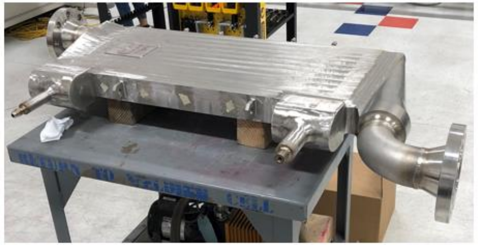
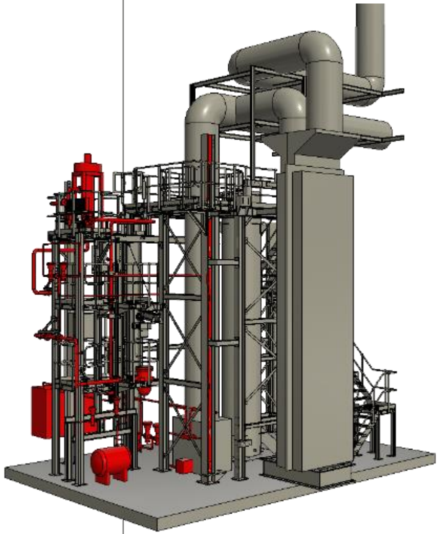
LFR Advanced components demonstration – VLF



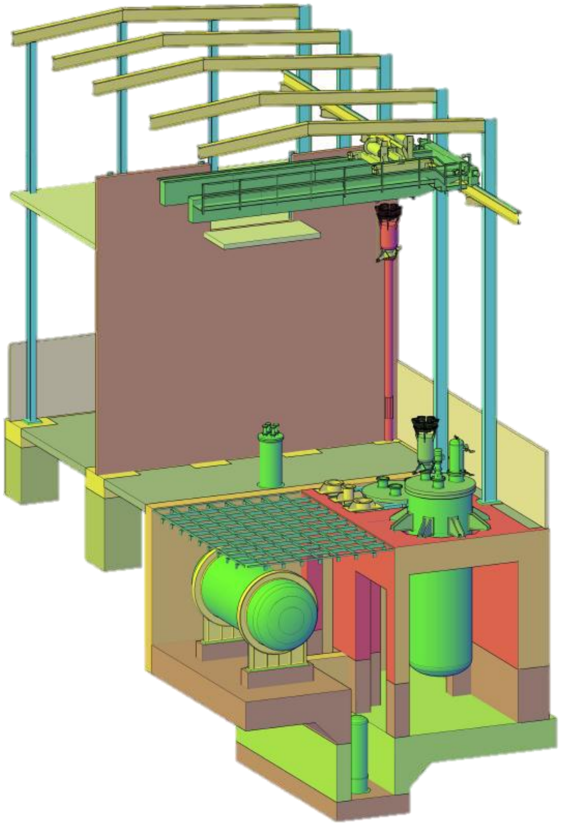
Power (kW)	500	**Sec. loop**	sH_2O
Lead inventory	3.5 tons	**Core**	19 pins
Lead cycle (°C)	390 – 530	**HX**	Microchannel
Mass flow (kg/s)	25.0		



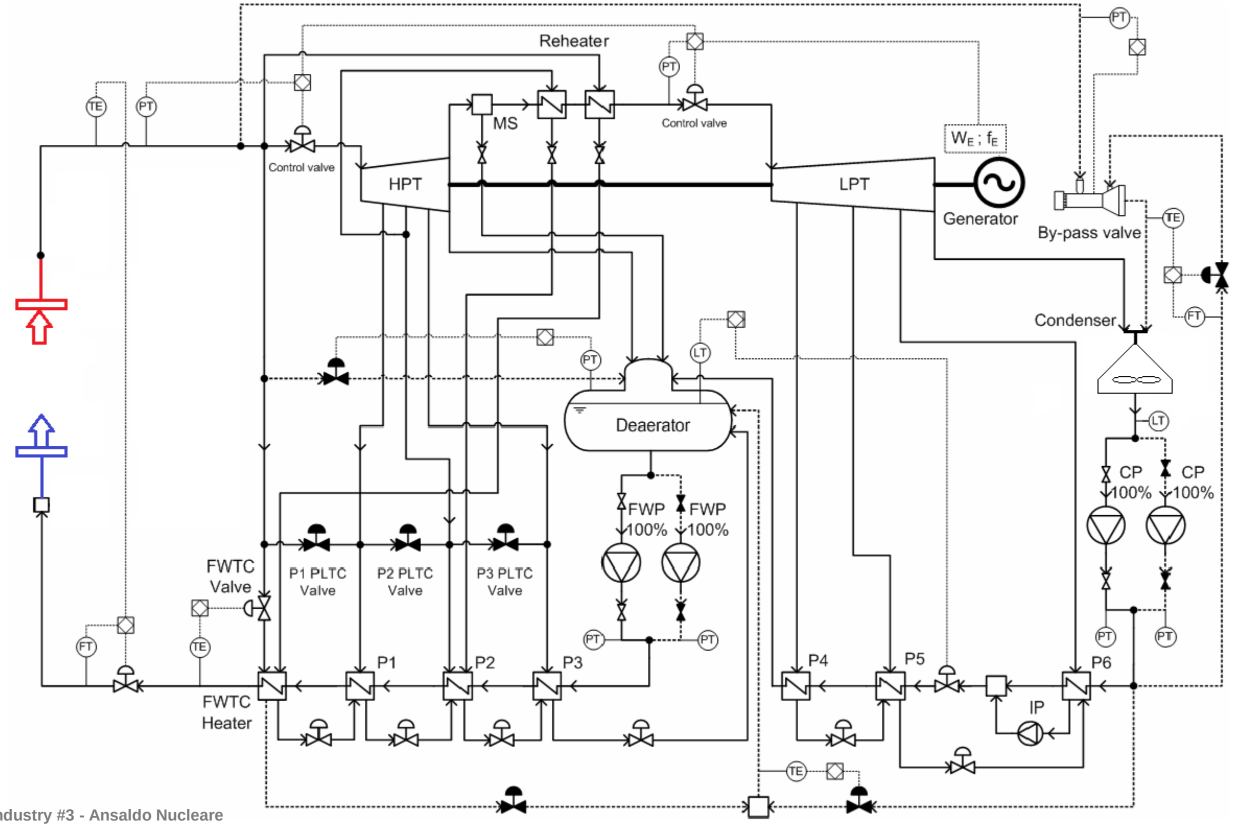
ATHENA Facility
(compared with VLF facility in the UK)



VLF under construction in the UK		ATHENA under construction in Romania
500	**Power (kW)**	2200
Loop	**Type**	Pool
3.5 tons	**Lead inventory**	800 tons
390 – 530	**Lead cycle (°C)**	400 – 520
25.0	**Mass flow (kg/s)**	250.0
No	**Accident testing**	Yes
sH_2O	**Sec. loop**	H_2O
19 pins	**Core**	127 pins
Microchannel	**Heat exchanger**	Bayonet
2 M€	**Budget**	20 M€



Balance of Plant Architecture



Energy storage technologies for EU-SMR-LFR

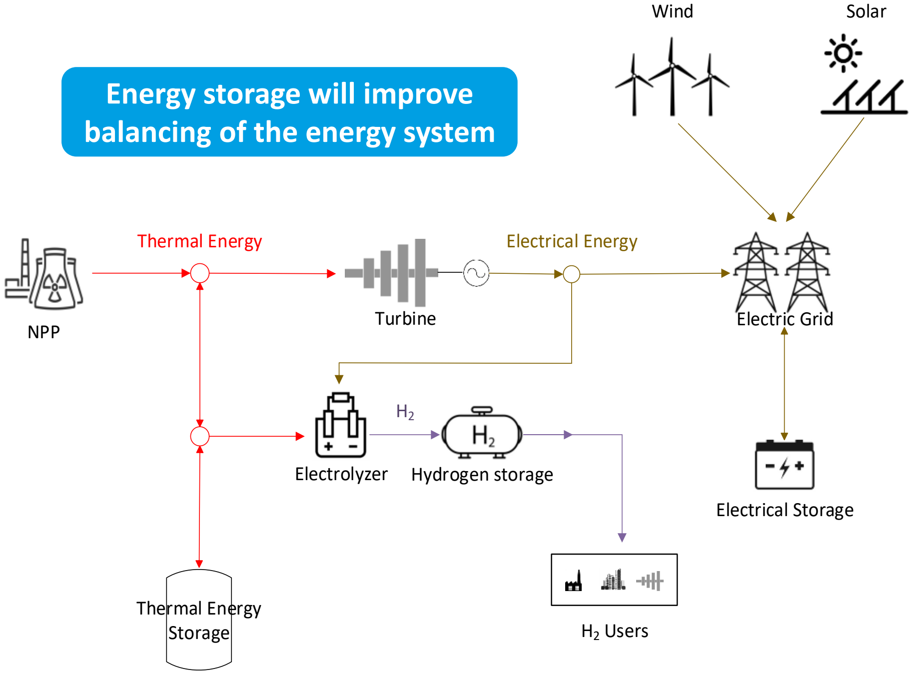
Technology	Thermodyn. Conditions	Storage Time	Efficiency	Cost	Techn. Status
Steam Accumulator	Main Steam Conditions	Hours	95% (T2T)	Very High	Commercial for CSP
Molten Nitrate Salts	290-565 ºC	Hours to Days	98% (T2T)	High	Commercial for CSP
Solid materials (e.g. concrete)	400ºC	Hours to Days	98% (T2T)	Low	Laboratory
FIRES[1][2]: NACC / NARC	550-700 ºC	Hours to Days	98% (E2T) <40% (T2E)	High	Laboratory
Hydrogen[1]: Electrolysis – Fuel Cells	-	Days	<80% (E2T) <60% (T2E)	High	Few Utility-Scale Projects - Laboratory
Hydrogen: NACC / NARC	550-700 ºC	Hours to Days	80% (E2T) 30% (T2E)	High	Laboratory
Electric Batteries	-	Days	90% (E2E)	Very High	Few Utility-Scale Projects

https://www.osti.gov/servlets/purl/1575201

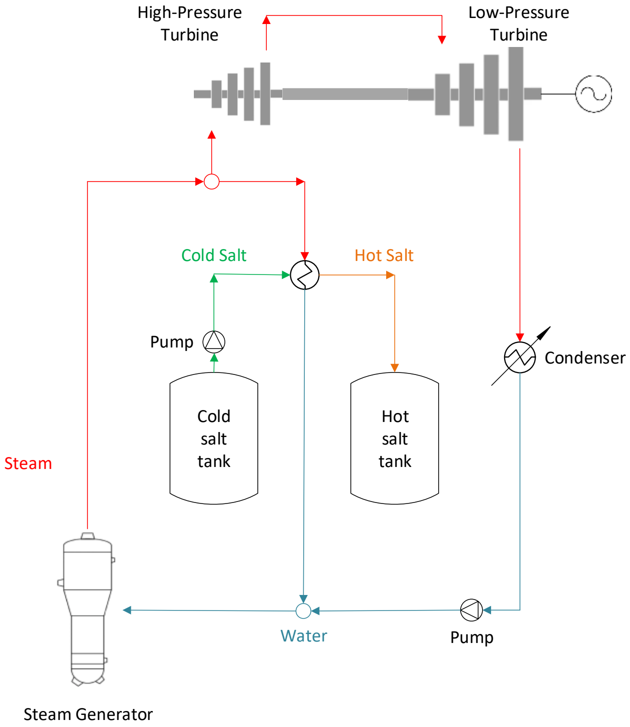
https://www.tandfonline.com/doi/full/

E2E – Electric to Electric
E2T – Electric to Thermal
T2T – Thermal to Thermal

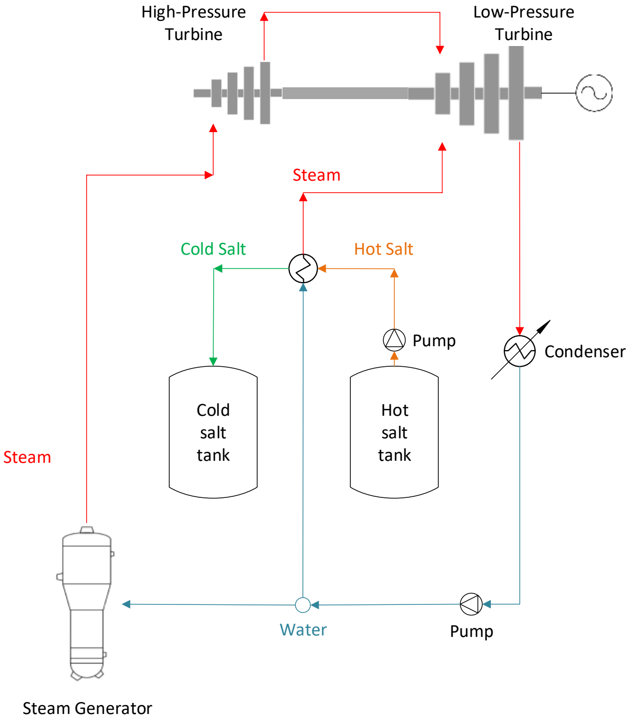
Energy storage will improve balancing of the energy system



Coupling with thermal energy storage



Loading Operating Mode Schematic



Unloading Operating Mode Schematic

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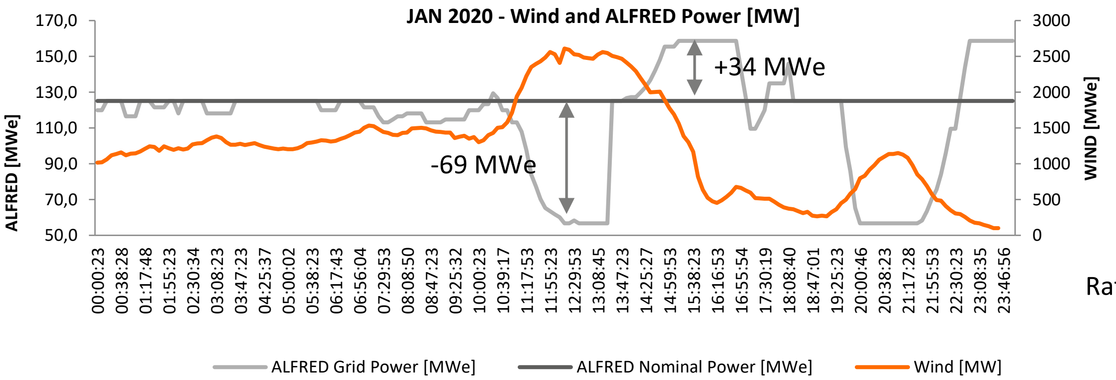
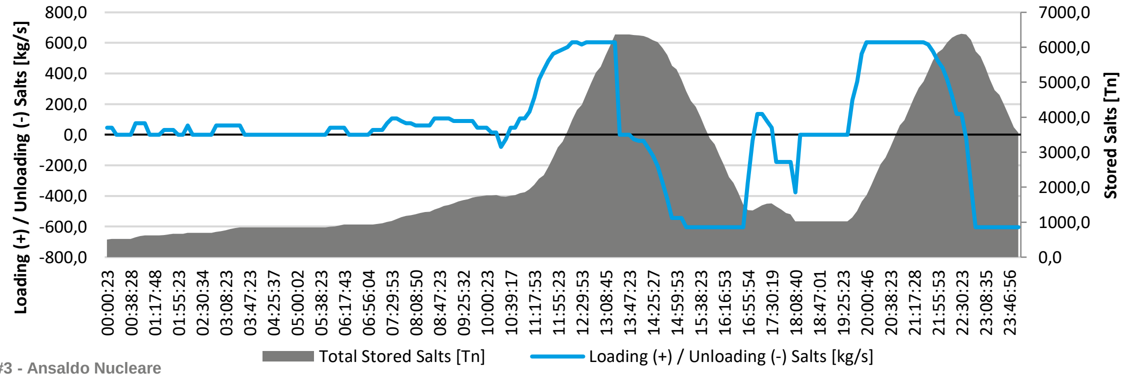
Load Following with TES (molten salts)

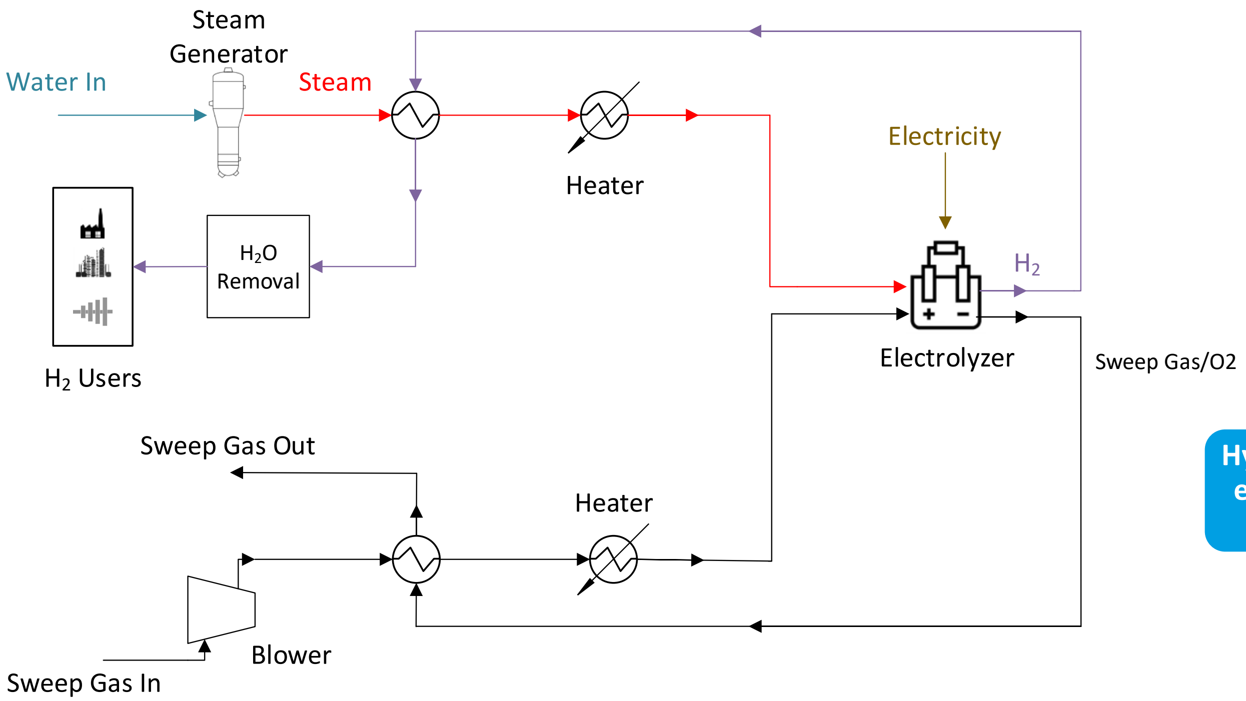
Molten salt thermal energy storage is an effective means to compensate RES volatility



Ratio = 34/69 = 50%



Coupling with high temperature steam electrolyzers



Hydrogen production is the most effective means to decarbonize hard-to-abate sector

Key takeaways

- **Ansaldo Nucleare's vision**: our vision considers nuclear as having the lowest environmental impact, the highest resilience and the lowest system costs. We've been investing in LFR as the most promising Gen-IV technology to meet the sustainability goals.
- **Using lead as a reactor coolant**: lead as a coolant is changing the paradigm in nuclear plant design, offering opportunities and challenges for the development of new ideas and concepts.
- **Staged approach**: as part of a progressive improvement, our goal is to deploy a demonstrator by relying on proven technologies and use the demonstrator itself to qualify new protective measures and materials to increase the plant overall performances.
- **International collaborations**: as demonstrated by the long-lasting FALCON Consortium and by new collaborations being pursued, we believe the synergies among international organizations are key to reach a critical mass for the nuclear innovation.
- **Licensing harmonization**: key to the success of SMRs delivery model, requires a multi-national approach with the involvement of multiple safety authorities. The LFR specificities require a fit-for-purpose interpretation and applicability joint review.
- **Joint experimental infrastructure**: part of the assets of the new-born EU-SMR-LFR Consortium, will support the performance verification and licensing demonstration, but will also offer new opportunities for students and researchers.
- **Advantages of high temperature**: LFRs have the key features to be fully integrated in energy systems with high penetration of renewables, offering new methods for load following through energy storage and cogeneration.

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Thank you for your attention

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