



EU-SMR-LFR

Enabling Commercial LFR Deployment through RDQ and Non-Electric Energy Applications

GIF talks with industry series #7

LFR Developers: Ansaldo Nucleare

05/10/2026

Safe Scalable Sustainable

Meet the speaker



Marco Caramello
Product Developer Manager
Commercial reactor design lead

Agenda



EU-SMR-LFR

Program & Product



RDQ

The LFR Needs

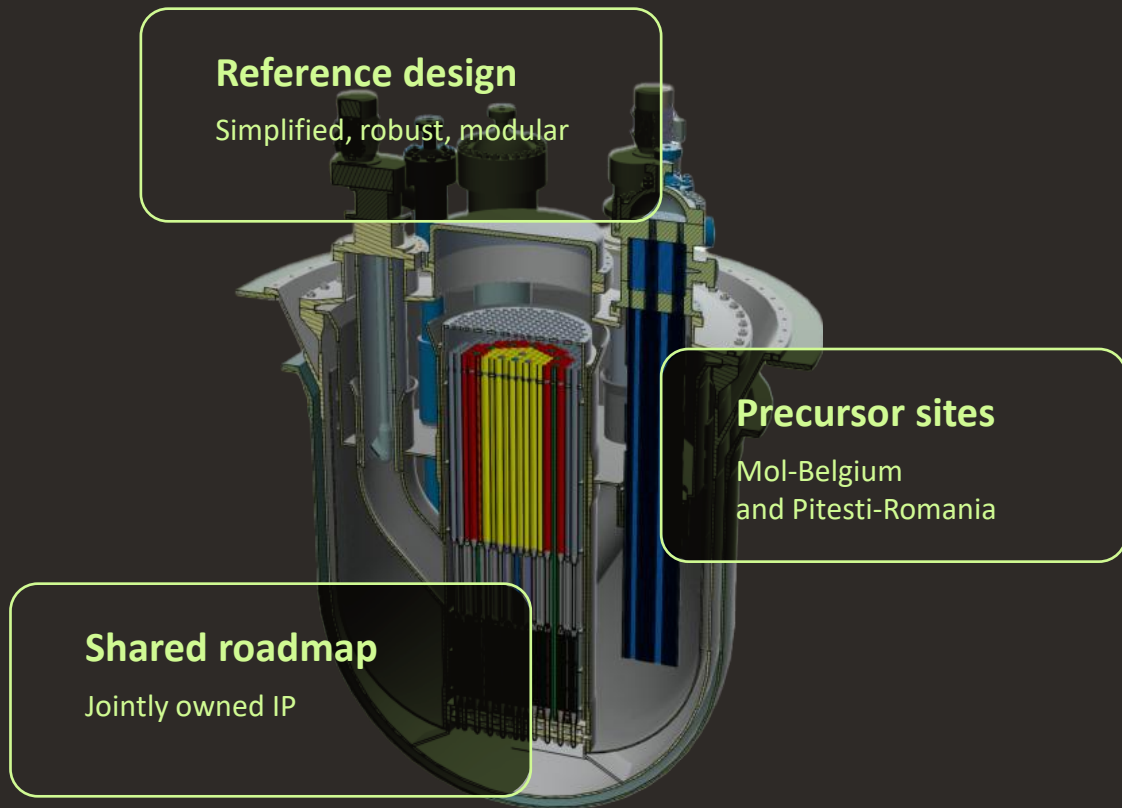


Uses

Beyond electricity
generation

EU-SMR-LFR

- Competitive economics
 - LCOE looking at future EU energy mix
 - Replacement of fossil fired plants
- Proven passive safety features
 - Enhanced grace time
 - Limitation of EPZ
- Sustainable closed fuel cycle
- High temperature heat
 - 520°C baseline / >600°C prospect
 - Hard-to-abate sectors
- Customers oriented
 - Utilities
 - Industrial districts
- Commercial fleet deployment by 2039



The Consortium

Italy

- Investing in LFR research since the 2000s.
- Continued to support industrial research and Euratom projects.
- Showing renewed interest in nuclear technologies.
- Very open to international collaboration.



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.

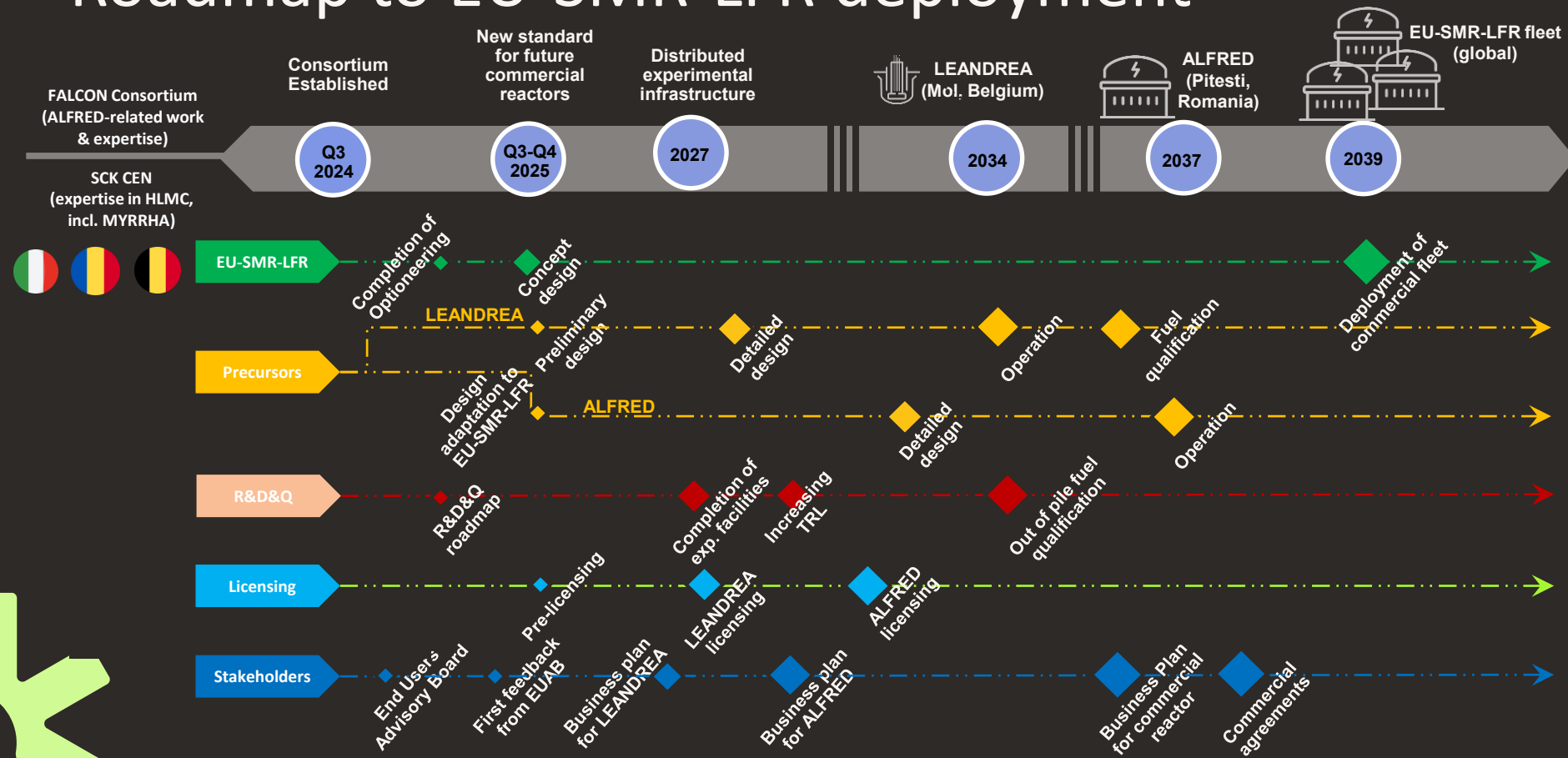


Belgium

- 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.



Roadmap to EU-SMR-LFR deployment



Enabling Assets

To ensure technological and engineering maturity, the Consortium will leverage two key precursors:



LEANDREA

The test reactor will provide an **irradiation capability** and technology **viability demonstrator**, with **focus on fuel and material testing**.

Mol, Belgium



ALFRED

The prototypical pilot plant will serve as reference for temperature conditions: a steppingstone toward commercial deployment of the EU-SMR-LFR.

Pitesti, Romania



Licensing strategy

Concept

Initial design validation
R&D&Q roadmap
Time-to-market driven solutions

Pre-licensing

Multilateral engagement
IAEA extra-budgetary project
BE, RO, IT involved

Early Permits

Harmonized standards
LEANDREA as pathfinder
ALFRED for standardization

Serial FOAKs

Building on a standardized approach
Opening to an EU framework
Exploiting serial effect



LEANDREA pre-licensing application officially started in May 2025, leveraging previous experiences.



In 2017, a preparatory phase to the authorization process of ALFRED was started with CNCAN.



ISIN joined the international pre-licensing programme in September 2025 as observer

Three regulators, one file: towards EU harmonization

International Pre-licensing Pilot Project of the IAEA NHSI

Vienna, 15 Sept. 2025

EAGLES Consortium signed Practical Arrangement for a NHSI International Pre-licensing Pilot Project with three regulators.



International Pre-licensing Pilot Technical Scope



Select and agree with the regulators on the **requirements, codes and standards** applicable to the technology



Define, agree with the regulators on, and implement a robust **safety approach** in the concept designs.



Present and agree with the regulators on a comprehensive **R&D road map**, covering all relevant areas to support the design and safety assessment needs.



Present and agree with the regulators on the **fuel qualification programme**.



Define and agree with the regulators on the **approach for security and safeguards by design**.

Main Design principles

Current design path, subject to
verification & validation



**Short sized
Fuel assemblies**



**Direct connection
from core outlet
to SG inlet**



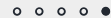
**Modular design
with limited on-
site special
processes**



Pumps in cold leg



**Independent
system per FSF**



Integrated R&D & Qualification strategy

The Consortium is finalizing an integrated R&D and Qualification Plan covering LEANDREA, ALFRED and EU-SMR-LFR.

Existing Experimental Assets

- Separate-effect and component testing
- Materials, chemistry and manufacturing trials
- Model validation and design evidence

LEANDREA

- Fuel and materials irradiation
- Representative fast-spectrum environment
- Technology and licensing evidence

ALFRED

- Full-scale components and systems
- Representative operating conditions
- Integrated construction and operation evidence

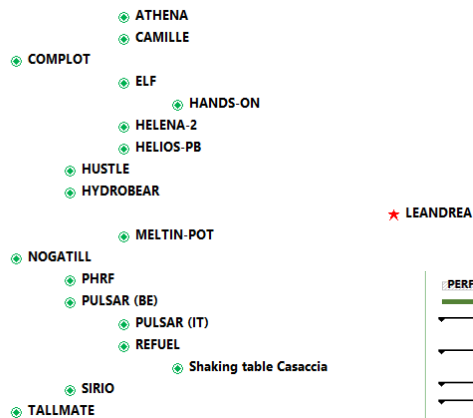
Safety & Licensing | Performance | Materials & Fuel | Manufacturing
Inspection & Maintenance | Operation & Handling

Integrated R&D & Qualification strategy

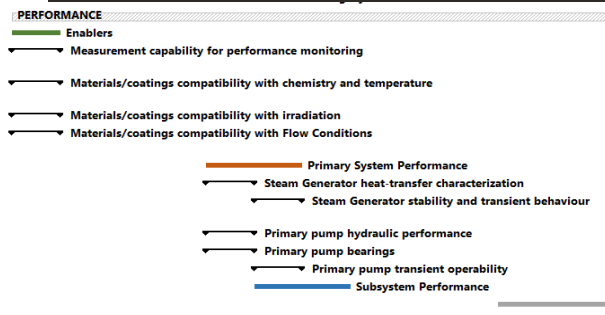
Technical Object	RDQ Stream	Program
Fuel pellet	Safety	Irradiation campaign
Fuel pellet	Safety	Simulation with lead and transport
Fuel clad	Safety	Irradiation
Fuel clad	Safety	Simulation in envelope conditions
Fuel clad	Safety	Simulation in envelope conditions
Fuel Grids	Safety	Heat transfer impact
Control rod	Safety	Insertion time and reliability
Steam Generator	Performance	TH performance under operating conditions and tr

Identified R&D
needs

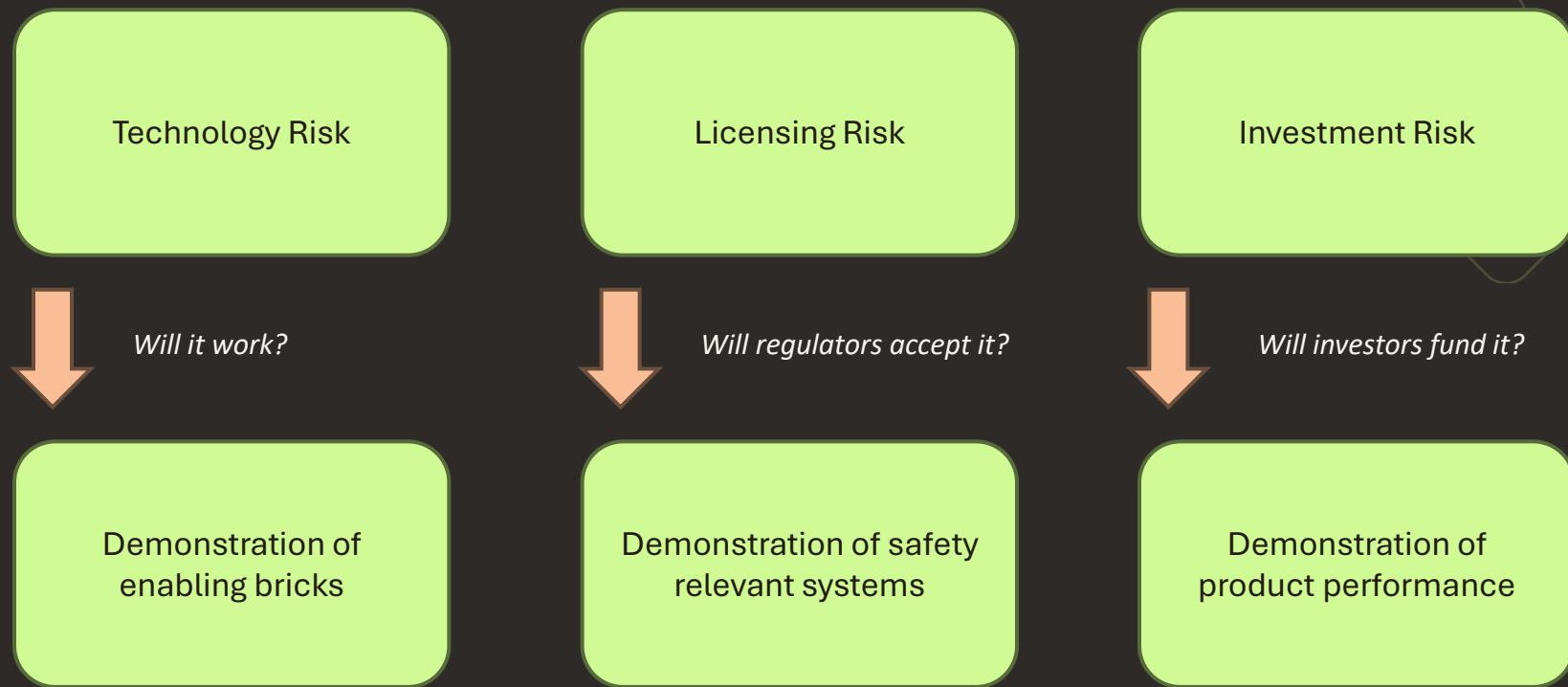
Documentation
and XP facilities



Roadmap



RDQ: From Technology Readiness to Market Readiness



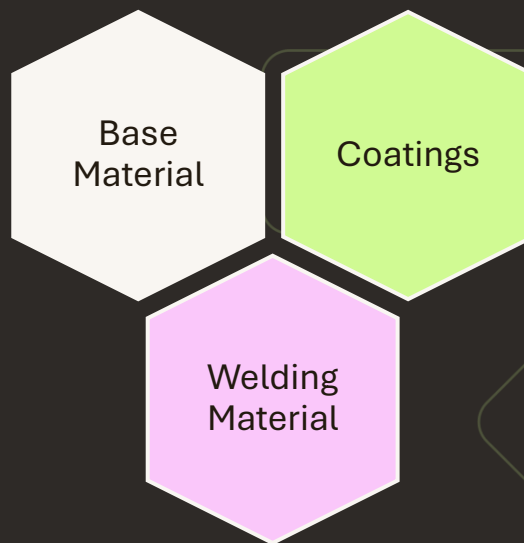
Technology Risk

Key Technical Challenges / Liquid Lead Environment

- Temperature: 380-550°C (nominal operation)
- Local hot spots up to 650°C
- Oxygen concentration control: 10^{-8} - 10^{-6} wt% O₂
- Heavy liquid metal corrosion
- Erosion under high velocity flow

Materials Qualification / candidate materials:

- 15-15Ti
- AISI 316L
- AFA steels
- Alumina-forming alloys
- Coatings (different forms/ techniques)



Demonstrate reliable performance under operational, accidental and lifetime conditions

Licensing Risk

Reactivity Control

- shutdown systems
- diverse shutdown systems
- Control under operation

Decay Heat Removal

- Natural circulation capability
- Freezing potential
- Heat removal with innovative systems

Lead-Specific Phenomena

- Retention of radioactive source
- Pressurization Control from BoP
- Demonstration of containment function

Separate effect tests

Shut-down Reliability
Heat transfer characteristics
Isotope retention

Integral effect tests

In-core worth calibration
Systems coupling for heat removal
In-lead material transport

Investment Risk

Primary Pumps

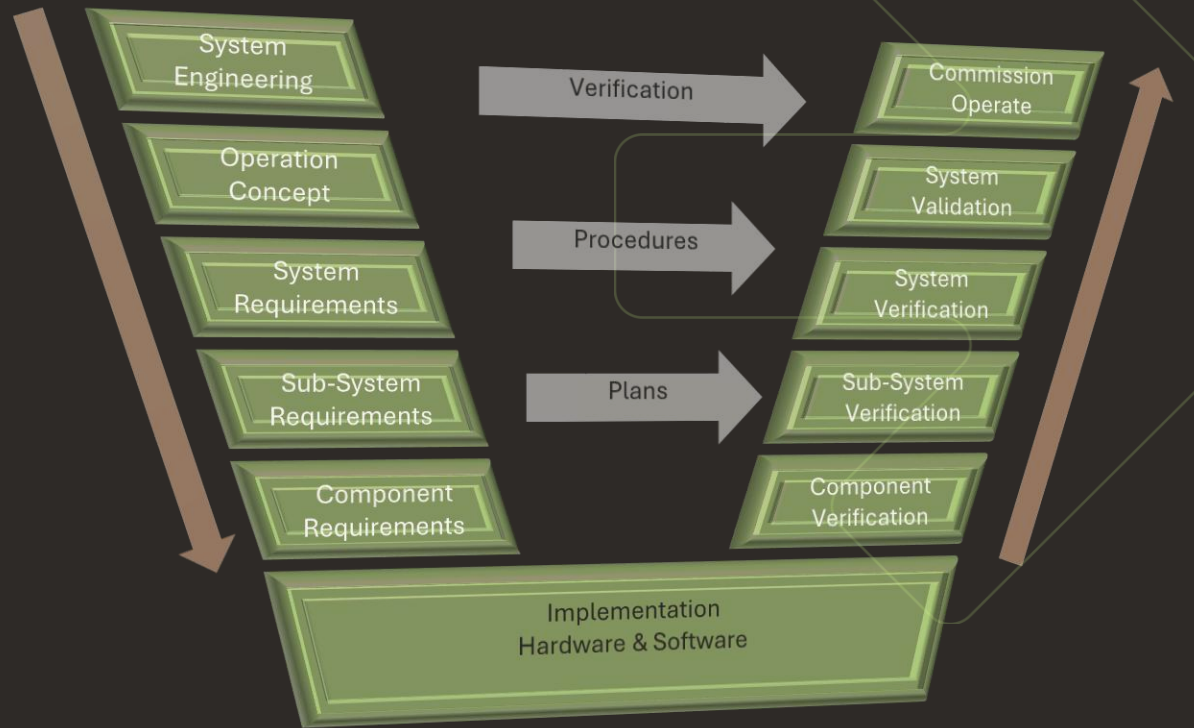
- hydraulic efficiency
- bearing behaviour
- long-term reliability

Steam Generators

- thermal efficiency
- In-Service Inspection
- Plugging

Fuel Handling System

- Remote operation
- Maintainability
- Accident recovery



To perform functions, as intended, with target performance

Fuel Qualification

Focus on the differences:

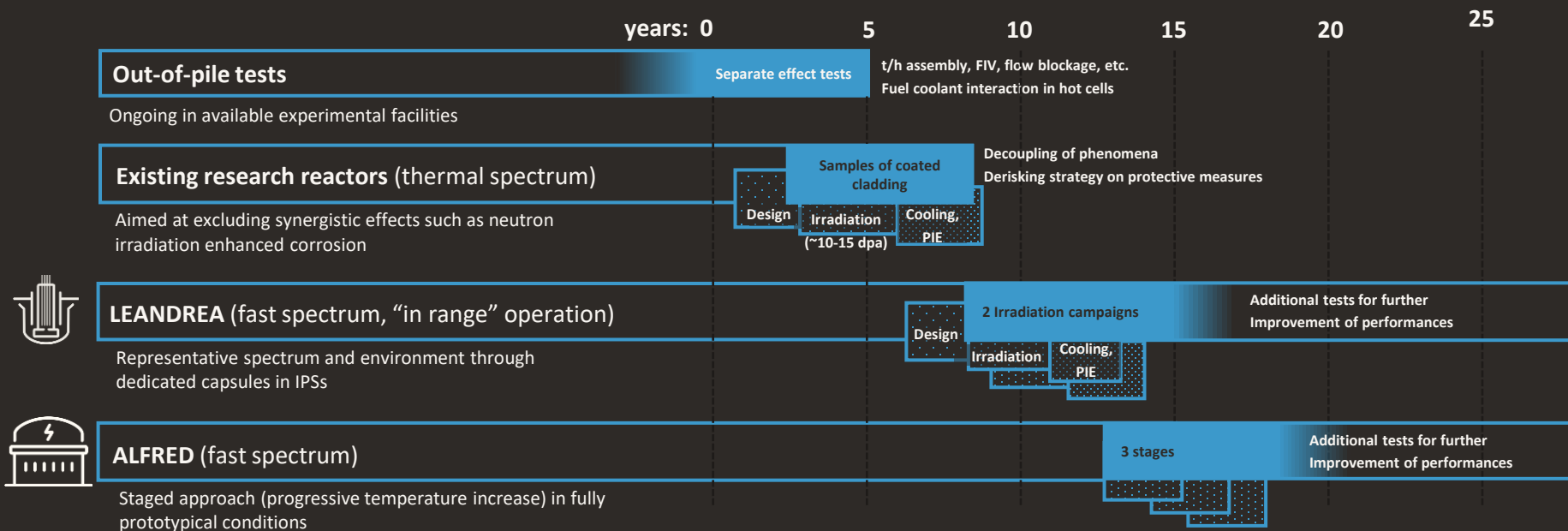
- Coolant-clad interaction: lead corrosion inhibited through a coating. What neutron irradiation effects?
- Fuel performances: minor deviation with respect to past EU experience. How is qualification affected?

Fuel	Material	MOX
	Pellet geometry	Solid, annular
	Inner diameter	In range
	Outer diameter	(+30.0%)

Fuel	Enrichment (Pu/HM)	In range
	MA content	In range
	Stoichiometry	In range
	Porosity	In range

Clad	Material	In range
	Outer diameter	(+25.0%)
	Thickness	(+3.0%)

Operat	Peak linear heat rating	In range
	Peak burnup	In range
	Peak clad temperature	In range
	Peak clad irradiation damage	In range



Transition is more than electricity

945 TWh/yr

Data-center demand by 2030

>20%

share of demand growth from
data centres in advanced
economies

~ 2/3

industrial final energy demand
used as heat

~ 50%

industrial heat above 400°C

Electricity

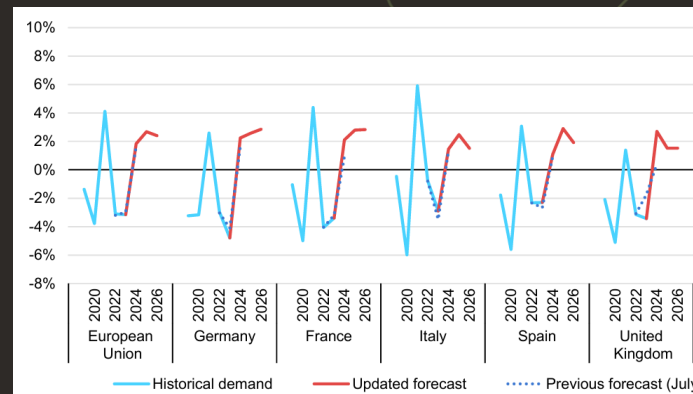
EVs, heat pumps, digital infrastructure,
electrified processes

Flexibility

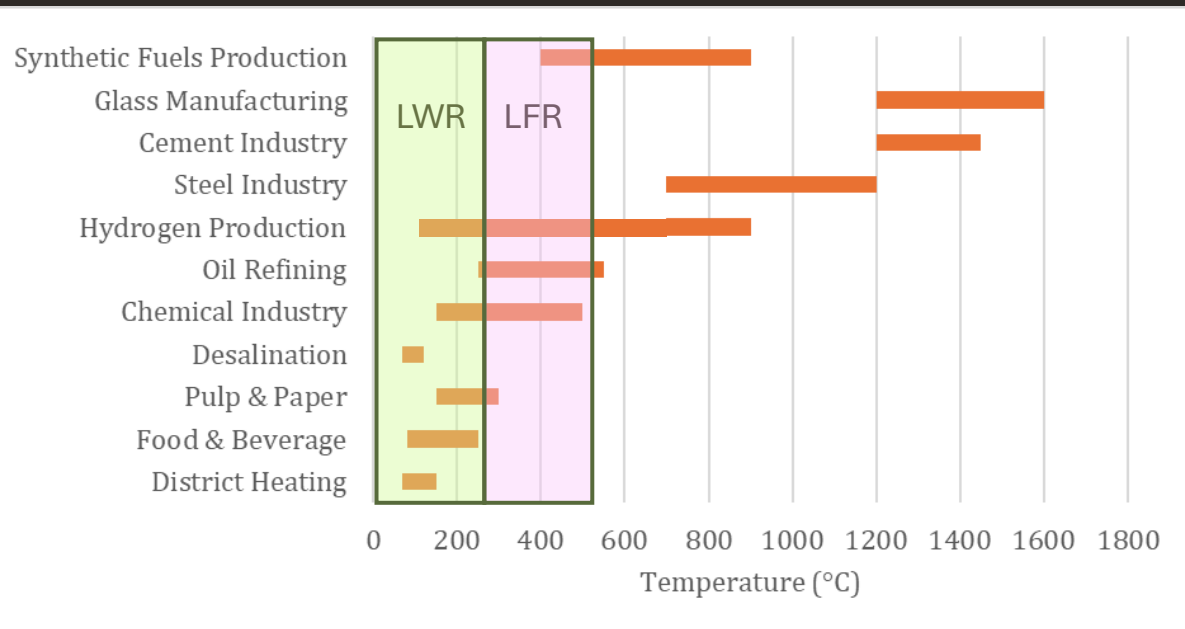
frequency, voltage, reserves and
capacity

Secondary uses

hydrogen, steam and process heat for
hard-to-abate sectors



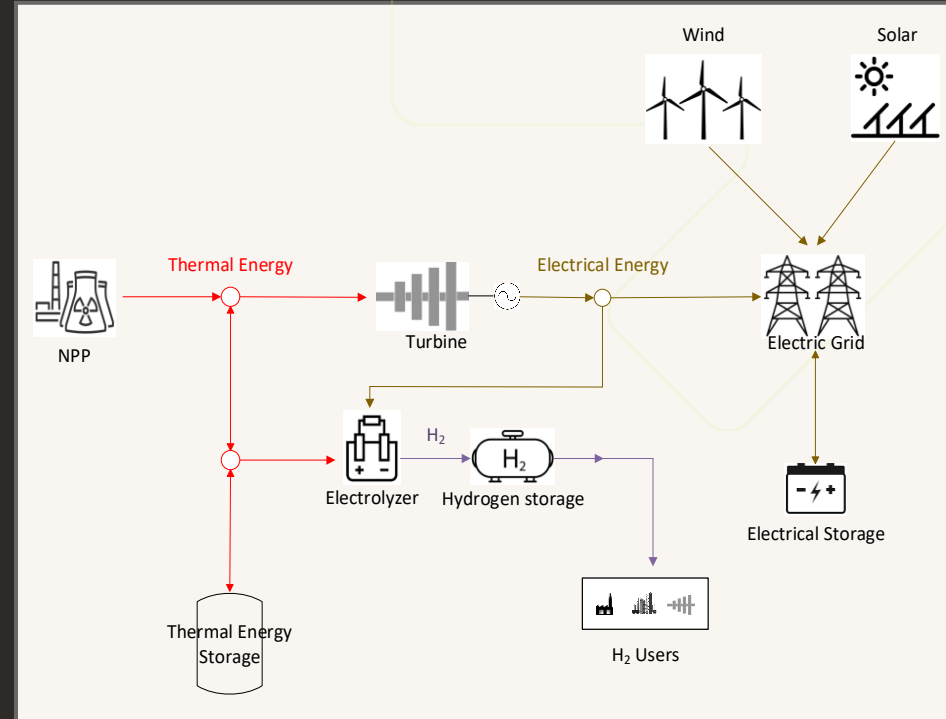
And it's a temperature challenge



- Low-temperature heat can often be electrified efficiently
- Above ~400°C, industrial pathways become more constrained
- A source delivering both electricity and steam reduces conversion losses
- Siting close to users it's increasingly important at higher temperature

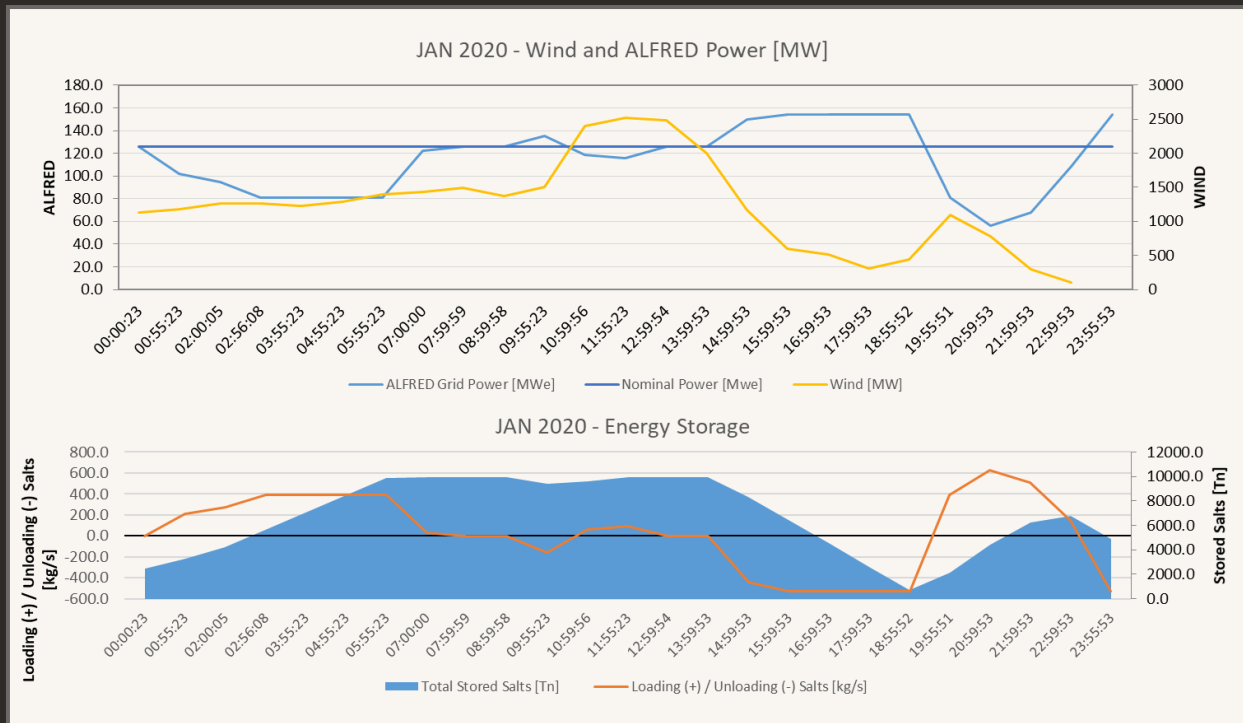
Flexibility is a premium request

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 °C	Hours to Days	98% (T2T)	High	Commercial for CSP
Solid materials (e.g. concrete)	400°C	Hours to Days	98% (T2T)	Low	Laboratory
FIRES ^{[1][2]} ; NACC / NARC	550-700 °C	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 °C	Hours to Days	80% (E2T) 30% (T2E)	High	Laboratory
Electric Batteries	-	Days	90% (E2E)	Very High	Few Utility-Scale Projects

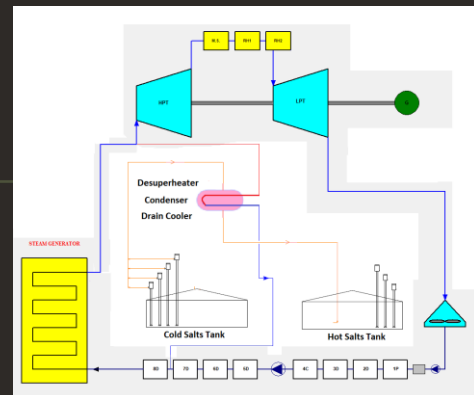


Still, an NPP needs 24/7 operation

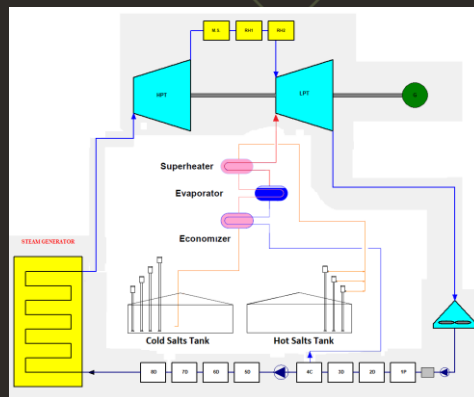
Load-following case study



Loading

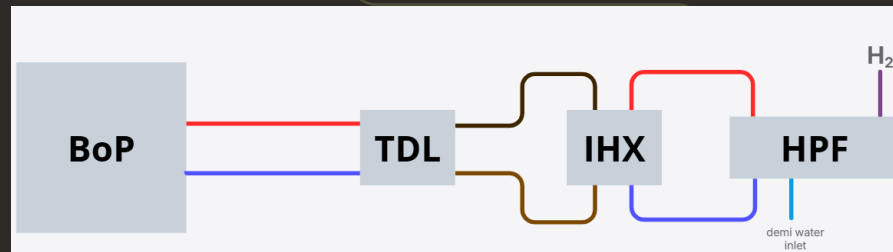


Unloading



Hydrogen Production with SOEC Technology

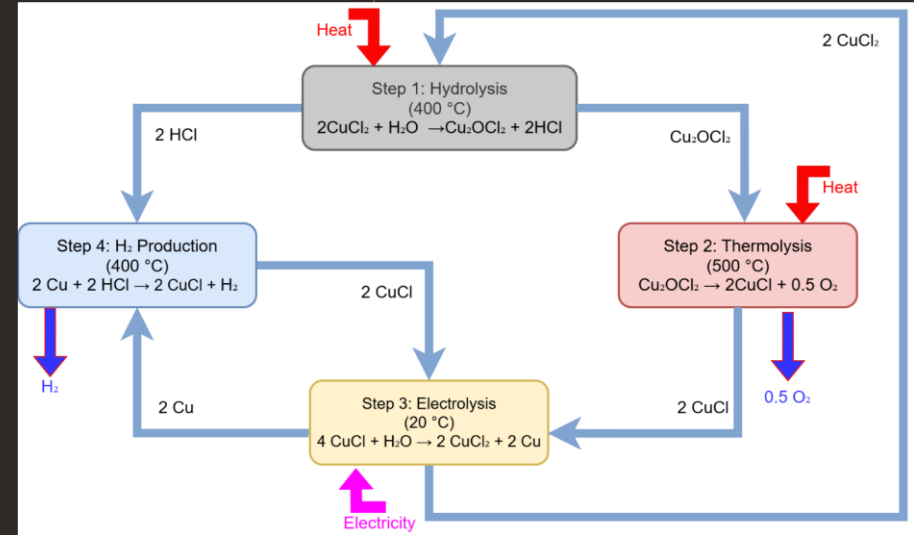
- **Steam** extracted from the **IPT** (Intermediate Pressure Turbine) section
- **TDL** (Thermal Delivery Loop) provides thermal energy to the **HPF** (Hydrogen Production Facility)
- Under **thermoneutral** SOEC operation, **only** the **heat** required to generate **process steam** is supplied
- The **HPF** is made by **multiple production lines** to maximize the system flexibility



	Capacity (HPF) 3xSOEC mod	SOEC x 1 module	NPP Output
EU-SMR-LFR	2192 kg/h	31 MW _e	282 MW _e

Hydrogen Production with CuCl cycle

- Medium-High temperature steam from NPP provides heat to the thermochemical cycle
- Heat transfer managed through a closed loop to separate nuclear island from hydrogen utility
- Heat transfer fluid: Solar Molten Salt (60% NaNO₃ + 40% KNO₃)
- Reduced power consumptions compared to electrolysis



1. Potential efficiency benefits
2. Temperature compatibility
3. Good integration with LFR

Other use cases

- High temperature heat
- District heating
- Coupled generation of heat and hydrogen
- Steel production integration

Each user has distinctive features

A challenge for standard design

Conclusions

1. Commercial deployment requires evidence, not only design

- LFR technologies already benefit from decades of international R&D
- Remaining challenges are focused on qualification and industrial deployment

2. RDQ must simultaneously address three risks

- Technology risk through materials, fuels and lead technology qualification
- Licensing risk through validation of safety functions and regulatory engagement
- Investment risk through demonstration of component reliability and plant performance

3. Europe already has a unique deployment pathway

- LEANDREA provides irradiation and fuel qualification capability
- ALFRED provides integrated system demonstration

4. LFR value extends beyond electricity

- Process heat above 400°C
- Hydrogen production

Powering Europe's clean, safe and competitive future.