



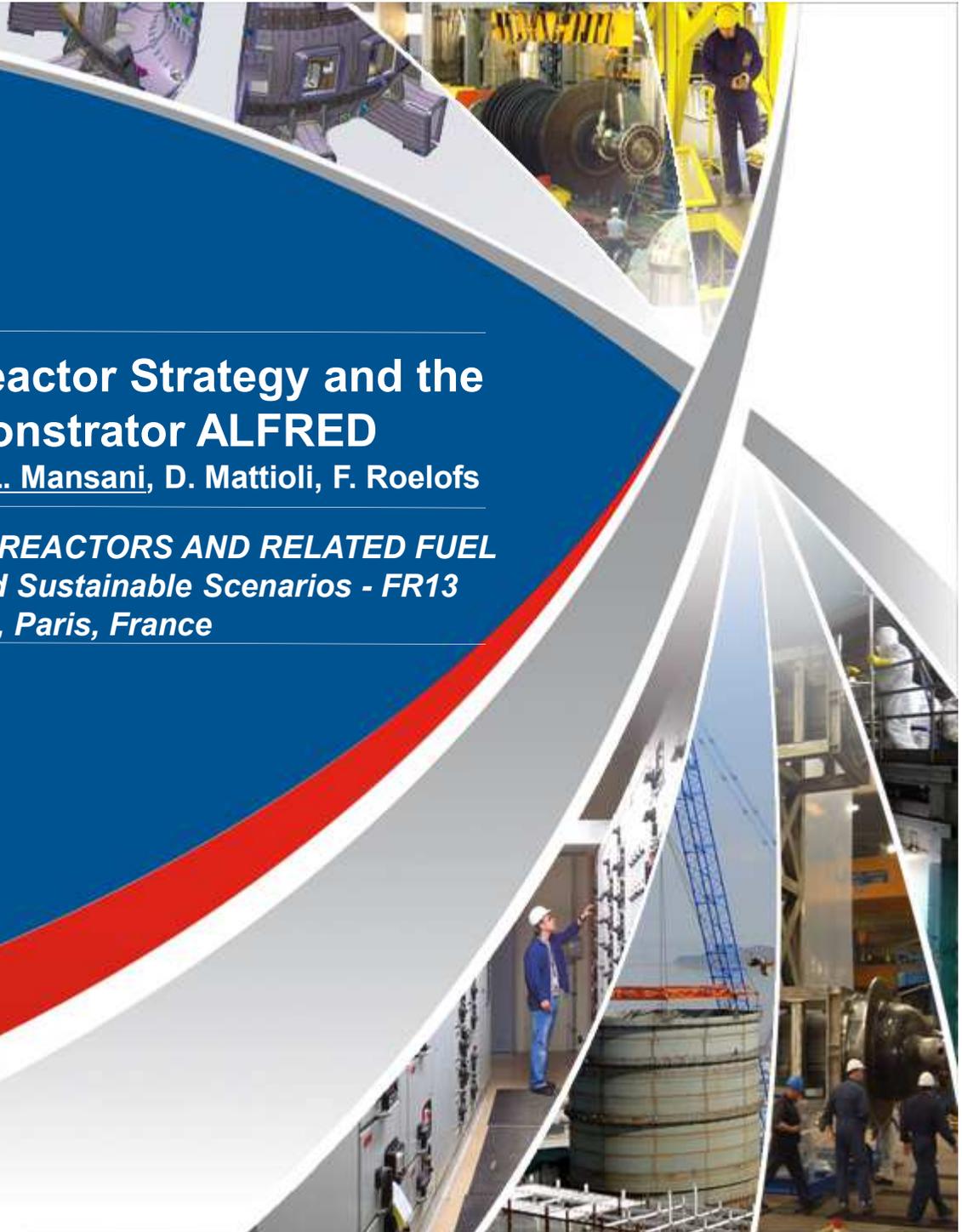
# The European Lead Fast Reactor Strategy and the Roadmap for the Demonstrator ALFRED

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## Introduction

### *Nuclear energy potential to satisfy world energy needs*

- 2 billion people worldwide have no access to electricity and all people have an inalienable right of better life conditions including energy supply
- Electricity demand is likely to increase significantly in the near future and Sustainable development addressing humankind future needs requires non CO<sub>2</sub> emitting sources of energy
- Nuclear energy will not be the whole solution but it will be an important part of the solution for the coming years and decades

### *Need for fast reactors*

- Fast Reactor technologies with its closed fuel cycle have the potential to:
  - multiply by a factor of 50 to 100 the energy output from a given amount of uranium (with a full use of U238)
  - improve high level radioactive waste management through the transmutation of minor actinides
- Fast Reactors are potentially able to provide energy for the next thousands of years, with the already known uranium resources

## *Generation IV Fast reactors*

- European Organizations launching the Sustainable Nuclear Energy Technology Platform (SNETP) have defined a common vision regarding the role of nuclear energy and R&D needs for the safe, sustainable, and efficient use of nuclear fission technology
- European Sustainable Nuclear Industrial Initiative (ESNII) promotes advanced fast reactors with the objective of resource preservation and minimization of the burden of radioactive waste:
  - Sodium Fast Reactor is considered to be the reference technology since it has more substantial technological and reactor operations feed-back
  - Lead(-bismuth) Fast Reactor is considered as the shorter-term alternative technology since it has significantly extended its technological base
  - Gas Fast Reactor technology is considered as a longer-term alternative option

## *Lessons from the Fukushima events*

- A great emotional reaction has produced anti-nuclear sentiment in the public opinion now it is no more disposed to accept nuclear accident consequences
- Accident sequences might be more complex than foreseeable requiring more simple and reliable safety systems and emergency procedures
- To nuclear scientific community is asked to pay a major attention to the safety aspects at large

## Introduction

### *The Lead Fast Reactor (LFR)*

- LFR meets the Gen IV goals:
  - in sustainability because of its capacity at effectively employing a closed fuel cycle,
  - in proliferation resistance and physical protection thanks to the possible operation of long-life cores
  - in safety by the choice of a relatively inert coolant
  - In economics due to the very innovative pre-conceptual design (ELSY, LEADER projects) of an industrial plant for electricity production with closed fuel cycle

### *The LFR safety features*

- LFRs have peculiar characteristics that facilitate the management of emergency situations and make possible to avoid an off-site management plan
  - Fukushima events have shown how in case of loss of ultimate heat sink very few resources are readily available for emergency reactor cooling: air and water that does not react with Lead are the most readily available in any nuclear site
  - Complete station blackout events can be effectively managed using passive systems for decay heat removal which is permitted by the physical and chemical properties of the Lead coolant
  - Hydrogen formation is easily avoided because structural materials are inert in lead environment
- The combination of lead coolant inherent characteristics and plant design features, specifically developed to face identified challenges, show a large potential for a very robust and forgiving design, even in very extreme conditions

## Need for technology breakthrough for LFR

- The development of the technology for a new reactor must follow a chain of gradual and progressive steps to reach maturity
- The main drawback facing the industrial deployment of a LFR fleet is the lack of operational experience
- A satisfactory technological readiness has been achieved in Russia in the past century driven by military research
- To fill the technology gap requires the setting up of a complete R&D roadmap, in analogy with what has been done in France for the development of the SFR technology chain, whose readiness is almost proven



Nuclear submarine  
705 serial  
(1976-1996)

## Key R&D topics

- To achieve commercial availability of Fast Reactors technologies by 2040, it is vital to continue and accelerate R&D on:
  - primary system design simplification;
  - improved materials and innovative fuels;
  - improved safety (safety standards not inferior to Gen III ones);
  - innovative heat exchangers and power conversion systems;
  - advanced instrumentation and in-service inspection capabilities;
  - plant costs reduction;
  - partitioning and recycling processes;
  - plant availability improvement.
- Specifically focusing on LFRs, the main challenges for their feasibility are:
  - corrosion and erosion of structural materials;
  - seismic risk due to large mass of lead;
  - in-service inspection of core support structures and possibility of replacing internal components;
  - refuelling at high temperature in lead and spent fuel management by remote handling;
  - managing of the Steam Generator Tube Rupture inside the primary system;
  - prevention of flow blockage and mitigation of core consequences;
  - radiation damage (at high temperatures).

## Experimental Facility for R&D Needs

### *Material and T/H studies*

- LFR R&D demands experimental facilities for studies on:
  - materials, coolant physics-chemistry and corrosion/erosion;
  - safety;
  - moving mechanisms, instrumentation, maintenance, in-service inspection and repair;
  - thermal hydraulics and heat transfer
- Several experimental facilities are already available on the European Lead Laboratory

### *Irradiation*

- There is a clear need to update European irradiation facilities, given that existing facilities are close to end of life
- New facilities are currently in construction or design phase in Europe:
  - JHR, the Jules Horowitz Reactor (Cadarache, France) dedicated to materials testing for nuclear fission
  - PALLAS (Petten, The Netherlands) for nuclear knowledge, services and medical isotopes production
  - MYRRHA (Mol, Belgium), a flexible fast neutron irradiation facility

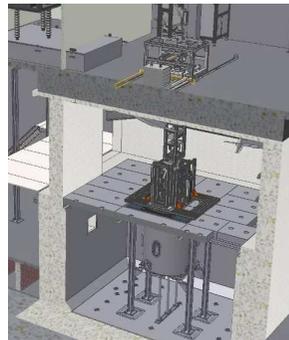
### *Reactor physics*

- There is a need to develop dedicated fast neutron experimental facilities for core design qualification, for design uncertainties reduction and for code qualification/validation
  - GUINEVERE, a zero power lead reactor already in operation in Belgium,
  - ELECTRA, a lead-cooled education and training reactor in design phase in Sweden,

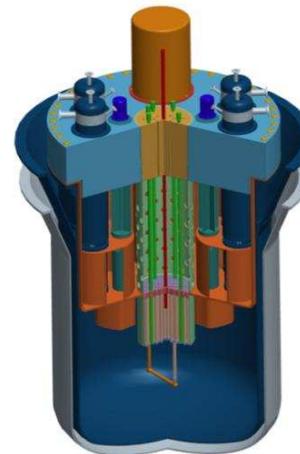
## Roadmap towards an industrial LFR fleet in Europe Facilities for LFR technology development

For the demonstration of the LFR technology chains, further facilities (either existing or under construction) are required to provide the overall frame for LFR technology development, like:

- all the existing and planned **EU lead labs** focused on thermal/hydraulics, materials development and corrosion testing;
- the zero-power facility **Guinevere**, already operating in Mol, Belgium,
- the irradiation facility and pilot plant **MYRRHA**, to be built and operated in Mol and,
- the European training facility **ELECTRA**, planned for realization in Sweden



**Guinevere**



**MYRRHA**

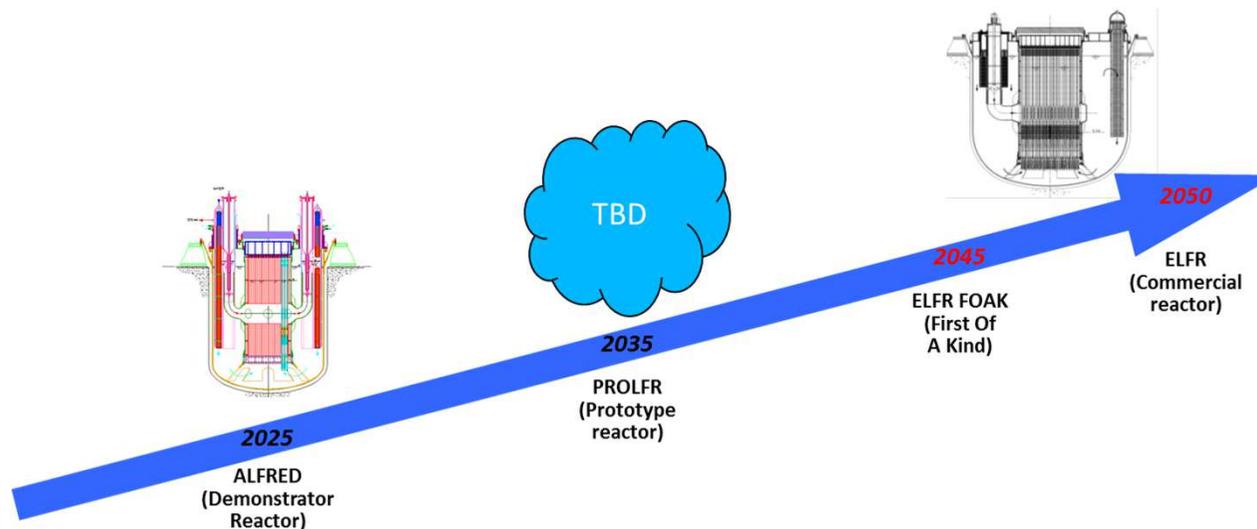


**ELECTRA**

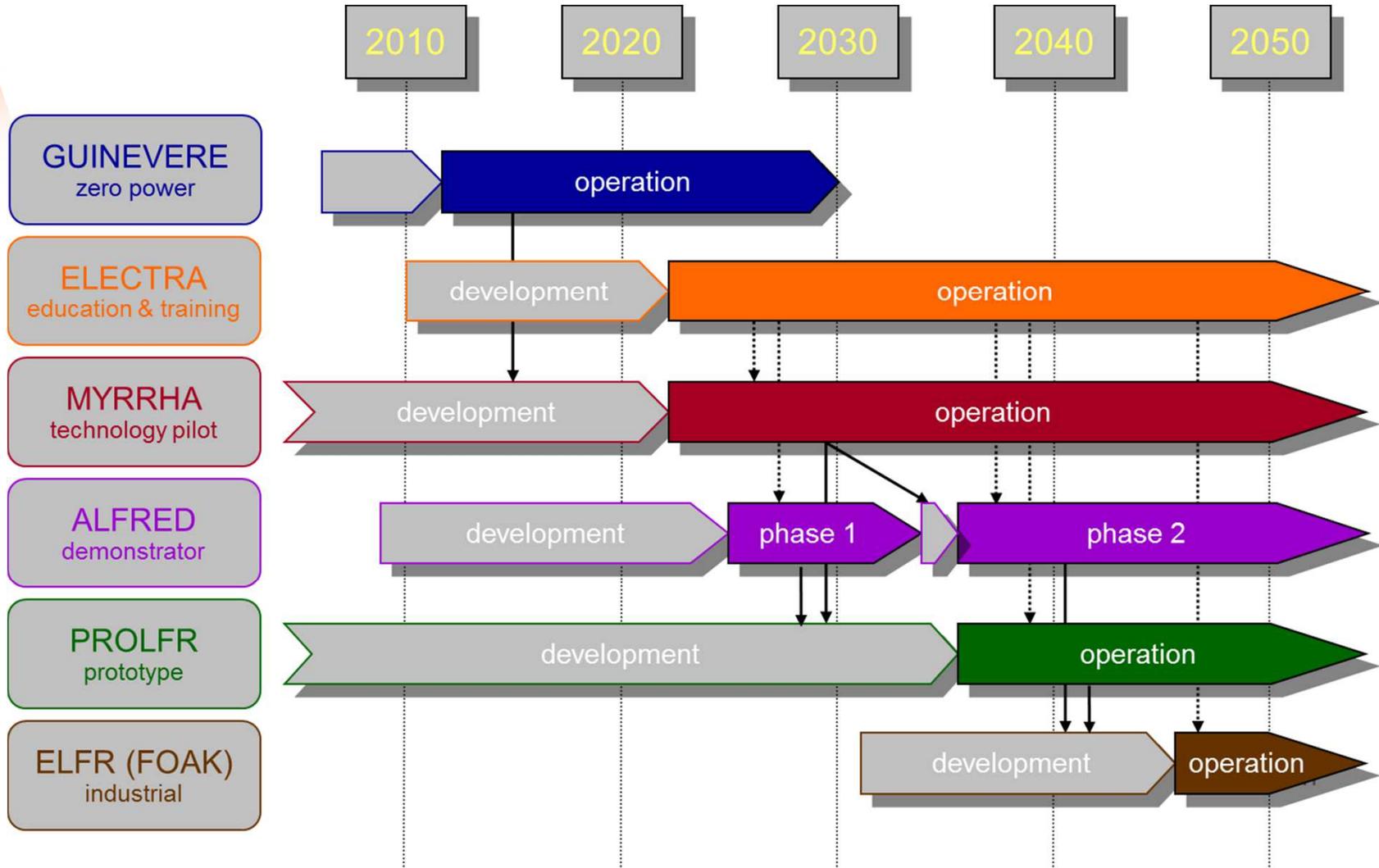
## LFR Roadmap towards industrial deployment

- First: a Demonstrator reactor (**ALFRED**) for proving the viability of reliable electricity production for LFR systems – 125 MWe
- Second: a Prototype reactor (**PROLFR**) is envisaged for testing the scaling laws at an intermediate step according to a common approach focused both on plant size and representativeness of the target reference system – 300 ÷ 400 MWe
- Third: a First-Of-A-Kind (**ELFR-FOAK**) representative of a commercial **ELFR** fleet – 600 MWe

Note: ALFRED and PROLFR could be also have its own development as SMR

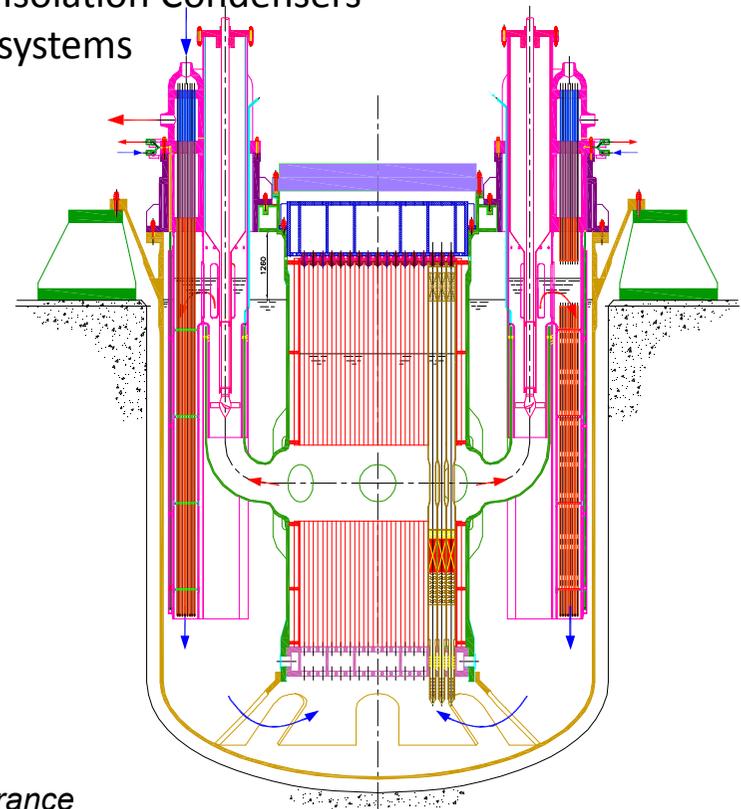
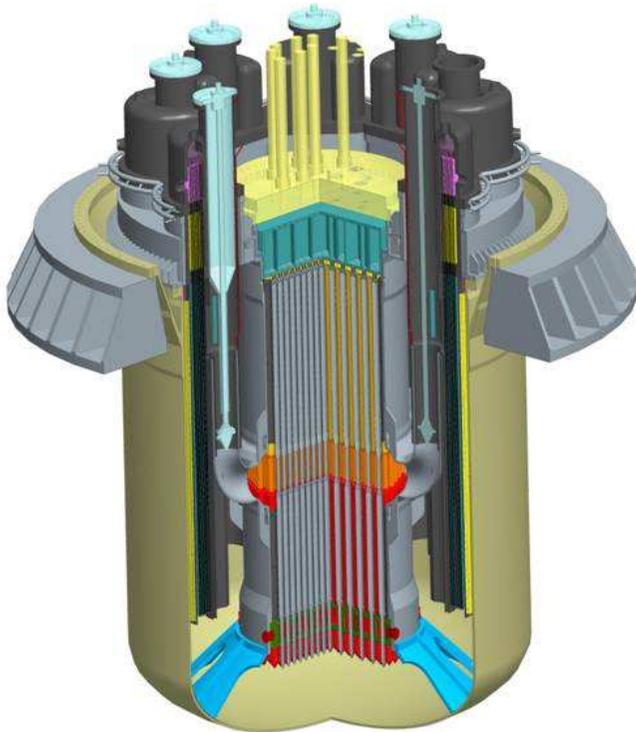


# Overall LFR Road Map



## ALFRED

- Pool type LFR of ~125 MWe (300 MWth), (widely described in companion papers)
- Primary coolant pure lead in forced circulation (natural circulation in emergency conditions), core inlet/outlet temperature 400° C/480° C.
- Secondary coolant water/superheated steam, steam temperature/pressure 450° C/18 Mpa, net efficiency ~ 41%
- All internals (core barrel, bayonet type steam generators with double walls, primary mechanical pumps, etc) are removable for inspection or replacement
- Core fuelled with MOX with hexagonal fuel assembly extended up to the cover gas, cladding material 15-15/Ti coated
- Two redundant passive DHR systems based on Isolation Condensers
- Two diverse and redundant control/shutdown systems



## ALFRED - Implementation plan

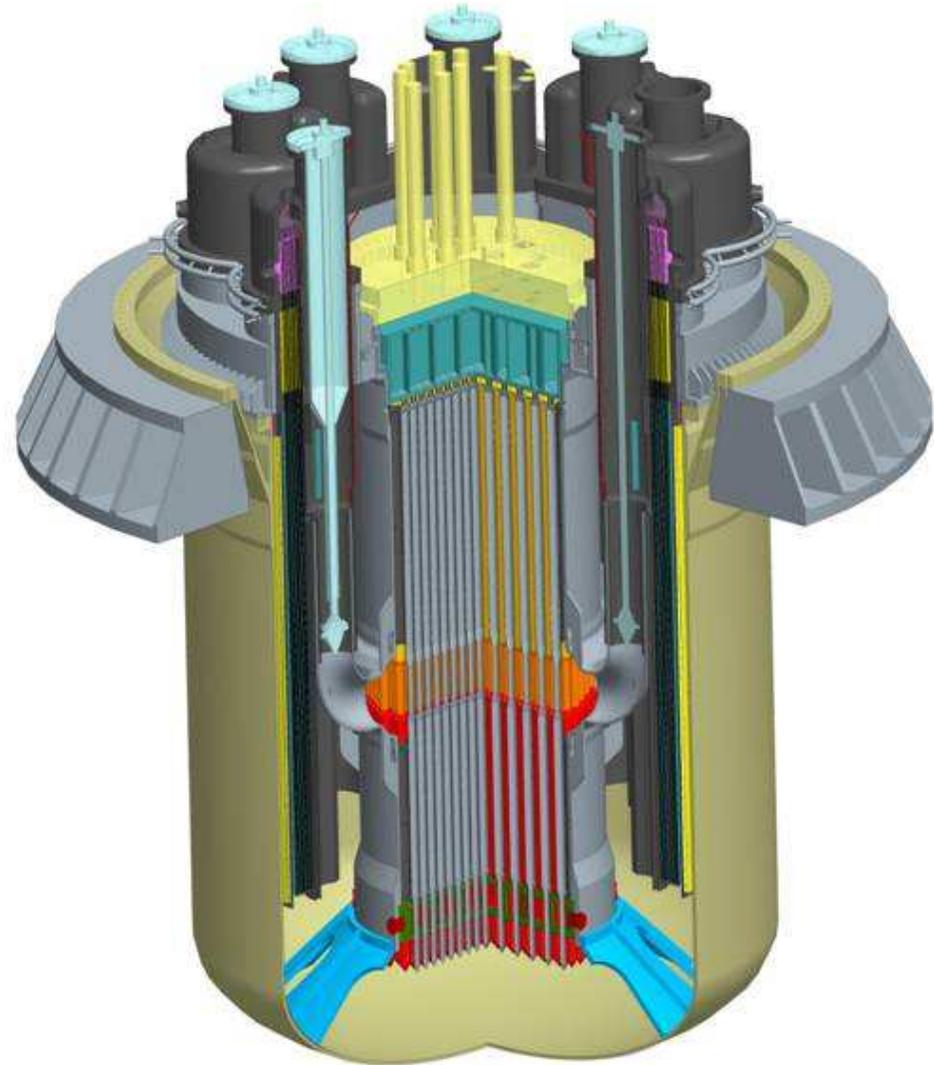
**ALFRED** realisation includes several phases (2010-2025)

- First of all set-up of an international consortium (2013)
  - ✓ Site for construction has been already chosen (Pitesti in Romania)
  - ✓ First consortium act, according to ESNI Implementation plan, is to search funding
- Several design steps have been individuated:
  - ✓ Conceptual design, on going in the LEADER project (2010-2013)
  - ✓ Basic design, siting and pre-licensing (2013-2016)
  - ✓ Detailed design and licensing (2016-2019)
  - ✓ components construction, civil engineering, on site assembly and commissioning (2019-2025)
- Support R&D program will provide answers to remaining technical challenges (2011-2018)

## Expected Impacts

- To ensure that nuclear energy remains a long-term contributor to a low carbon economy it is necessary to increase its sustainability through demonstrating the technical, industrial and economic viability of Gen IV fast nuclear reactors
- With the construction and operation of MYRRHA and ALFRED, Europe will be in an excellent position to secure the development of a safe, sustainable and competitive fast nuclear technology
- ALFRED Demonstrator Roadmap will:
  - ✓ play a key role by involving European industry and maintaining and developing European leadership in nuclear technologies worldwide
  - ✓ allow to investigate and address the main technological issues that can be implemented in the LFR prototype (2035)
  - ✓ make possible commercial deployment, by the European industry, of these technologies by 2050 and beyond
  - ✓ contribute significantly to the development of a sustainable and secure energy supply for Europe from the second half of this century onwards

*Thank you for your attention*



**ALFRED**