

sck cen
Belgian Nuclear Research Centre

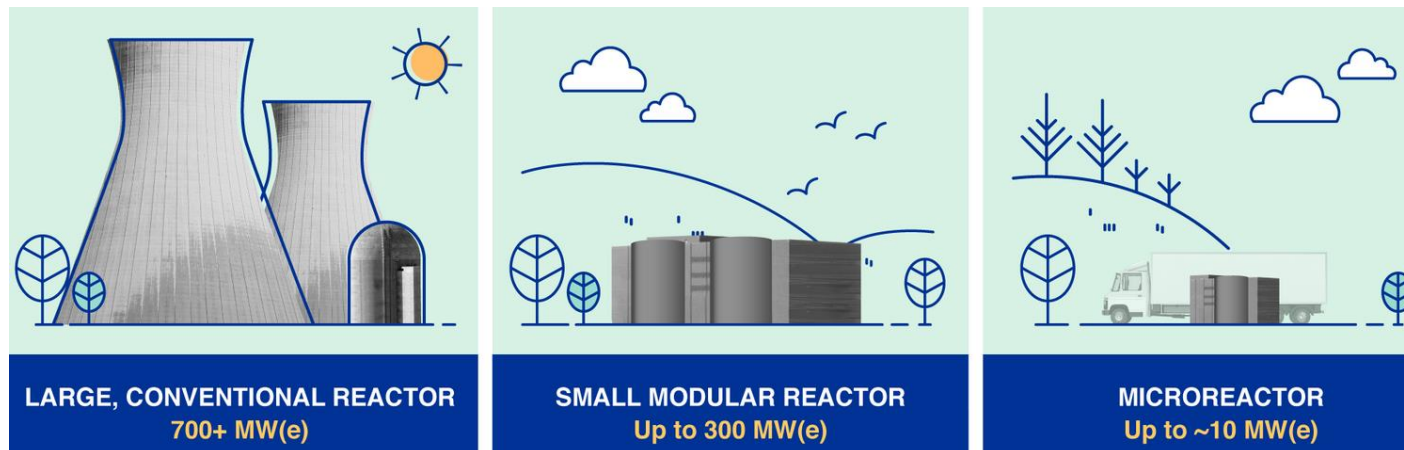
A vision for a Belgian contribution to a generation IV SMR

Marc Schyns

BNEN Opening of the 22nd academic year 2023-2024 - ULiège, September 21, 2023

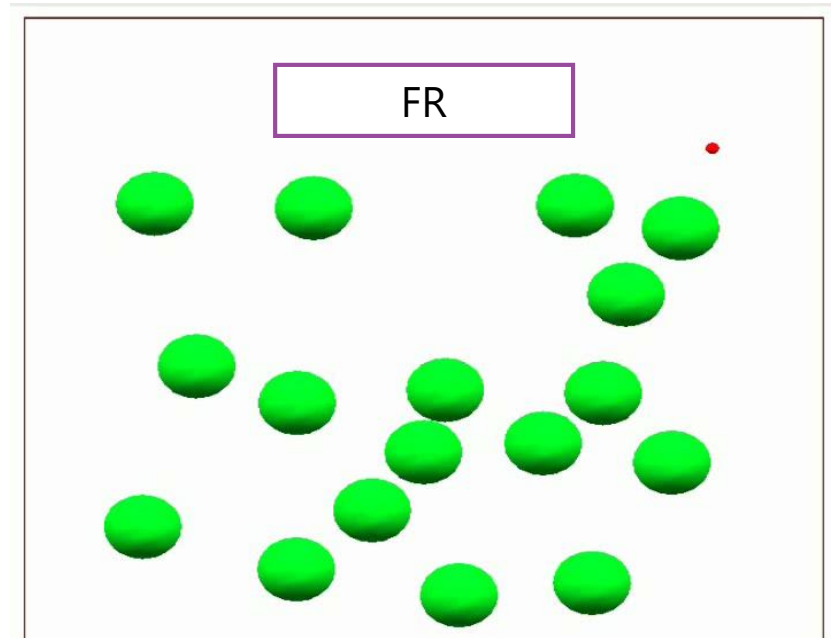
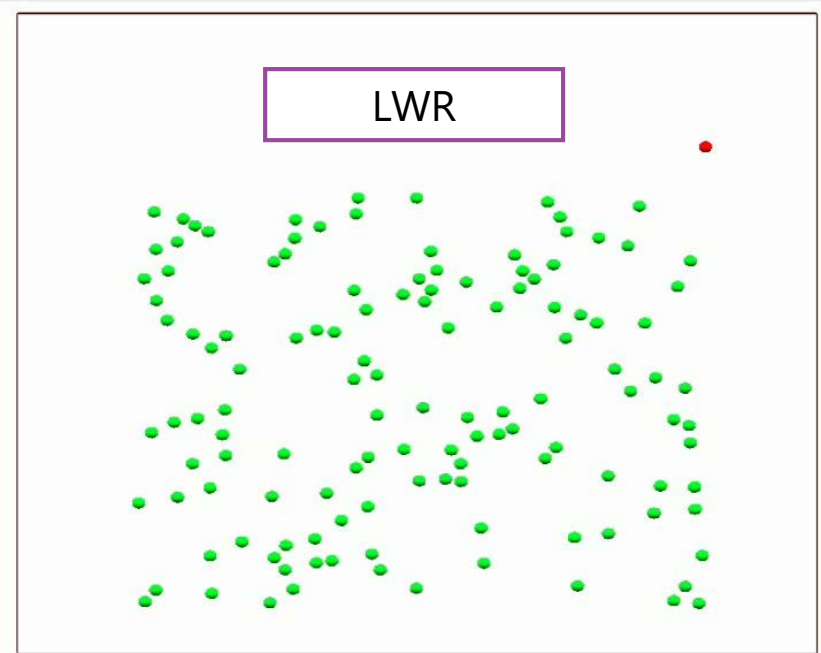
In a nutshell: Small Modular Reactors (SMR)

- **Small** Reactor: up to 300 MWe
- **Modular** reactor: grouping of individual reactors that form a larger nuclear power plant through use of factory pre-fabricated modules assembled on-site, “plug-and-play”
- Two main technologies of Small Modular **Reactors**:
 - Mature: Light Water Reactor technology: LWR-SMR
 - Innovative: Fast Reactor SMR technology: FR-SMR for increasing sustainability



FR-SMR: how, what, why

- FR-SMRs use an alternative coolant to **water**
- Eligible alternative coolants (today)
 - Gas (He, Air or even CO₂)
 - Liquid metals : sodium, lead or lead-bismuth
- For liquid metal
 - Working at atmospheric pressure in the reactor vessel, increased safety
 - **Lead and lead-bismuth** do not present violent chemical reactivity



FR-SMR: how, what & why

Advantages

of FR-SMRs in comparison with LWR-SMRs:

- Less high radiotoxic nuclear waste produced
- Better use of natural resources
- Long to very long fuel cycle (8 to 15 y)
hence reducing proliferation risk

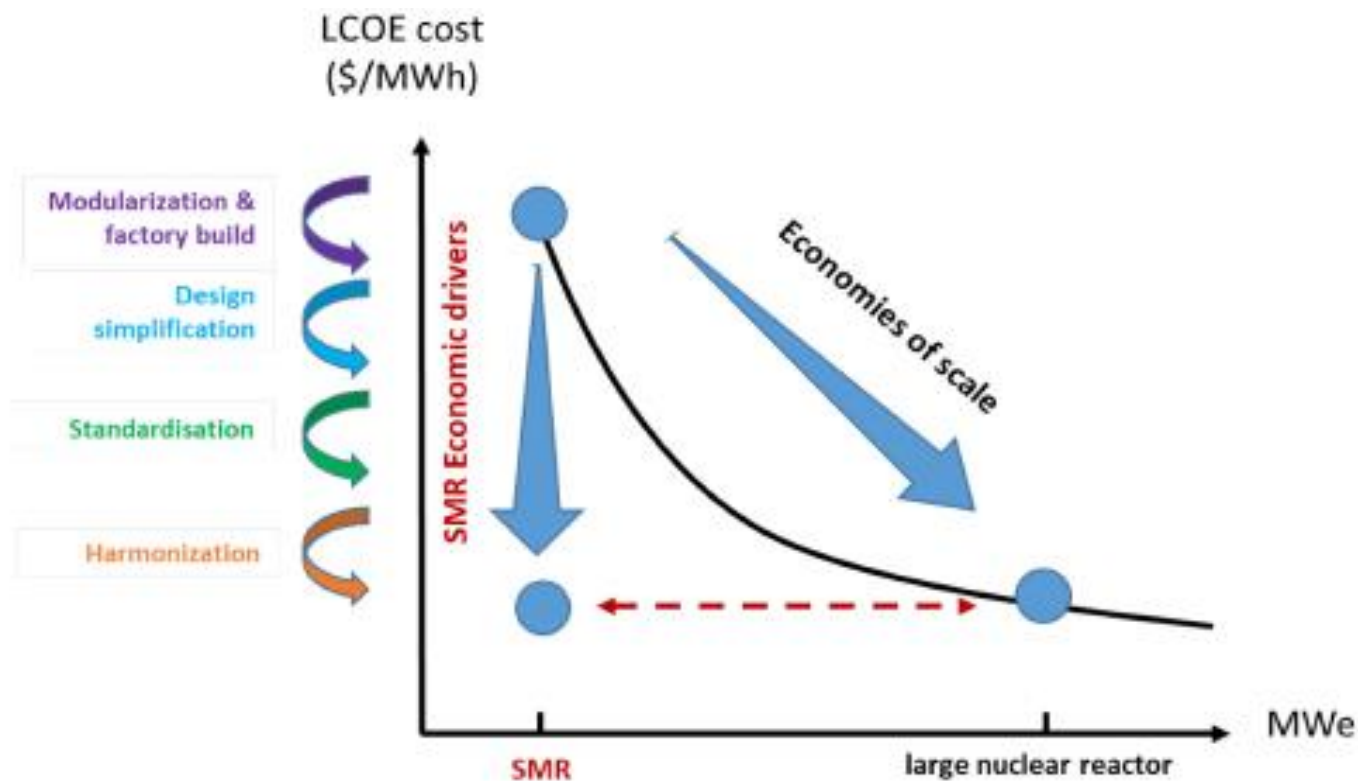


Benefits SMR: 1. Economics

Affordability
(known info for LWR-SMR)

- **Lower upfront** capital cost
- Expected CAPEX : **3000 – 5000\$/kW**
- **~1B\$** range project
(*instead of ~10B\$*)

Source: Tractebel

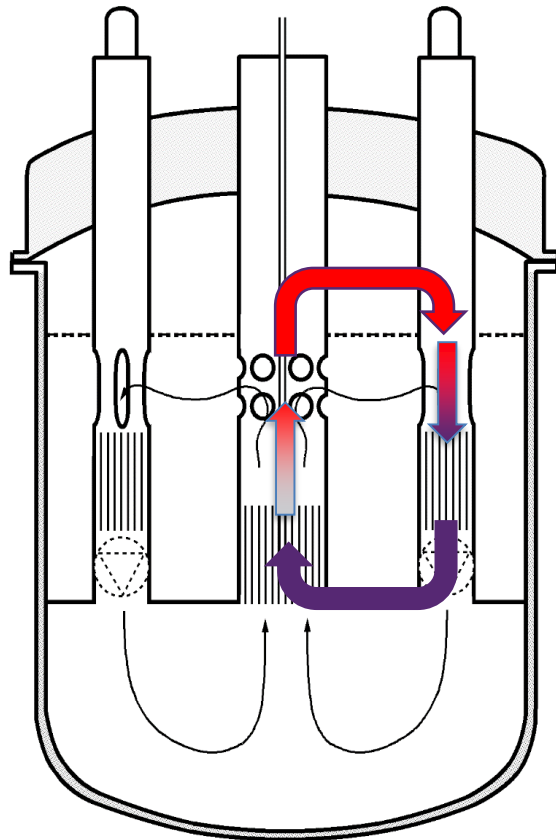


Source: NEA (2020).

Note: kW_e = kilowatt electric.

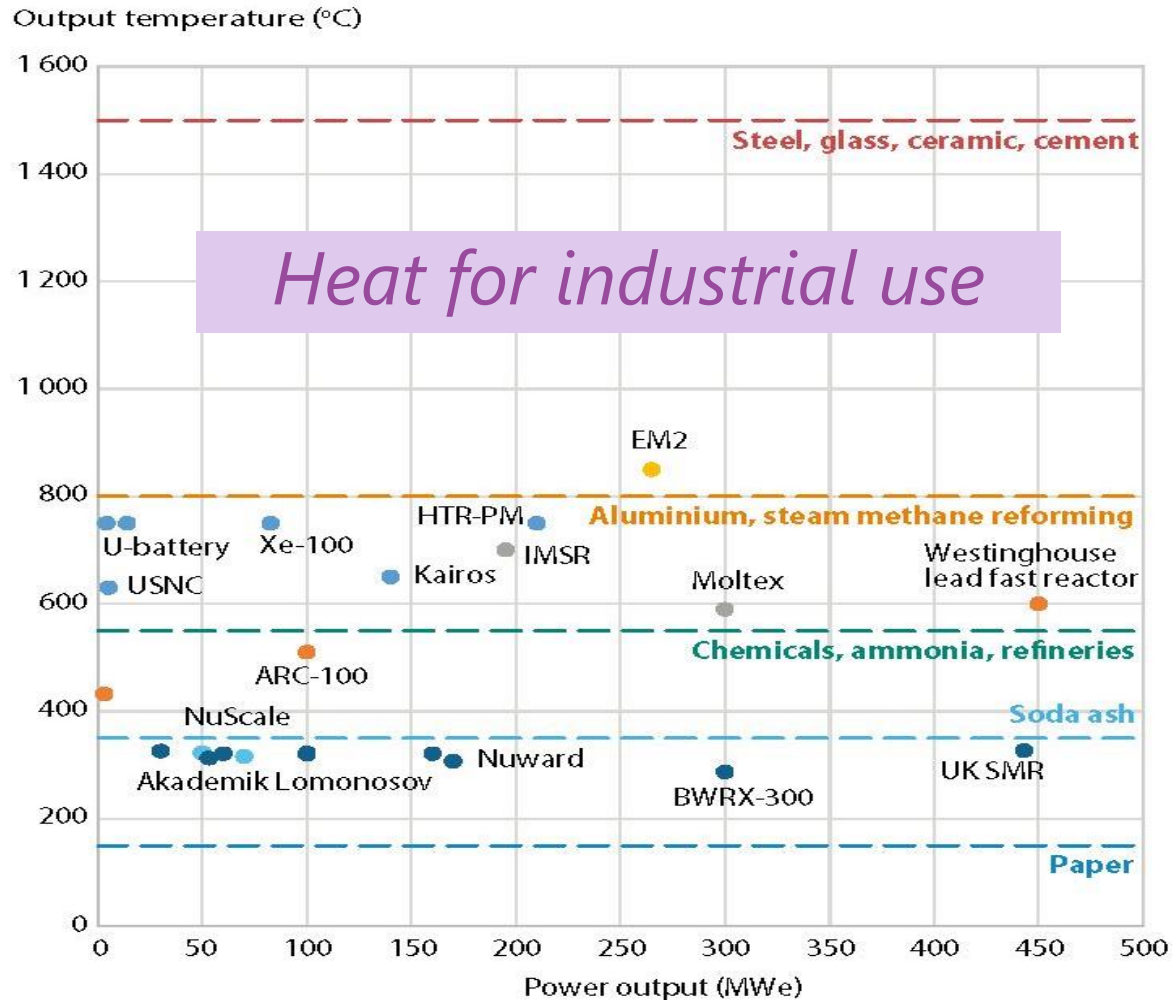
SMR Benefits: 2. Climate & Safety Benefits

Passive DHR principle by natural circulation



- No need for any active system (no electricity)
- Based on natural circulation of the coolant by gravity between the cold Heat Exchanger (HX) and the hot core
- Implemented in the MYRRHA experimentally demonstrated
- Proven experimentally at appropriate scale

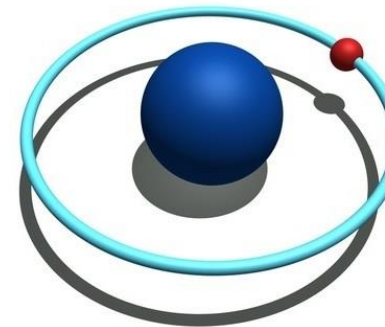
SMR Benefits: 3. Beyond electricity



- High temperature reactors
- Gas fast reactors
- Liquid metal fast reactors
- Floating light water reactors
- Molten salt reactors
- Light water reactors-SMRs

Source: NEA, forthcoming.

Hydrogen production





Belgium / SCK CEN Gets Go-Ahead For Research Into Next-Generation SMRs

The research centre SCK CEN is to conduct research into small, modular reactors of the next generation. The research is being funded by the federal government.



Belgium to fund development of advanced small modular nuclear reactors

The Belgian government has announced that it will provide funding of €100-million for research into advanced small modular nuclear reactors (SMRs). The money will be given to the country's SCK-CEN nuclear research centre in tranches of €25-million a year, over four years. The announcement was made at a function marking the seventieth anniversary of the SCK-CEN.



Belgium government allocates funding for SMR research

"In addition to the substantial progress of renewable energy, the government has also decided to study other technologies which could make a contribution by 2050," said Minister of Energy Tinne Van der Straeten during a ceremony to mark the 70th anniversary of SCK-CEN's founding. "To this end, the government is making EUR25 million available per year for research into fourth-generation small modular reactors for a period of four years."

"This should allow to verify whether nuclear energy is truly the world best and are making breakthroughs in both the field of active and passive safety."

minimisation of long-lived waste and economic feasibility." The government wants to use the research SMRs as a coolant. A gas or a gas-liquid cycle is also possible.

Initiative in Belgium for SMR R&D&I

- Based on innovative concepts
- Horizon 2040
- 100 M€

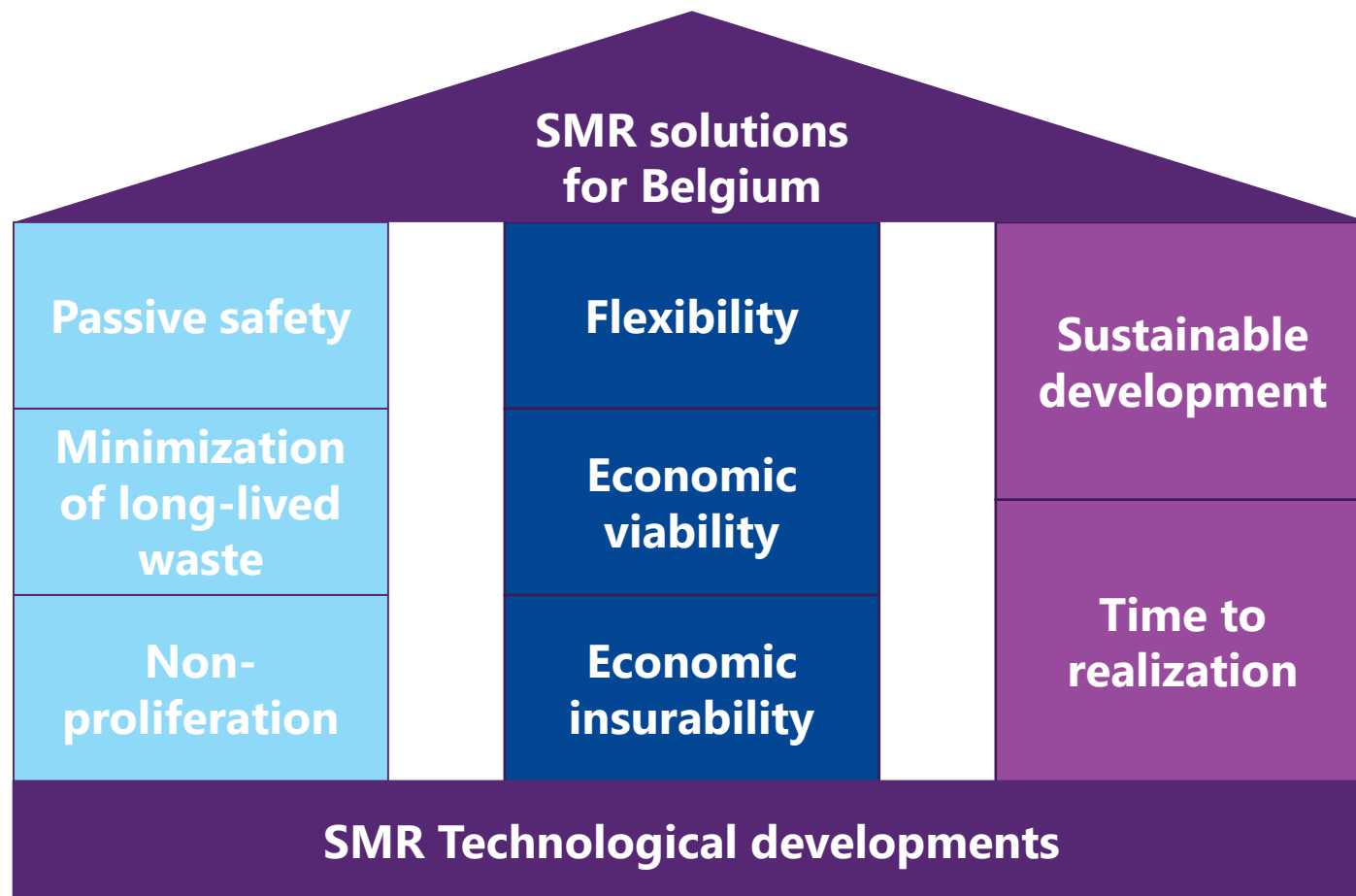


Technologic evaluation-report

SMR concepts for production from 2040 on of:

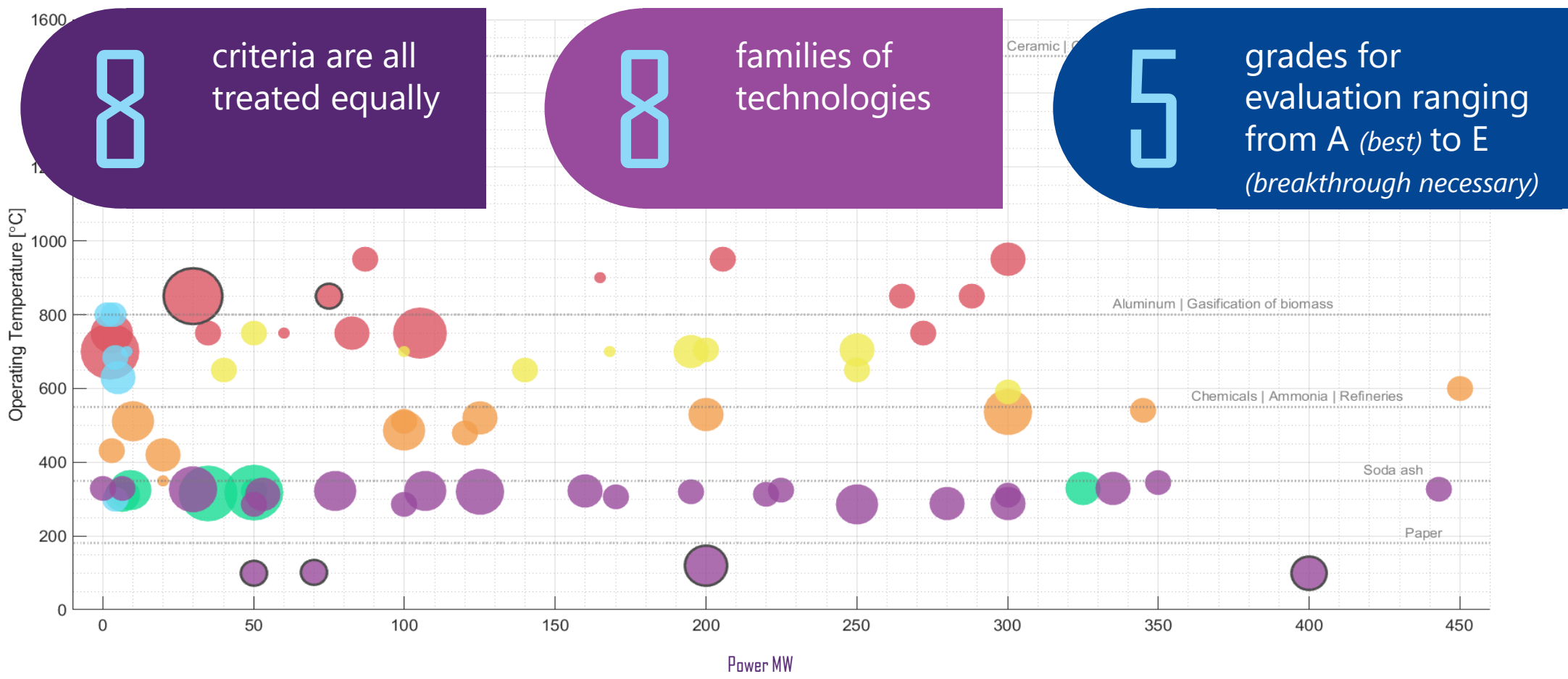
- Electricity
- Industrial heat
- Hydrogen

8 criteria for comparing SMRs concepts



- 1 Reducing potential impact on society by technological advances
- 2 Benefits to the Belgian economy and industry
- 3 Responsible and timely planning of the future energy landscape

Evaluation of SMR's concepts



Recommendations

- Assessing **integration of SMR's to the energy mix** in a holistic approach
- Choosing for an **SMR-LFR** building upon the know-how from **MYRRHA** and the **MOX**-technology
- Developing **strategic partnerships** in view of the construction of a **SMR-LFR demonstrator** at SCK CEN
- **Contributing to harmonizing of the licensing process** on international level
- Maintaining the **nuclear know-how** in Belgium



Why Fast Reactor SMR & Lead FR-SMR ?

Link to MYRRHA



MYRRHA: World Class Technology complex to serve HLM SMR development



- LiLiPuTTeR-II
- HELIOS 3
- HLM Lab
- MEXICO
- CRAFT
- LIMETS 3
- RHAPTER
- COMPLOT
- ESCAPE
- Ultrasonic Lab
- GUINEVERE

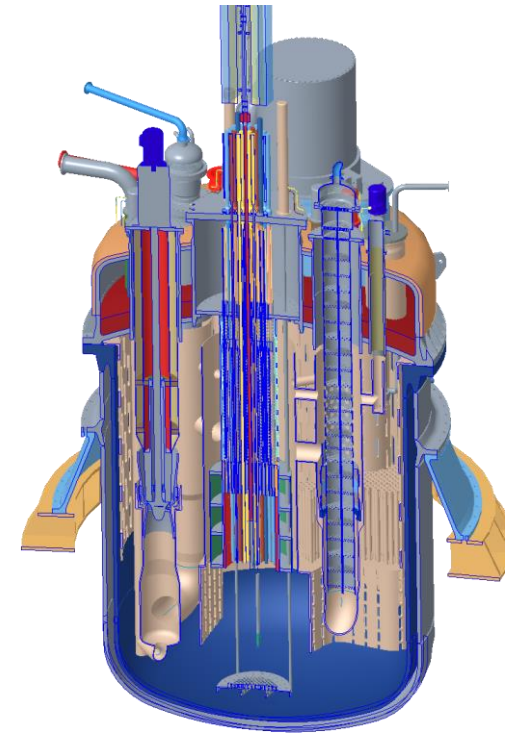
Lead-Bismuth Chemistry
& Conditioning

Material development
& testing

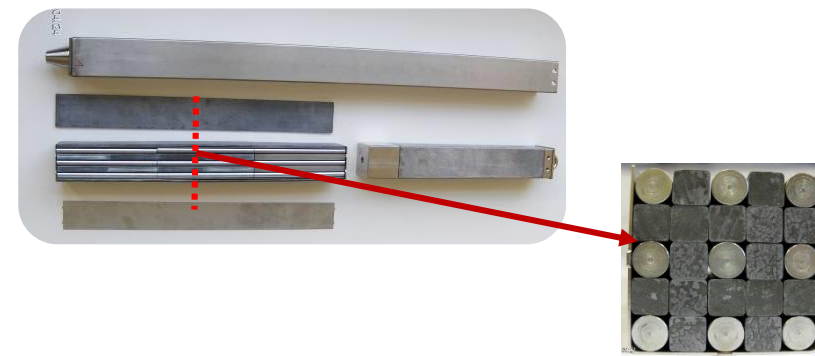
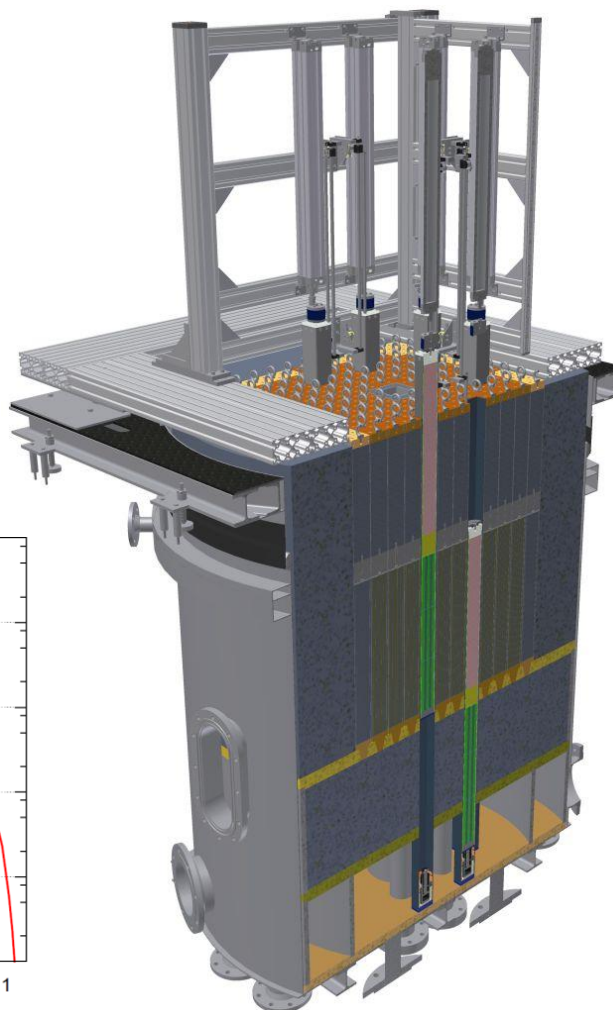
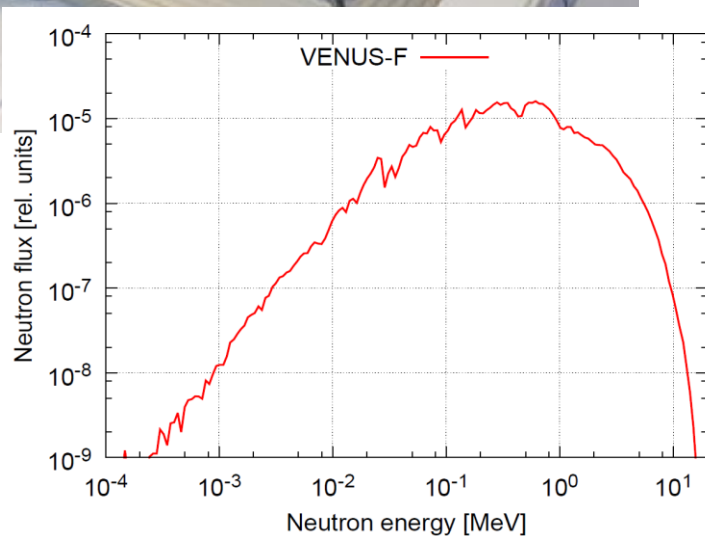
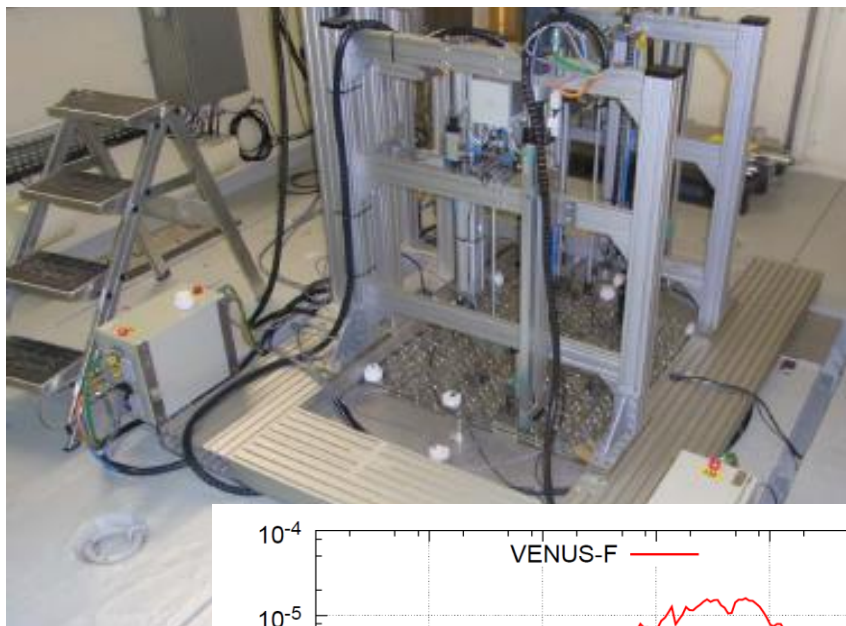
Component testing &
Thermal Hydraulics

Instrumentation & Visualisation

Lead Zero Power Reactor

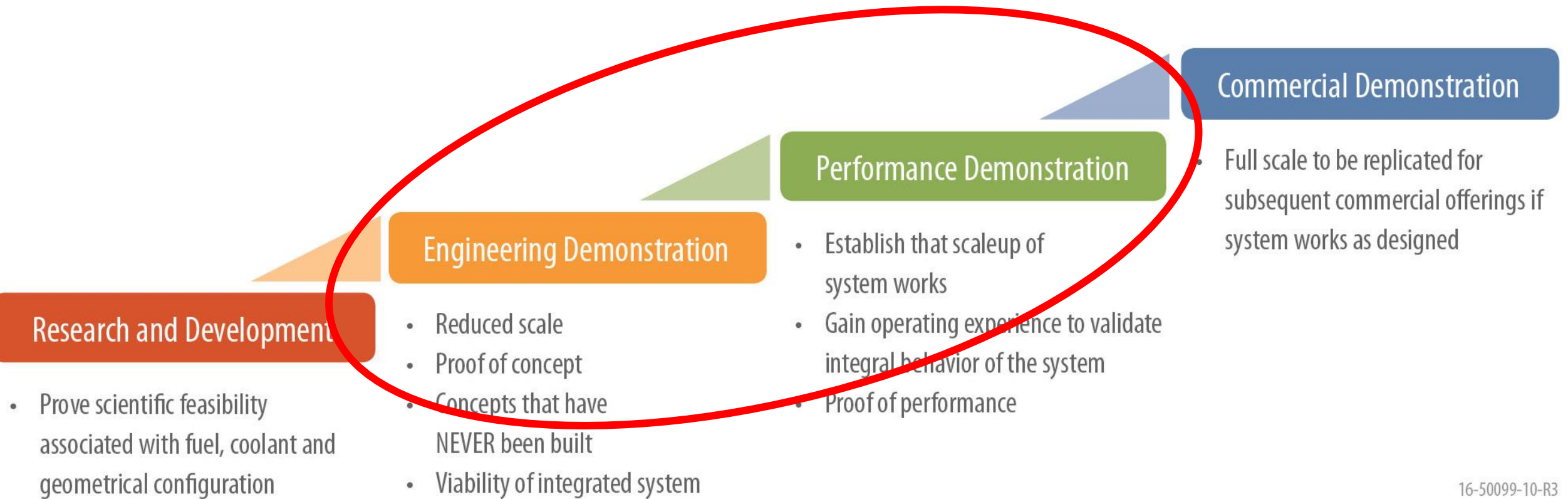


The VENUS-F reactor



- Zero Power (~ 500 W) Fast Reactor
- 30 % Enriched Metallic Uranium
- Al₂O₃ pins for UO simulation
- Lead reflector
- Lead, Bismuth or Pb-Bi coolant simulator
- No active cooling system
- B4C Safety rods with fuel follower
- ADS mock-up
- **Max total flux: 10^{10} n/cm²s**

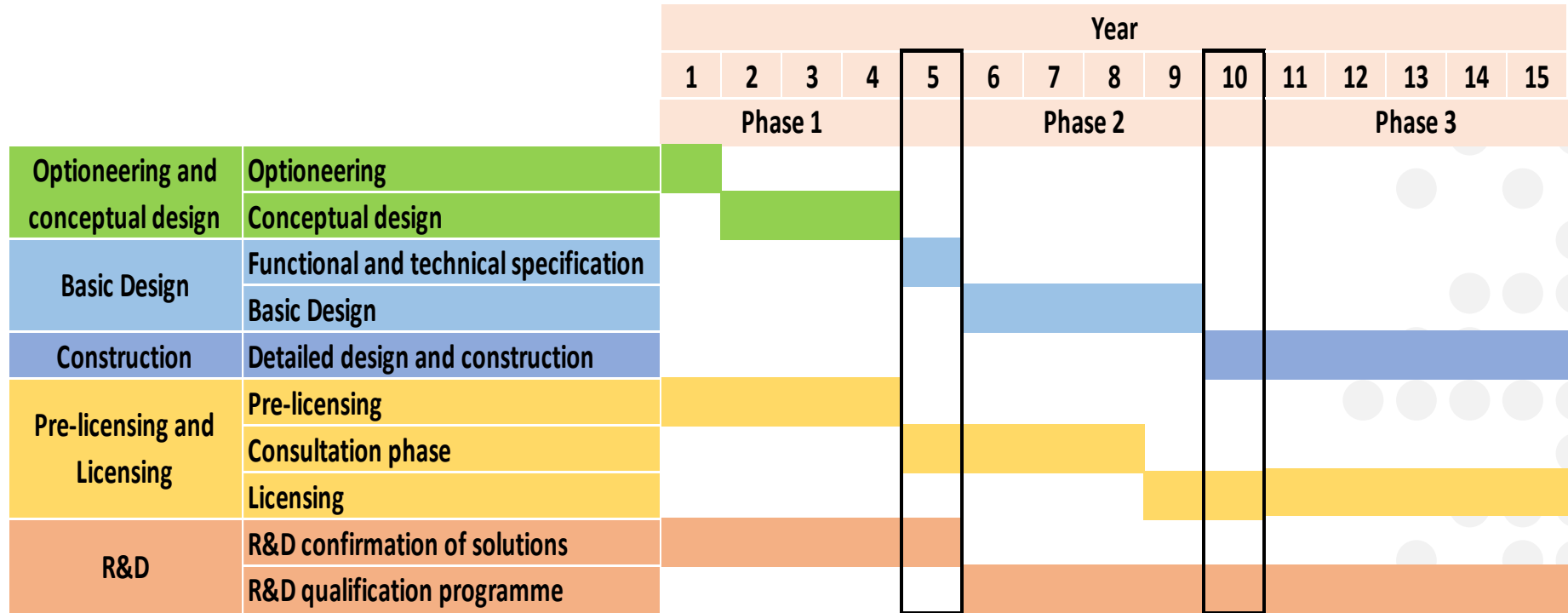
Reactor development and deployment steps based on international experience



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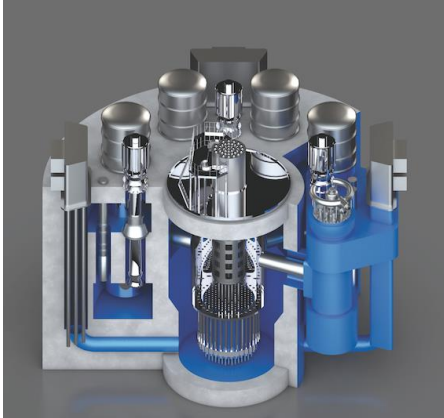
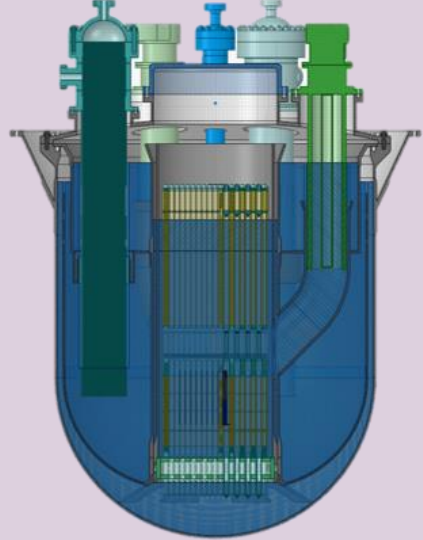
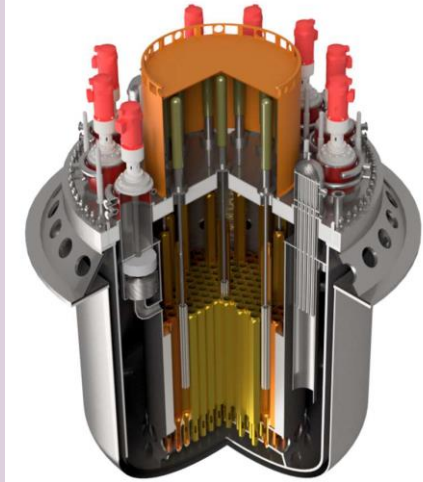
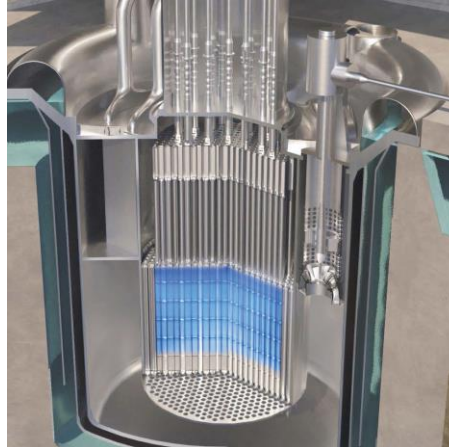

Source: "Advanced demonstration and test reactor options study". INL, Technical Report INL/EXT-16-37867 - <https://doi.org/10.2172/1364524>

Phased approach for a SMR-LFR TD



Based on the inputs, contributions and experience of the consortium partners an acceleration leading to a **planning targeting 2035** for the construction could be envisaged.

Selected SMR-LFRs under development

BREST	ALFRED	SEALER-55	WLFR	LFR-TL-30
				
300 MWe	300 MWth	55 MWe	450 MWe	30 MWe
Niket (Russia)	ANSALDO (Italy)	Leadcold (Sweden)	Westinghouse (US)	Newcleo (UK)

Proposed Workplan of the first phase (Y1 to Y5)

3 Pillars

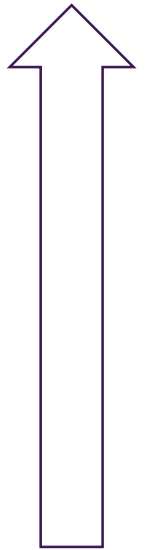
Tech. push



1. Technology

2. Industrialization

3. Integration into the energy mix



Market pull

Proposed Workplan of the first phase (Y1 to Y5)

Objectives

1. Technology,

- optioneering and **conceptual design** in collaboration with international partners of the consortium with experience in reactor design,
- support of the **pre-licensing** activities in which FANC and BelV will contribute
- **R&D activities** in confirmation of the selected technical options
- **cost estimate** (CAPEX/OPEX) of the TD and the cost of basic design phase

2. Industrialization,

- facilitation of a **supply chain** list

3. Integration into the energy mix.

- establishment of **requirements** of SMR-LFR defined by users
- studies related to the **integration of SMR-LFR systems** into the BE energy mix

SMR-LFR Technology Demonstrator pgm Ambition/Vision

- As Centre of Excellence of HLM technology thanks to MYRRHA, SCK CEN becomes the **reference for SMR-LFR technology** development.
- In partnership, SCK CEN will **construct at its site a technology demonstrator** in view of the deployment of the SMR-LFR technology. Moreover, the integration of SMR-LFR into the future Belgian energy mix is targeted.

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SCK CEN

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