EXPLORING THE DEPLOYMENT OF ADVANCED REACTOR SYSTEMS FOR DECARBONIZATION OF FUTURE ENERGY GENERATION

Geert-Jan de Haas, Ferry Roelofs
SNETP Forum, Lyon, 2. June 2022

26197/237144

EU DuC = N

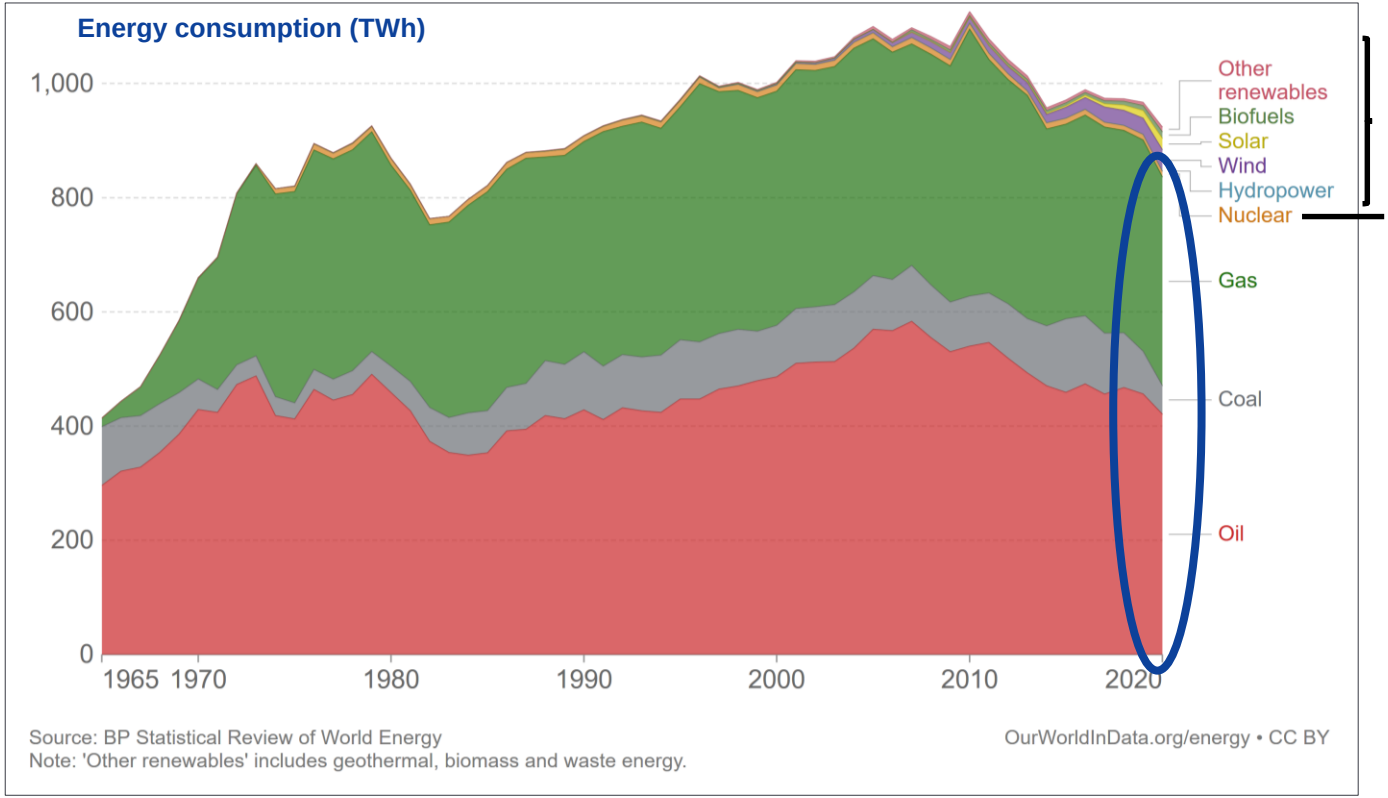
NRG

Nuclear. For life.

European Commission

SNETP
Sustainable Nuclear Energy Technology Platform

The Dutch energy challenge



NRG
Ensuring Nuclear Performance

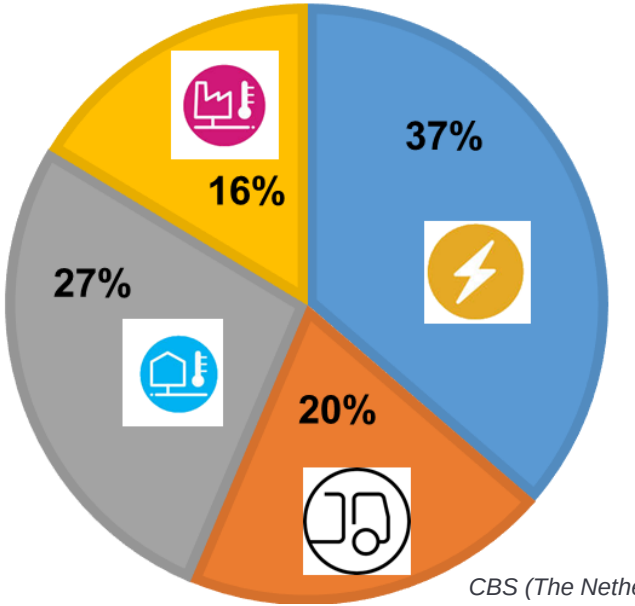
Energy functions

Electricity

Low T heat

High T heat

Transport



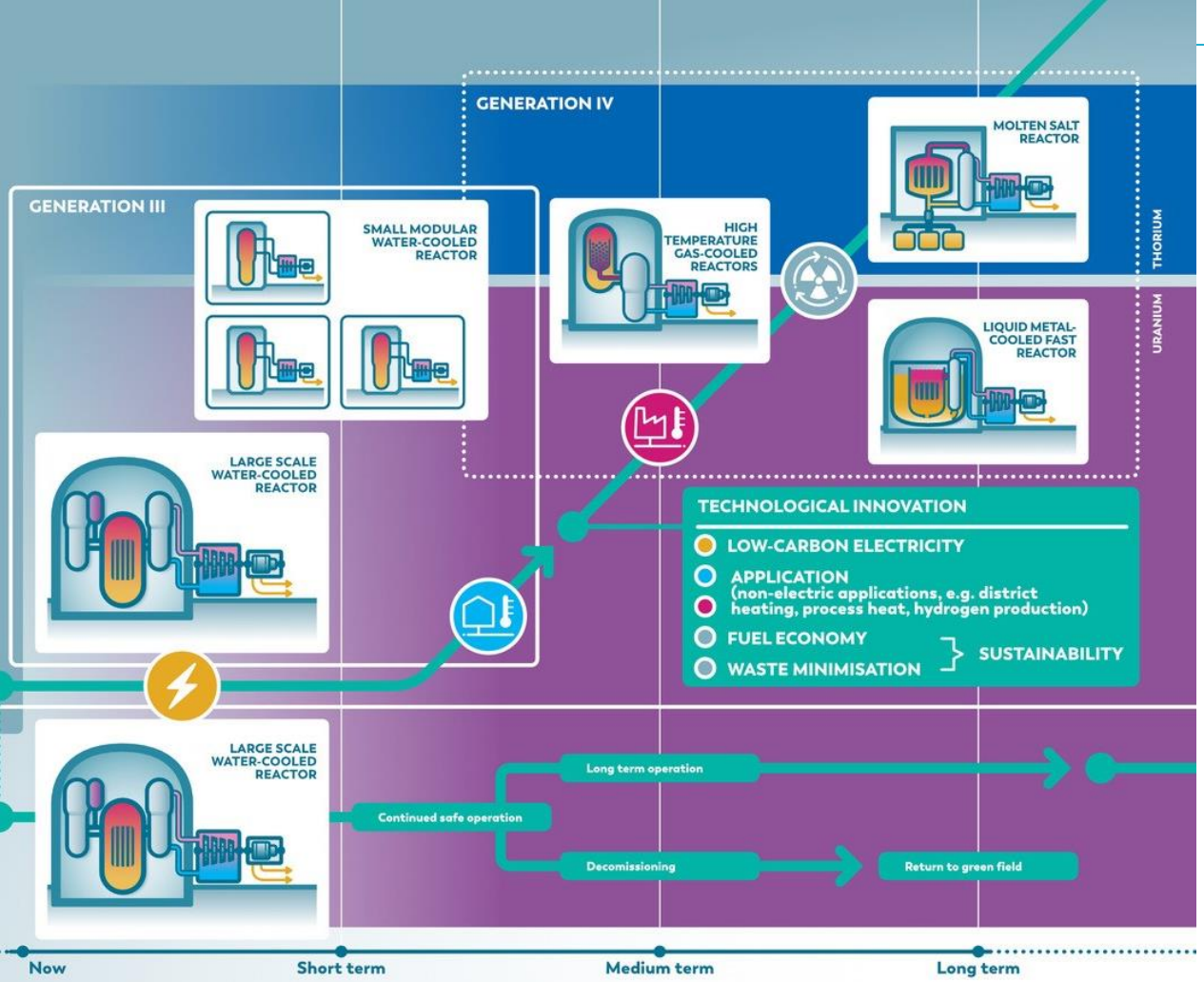
CBS (The Netherlands), 2015

Future energy landscape

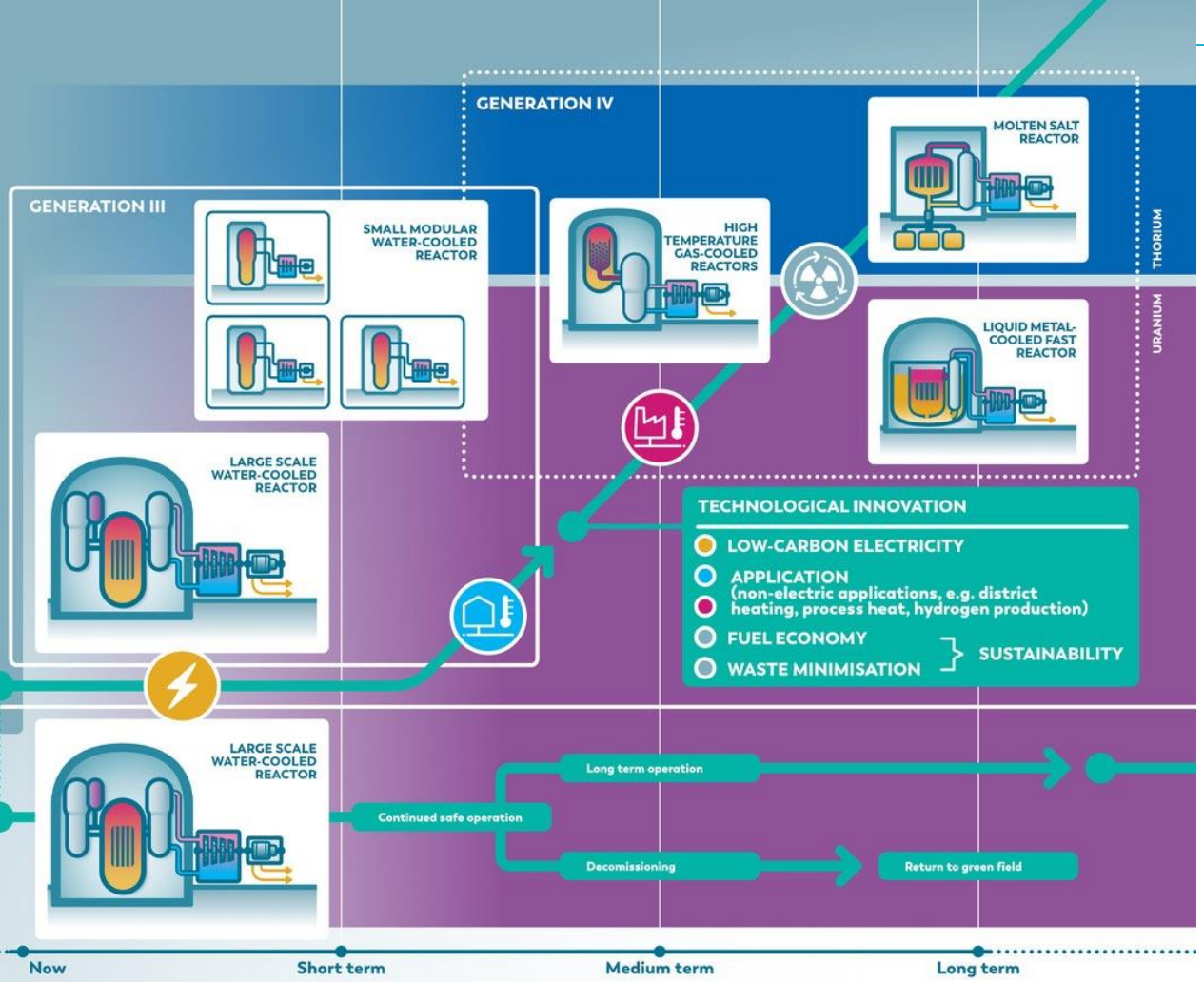
- Electrification
- Clean / carbon free
- Reliable
- Safe
- Affordable
- Small footprint
- Integration in energy mix

energienext.nl

Nuclear innovation roadmap - developments

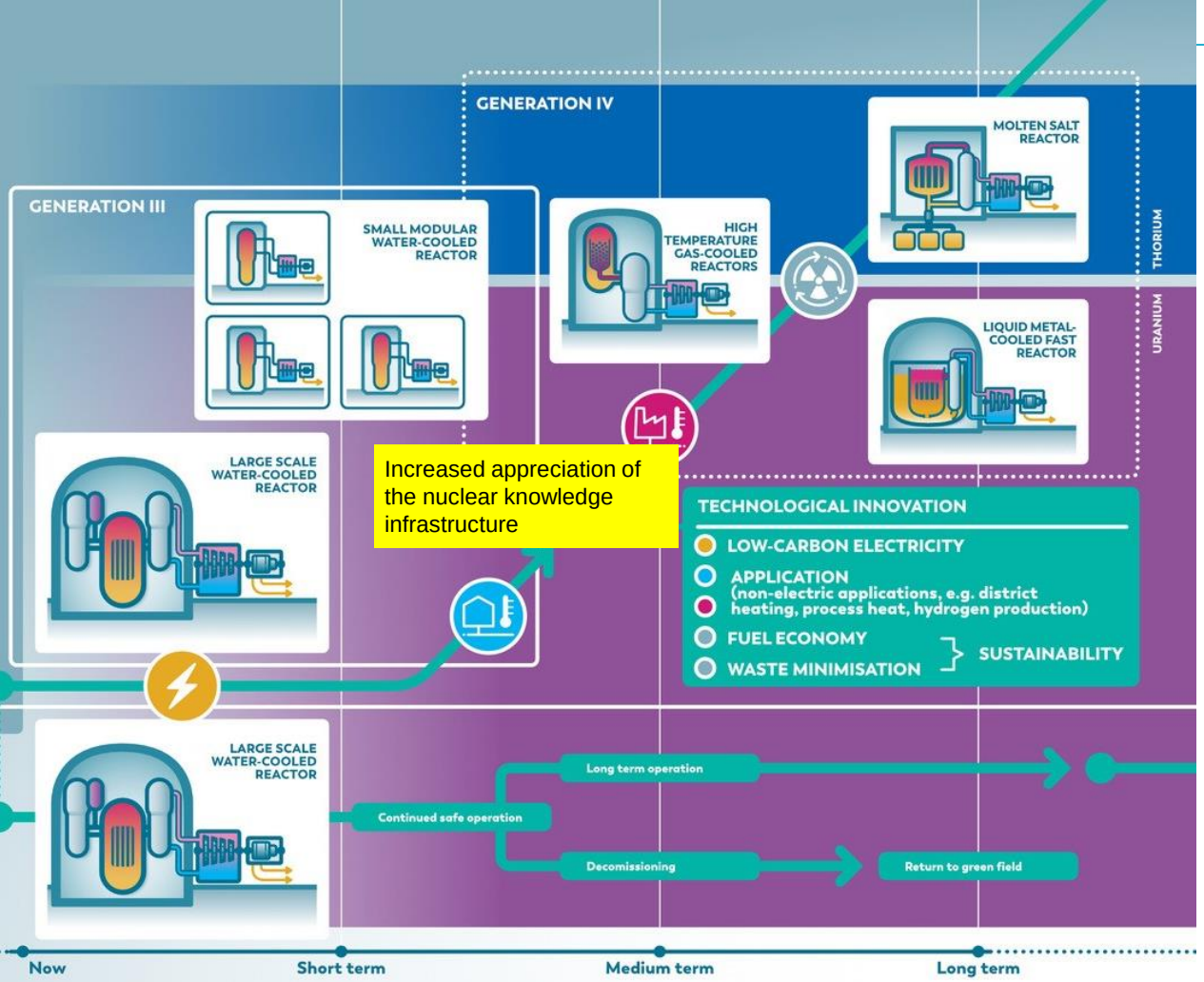


Nuclear innovation roadmap - developments



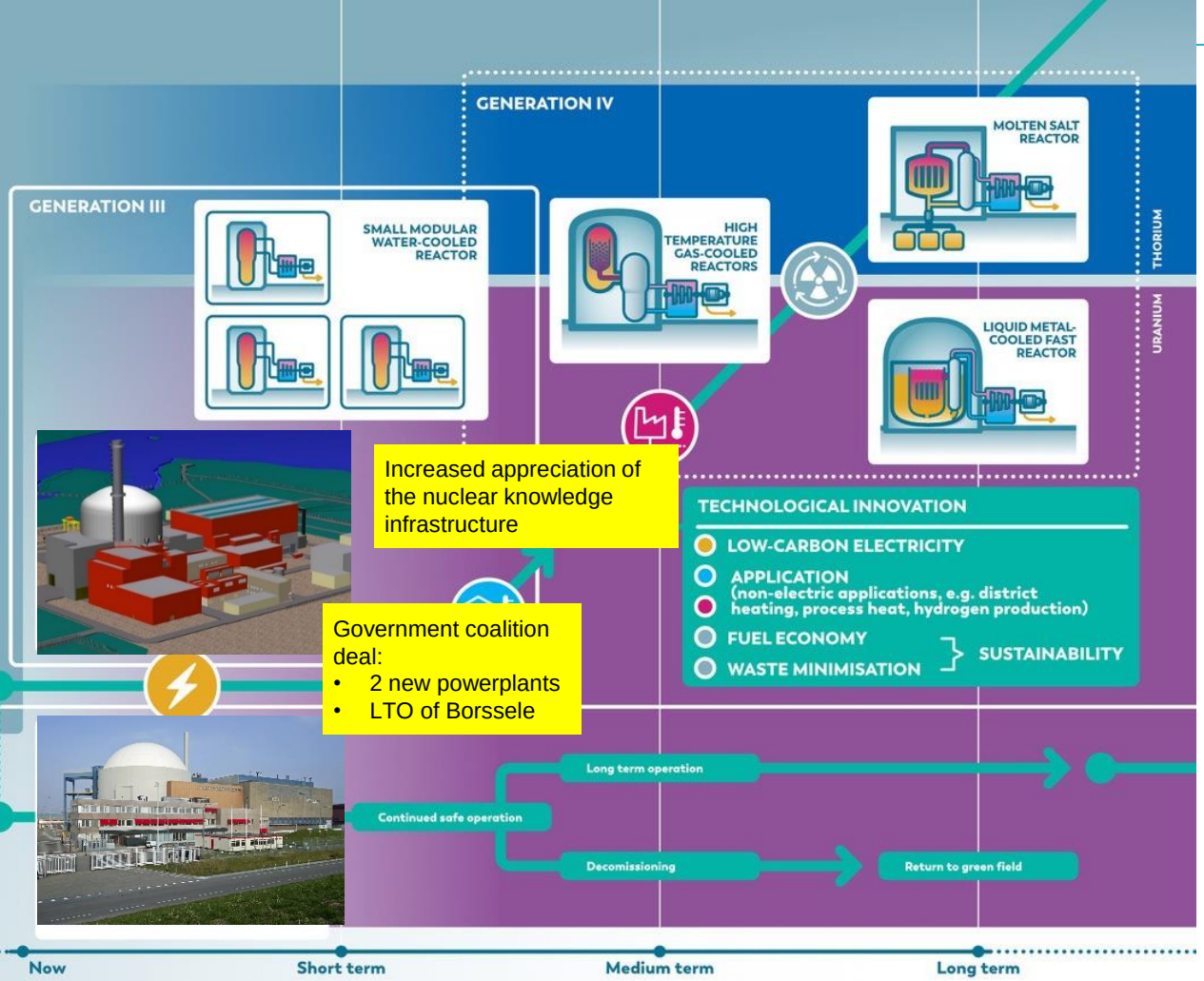
Multiannual research programma 2021-2024

Nuclear innovation roadmap - developments



Multiannual research programma 2021-2024

Nuclear innovation roadmap - developments



Multiannual research programma 2021-2024

Bridging the gap from R&D to deployment

- Various options to contribute to further decarbonization of the present energymix.
- Parts of the knowledge base have previously been developed.
- Fulfillment of the prospects has been pending for many decades.
- Some technologies may now be on their way to deployment.

MRSE ORNL (USA)

BN800 (Russia)

LWR-SMR, CAREM (Argentina)

HTR-PM (China)

BUT

- if nuclear energy is to contribute to further decarbonization …..
- if the promising prospects are really to be fulfilled….

THEN

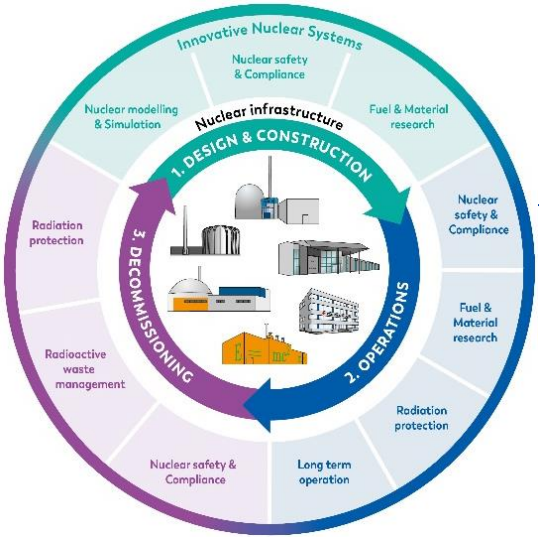
a concerted effort from the research community, policy makers, and industry is required to expand the knowledge base enabling future evaluation and assessment of the safety features by regulatory bodies.

PIONEER programme

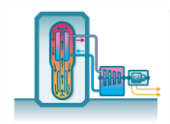
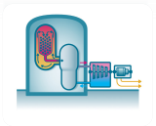
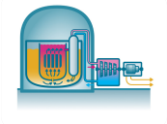
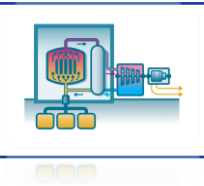
Program for **I**nnovation and c**O**mpetence development for **N**uclE**E**ar infrastructur**E** and **R**esearch

- NRG Multiannual research program 2021-2024
- Funded by Ministry of Economic Affairs and Climate policy
- 7 themes

1. Long Term Operation
2. Nuclear Safety and Compliance
3. Nuclear Modelling and Simulation
4. Fuels and Materials
5. Radioactive Waste Management
6. Radiation Protection
7. *Innovative Nuclear Systems*



PIONEER contributions to Generation IV deployment

	Fuels	Materials	System Simulation	Component Simulation
	?	?	✓	?
	✓	✓	✓	✓
	✓	✓	✓	✓
	✓	✓	✓	✓

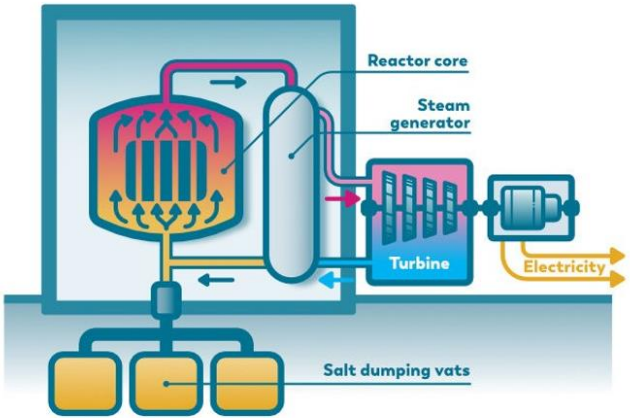
? Possible future activities

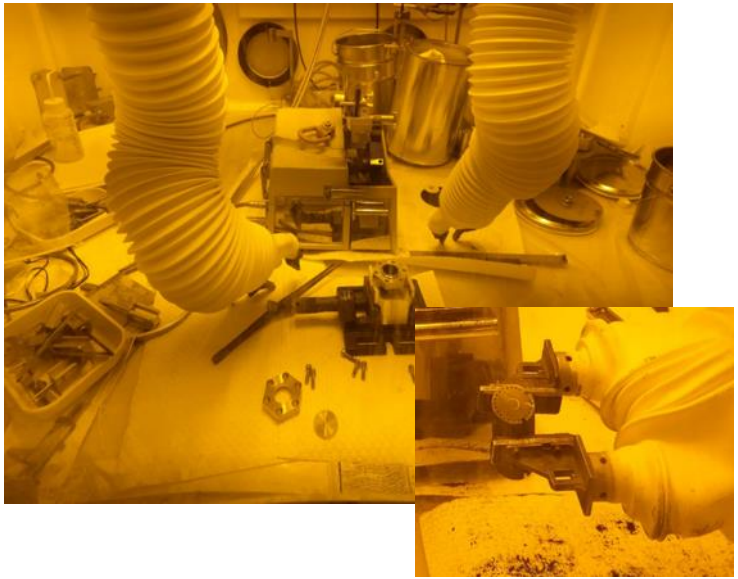
✓ Past and current activities

✓ Focal point activities

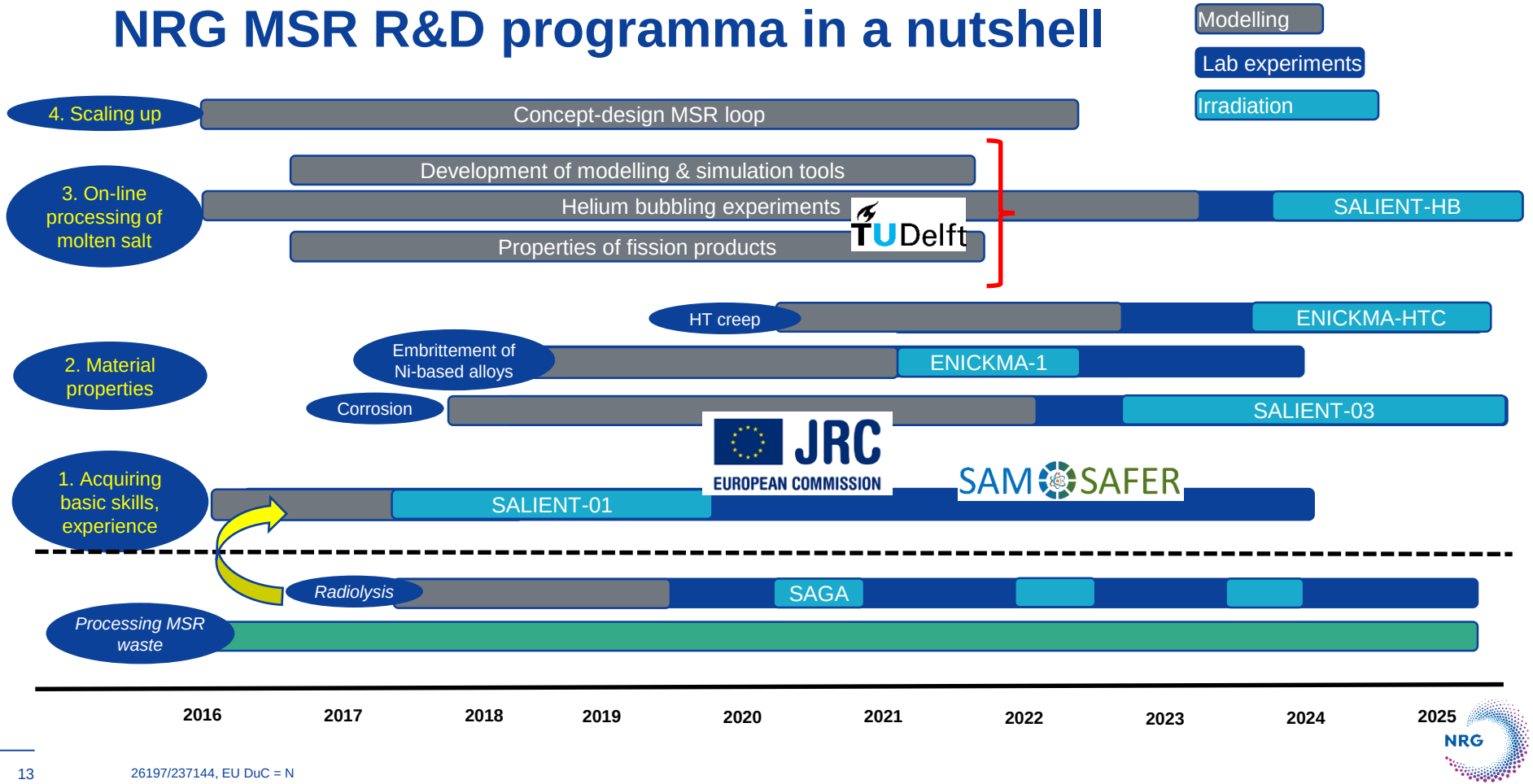
Highlight 1. Molten Salt Reactors

- Continuous recycling of thorium
- Almost no high level radioactive waste
- Electricity and heat for coming centuries





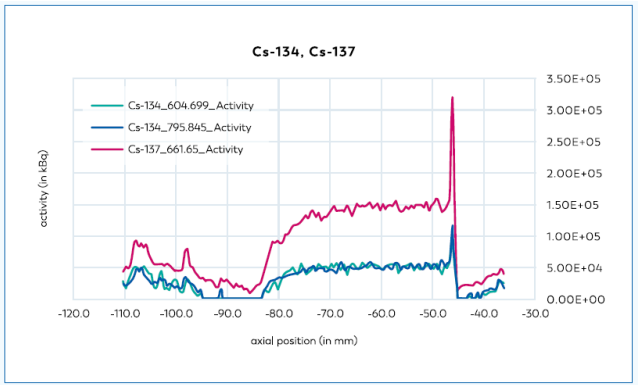
NRG MSR R&D programma in a nutshell

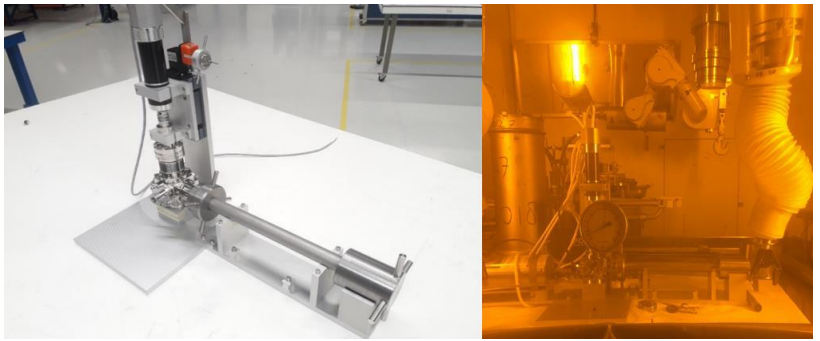


MSR: fuelled salt irradiation

Issue: hardly any experience with molten salt fuel irradiations and handling of fuelled salts

- Graphite
- Salt composition based on manufacturing possibilities (78LiF-22ThF$_4$)
- Irradiation at two temperatures during ~500 full power days
- Determination fission gas release
- Gamma spectrometry
- Electron microscopy
- Fission gas release





MSR: radiolysis

Issue: F_2 formation at lower temperatures (in-between irradiation cycles)
→ pressure build-up
SAGA: gamma irradiation fuel salt at low temperature

- HFR spent fuel as gamma source
- First irradiation completed
- Recombination tests ongoing
- Preparation second irradiation

MSR: processing of waste

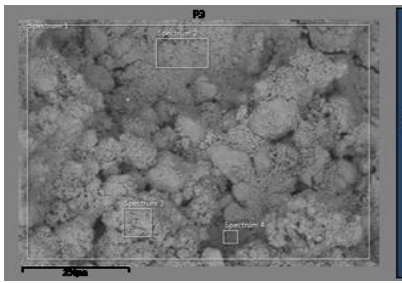
Any experimental programme generates new waste streams.
Lessons from the past: experimental fuel research has to be attended with research into the stabilization of waste.

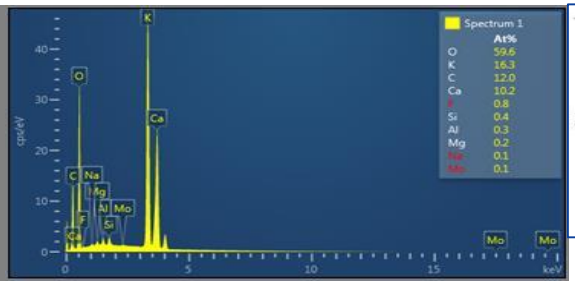
Issues:
1) MSR waste is corrosive.
2) Ambient conditions will give rise to radiolysis (room temperature).

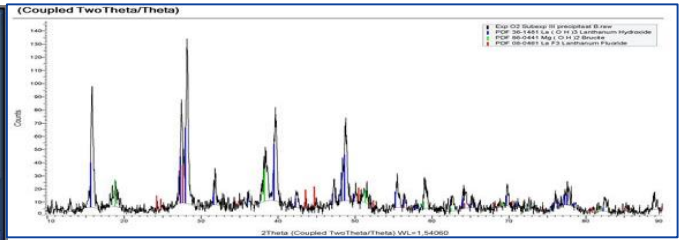
Required: onversion to stable waste forms acceptable for COVRA, Dutch facility for radioactive waste storage

Mixed fluoride salts → oxide waste and cementable liquid waste

Phase 1: simulated waste (non-active components)
Phase 2: radioactive samples from SALIENT-01 experiment in hot-cell







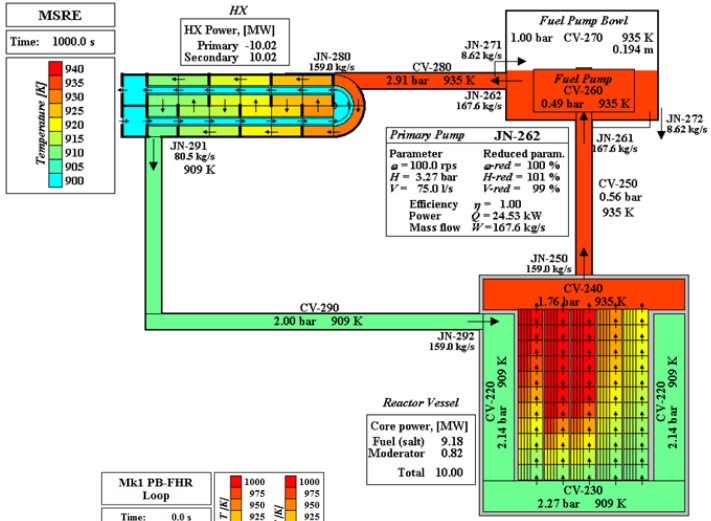
MSR: system thermal hydraulics

Molten salt model development:

- delayed neutron precursor drift
- heat removal by natural circulation
- fission product transport in (fueled) molten salt reactors
- noble gas and noble metal behavior
- noble metal extraction
- chromium leaching and deposition

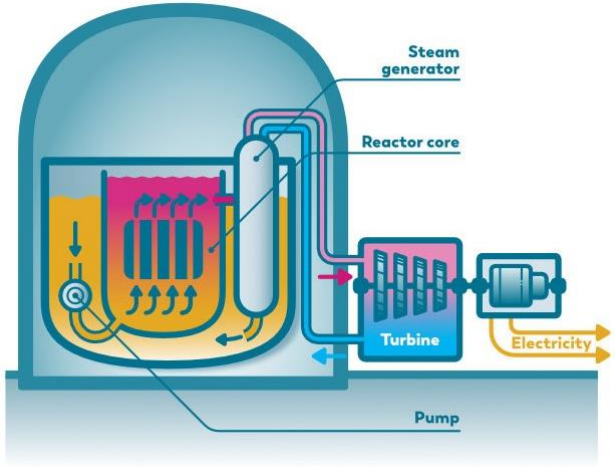
Comparison and validation
(whenever possible)

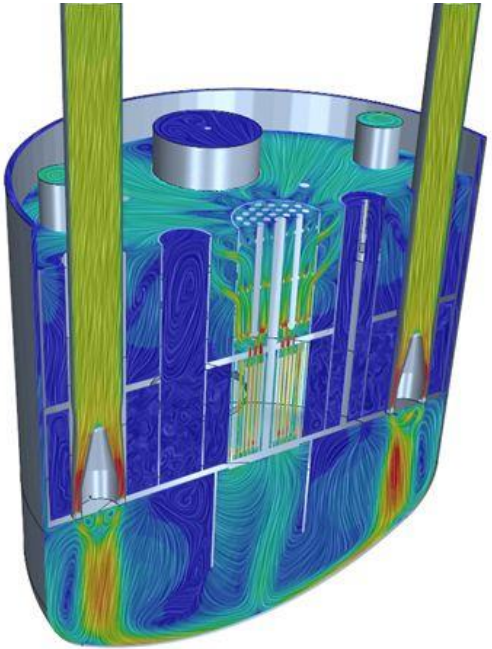
- MSRE
- Mk1-PB-FHR



Highlight 2. Liquid Metal-Cooled Reactors

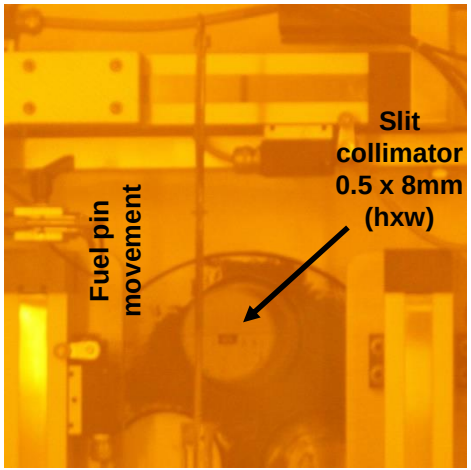
- Multi-recycling of uranium
- 20x more energy from uranium
- Less high level radioactive waste
- Electricity and heat for coming centuries

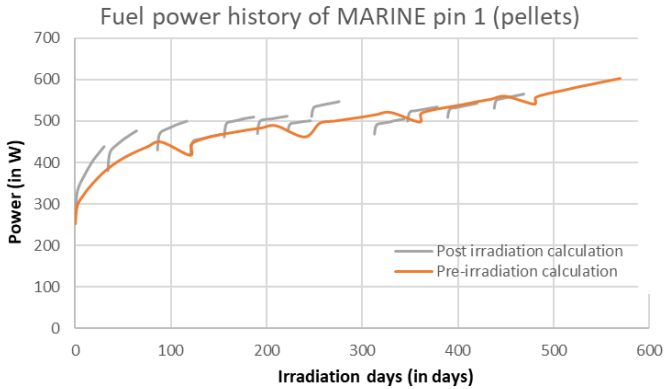


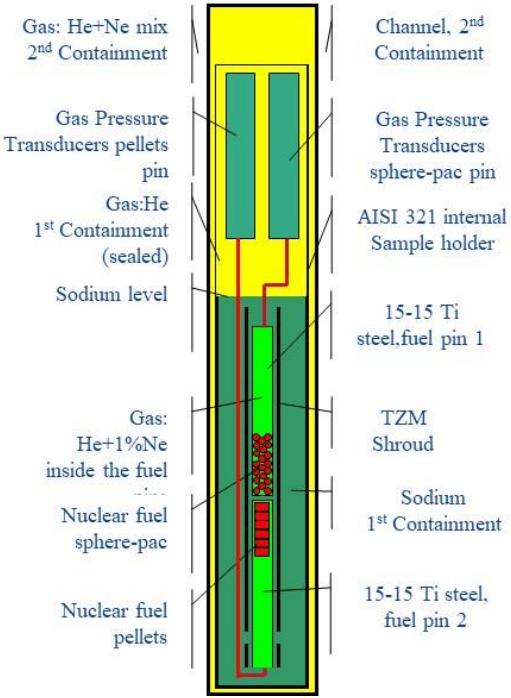


LMFR: transmutation of actinides

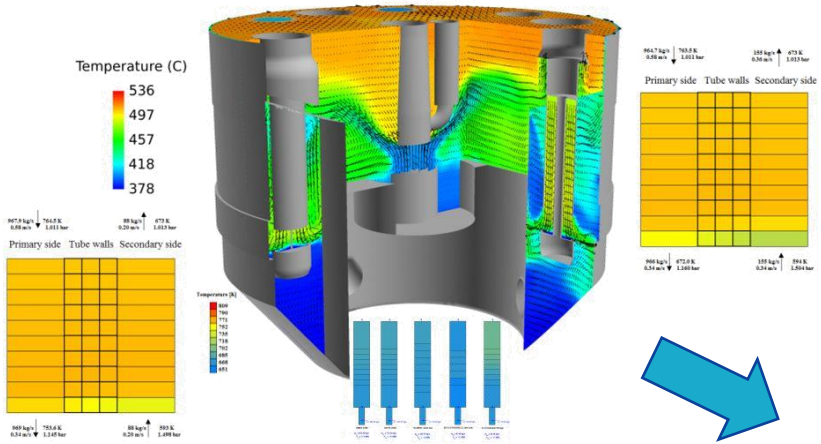
- Comparison of pellet and sphere-pac blanket fuel ($U_{0.85}Am_{0.15}O_{2-x}$)
- Focus on He and fission gas production / release
- Measuring gas release into the pin plenum online
- Nuclear analysis and non-destructive examination
- Future activity: destructive examination



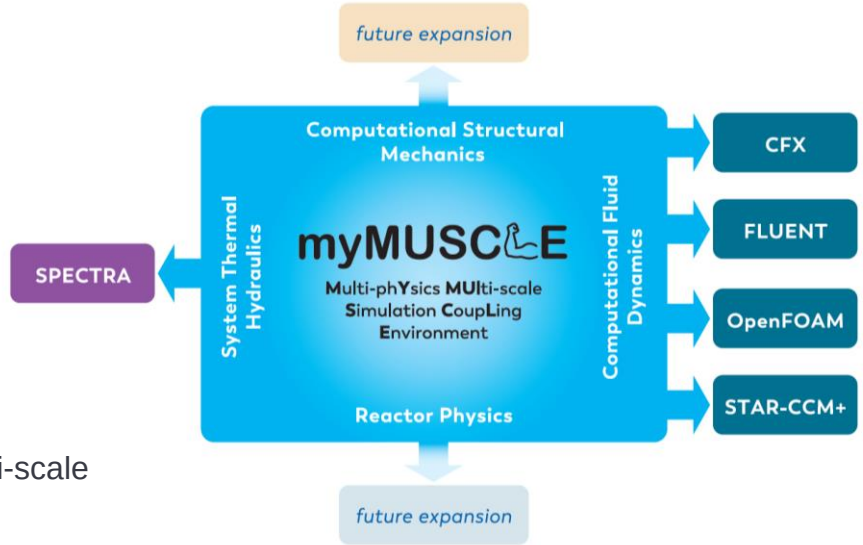




LMFR: multi-scale thermal hydraulics



Phénix: asymmetric transient

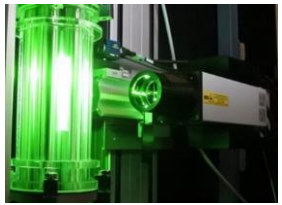


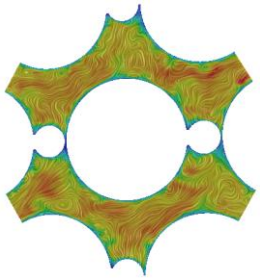
Development of myMUSCLE generic multi-scale multi-physics coupling tool:

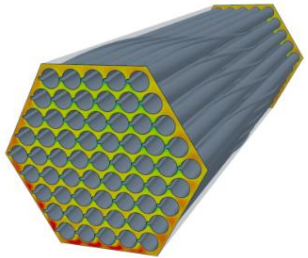
- Coupling methods
- Coupling algorithms
- User-friendly interface

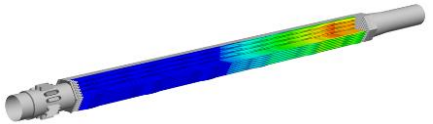
LMFR: core thermal hydraulics

wire wraps



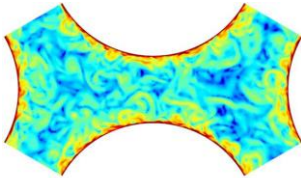


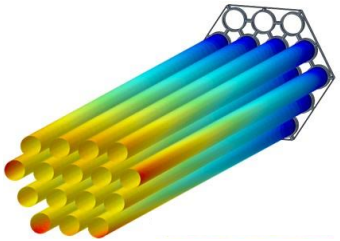


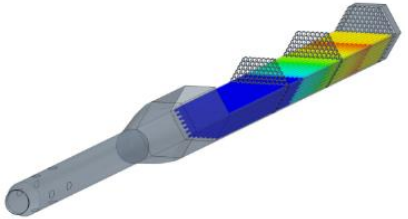


experiment & high fidelity → model validation and application

grid spacers







Disclaimer

Goods labeled with an EU DuC (European Dual-use Codification) not equal to 'N' are subject to European and national export authorization when exported from the EU and may be subject to national export authorization when exported to another EU country as well. Even without an EU DuC, or with EU DuC 'N', authorization may be required due to the final destination and purpose for which the goods are to be used. No rights may be derived from the specified EU DuC or absence of an EU DuC.