Applications of nuclear technology in isotope production and nuclear R&D

Nuclear Technology and opportunities for Engineers
20 februari 2023
Koninklijk Instituut Van Ingenieurs (KIVI)
Students Twente / SV Watt

Geert-Jan de Haas
NRG|PALLAS

Applications of nuclear technology in isotope production and nuclear R&D

Geert-Jan de Haas
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1. Introduction NRG|PALLAS
2. Energy research
3. Medical research
4. Trainee programme, internships

Locaties NRG|PALLAS

Energy & Health Campus, Petten

Commerce, operations, consultancy, R&D

Alkmaar Office

Staff new Build Programme

Arnhem

Consultancy, inspection, R&D

Energy & Health Campus Developments

NRG|PALLAS: working towards three public goals

1. Medical care

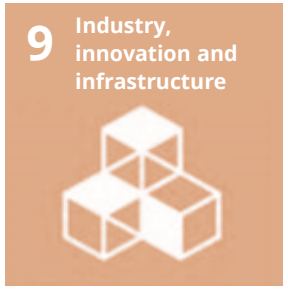
- Security of supply of medical isotopes
- Accerlerated development of new therapies
- Contribution to affordable care
- Autonomy production of medical isotopes within Europe

2. Climate neutral energy production

- Maintenance and reinforcement of the nuclear knowledgde infrastructure
- Development of advanced reactor technologies

3. Earning power of the Netherlands

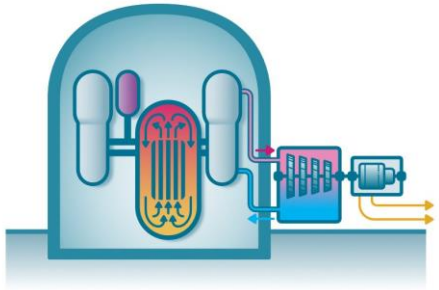
- Innovative strength
- Nuclear knowledge, educations, added value for the nuclear sector
- R&D-network EU

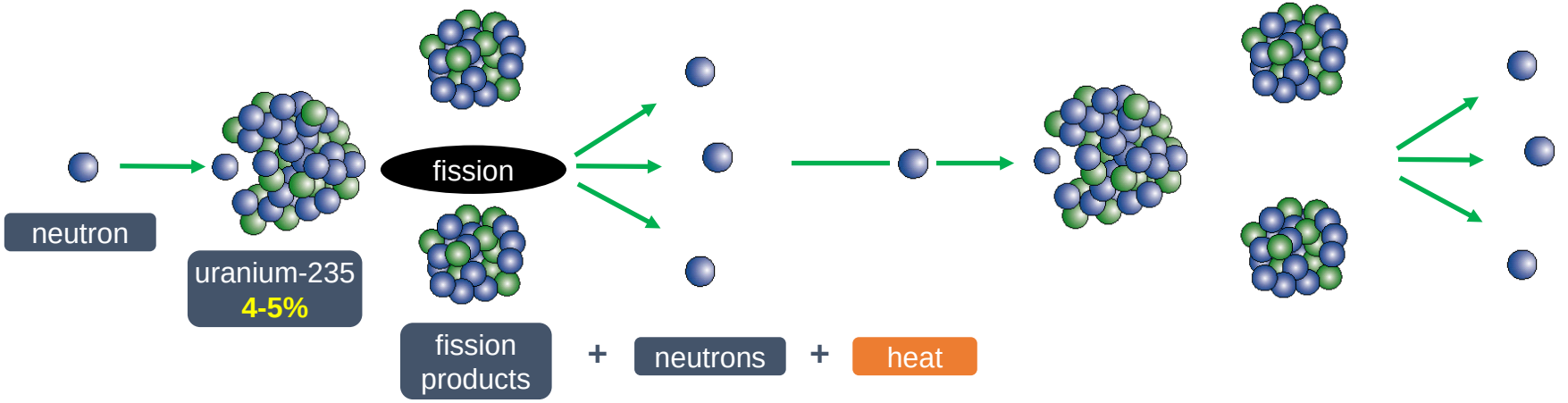


Bron| Sustainable Development Goals Verenigde Naties

The High Flux Reactor – A Material Test Reactor

Nuclear power plant





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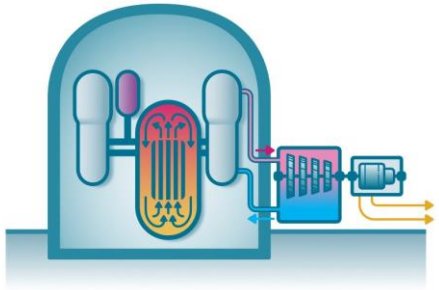
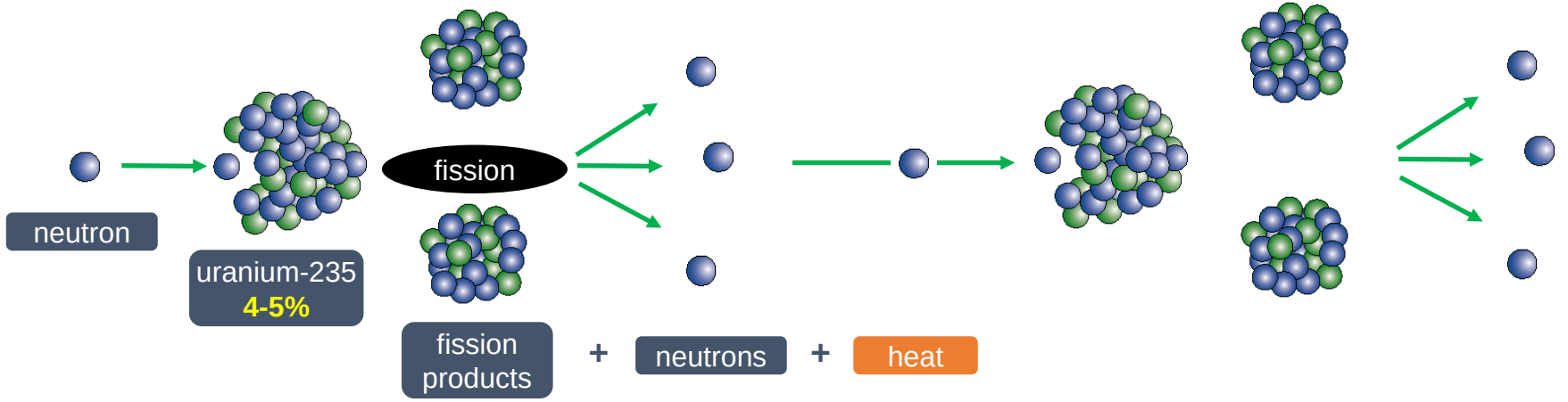
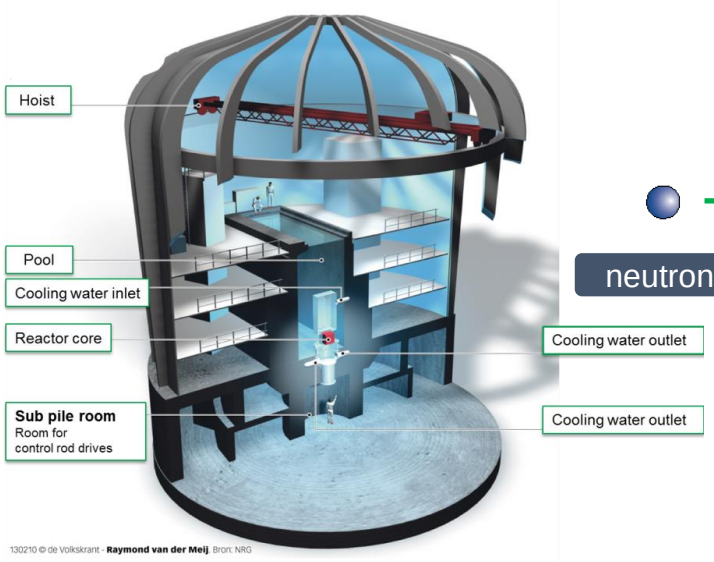
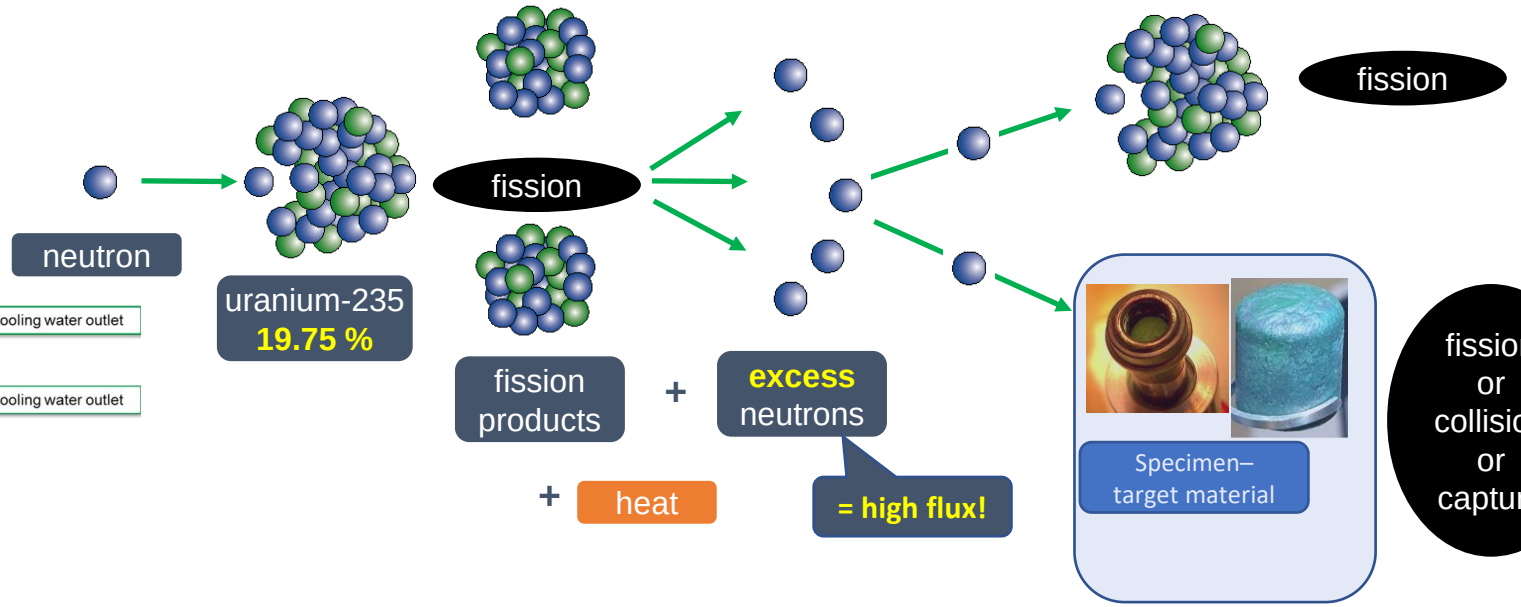


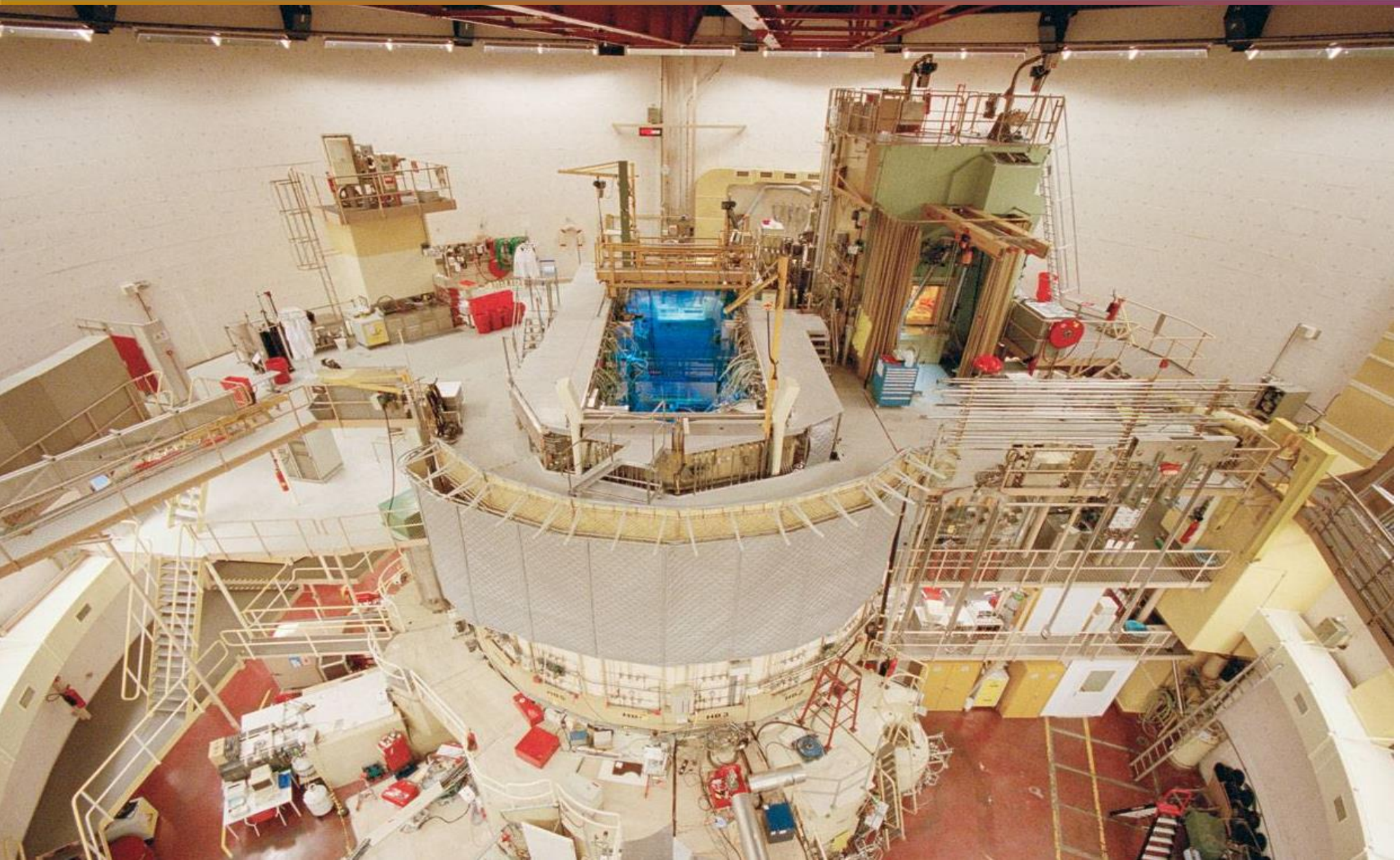






- properties of fuels
- radiation damage, ageing
- transmutation, generation of new nuclides

The High Flux Reactor



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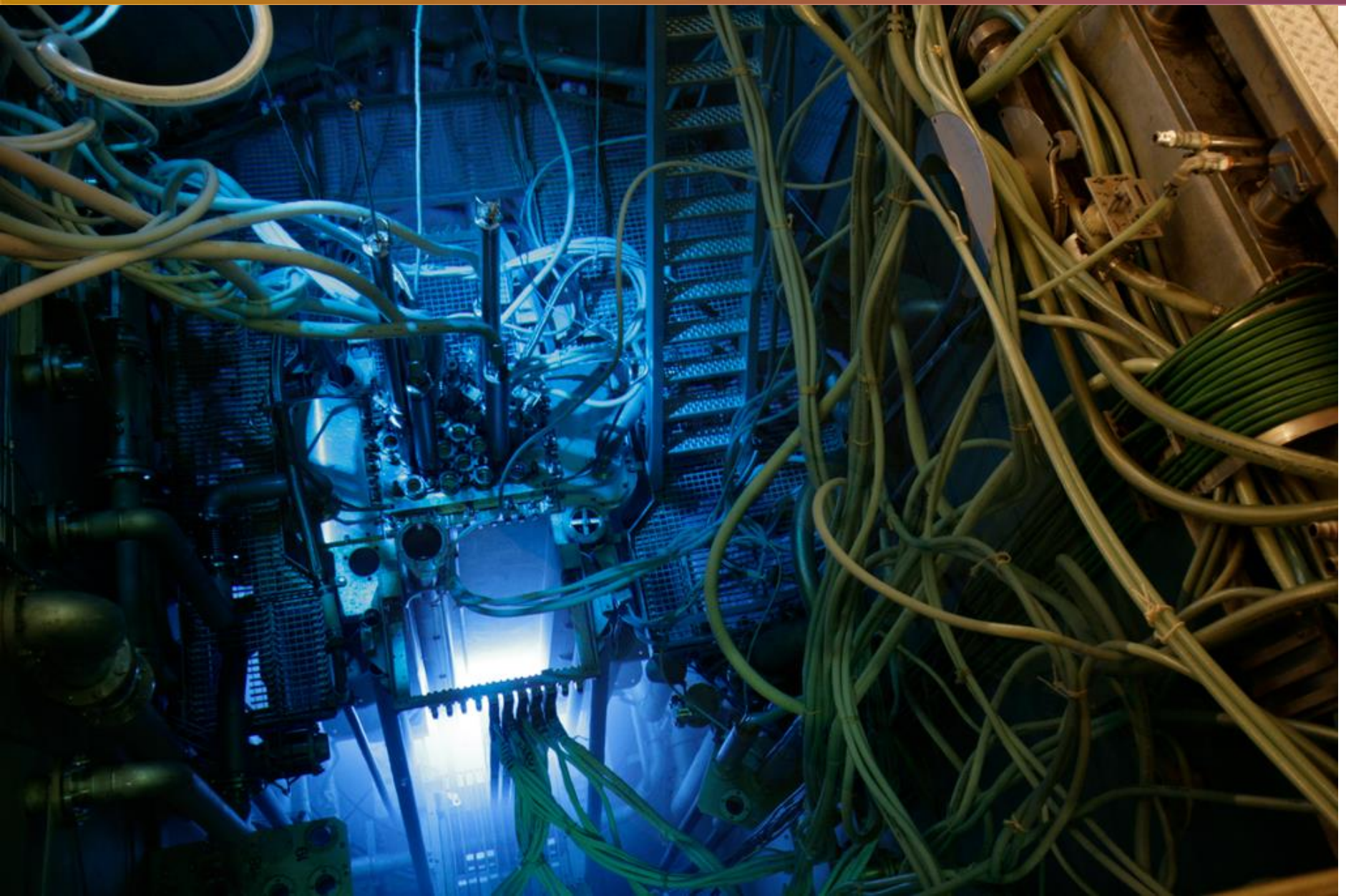
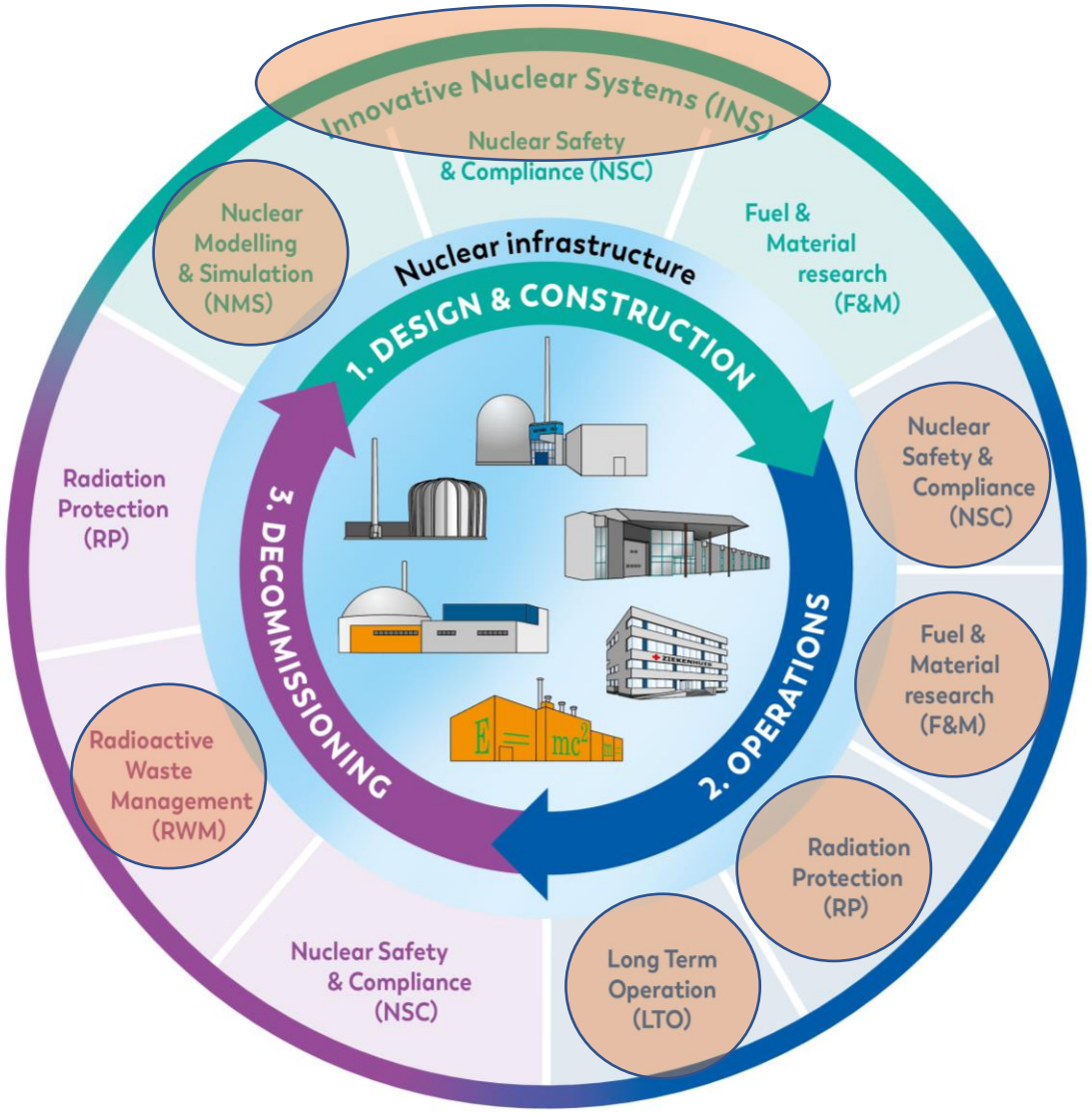


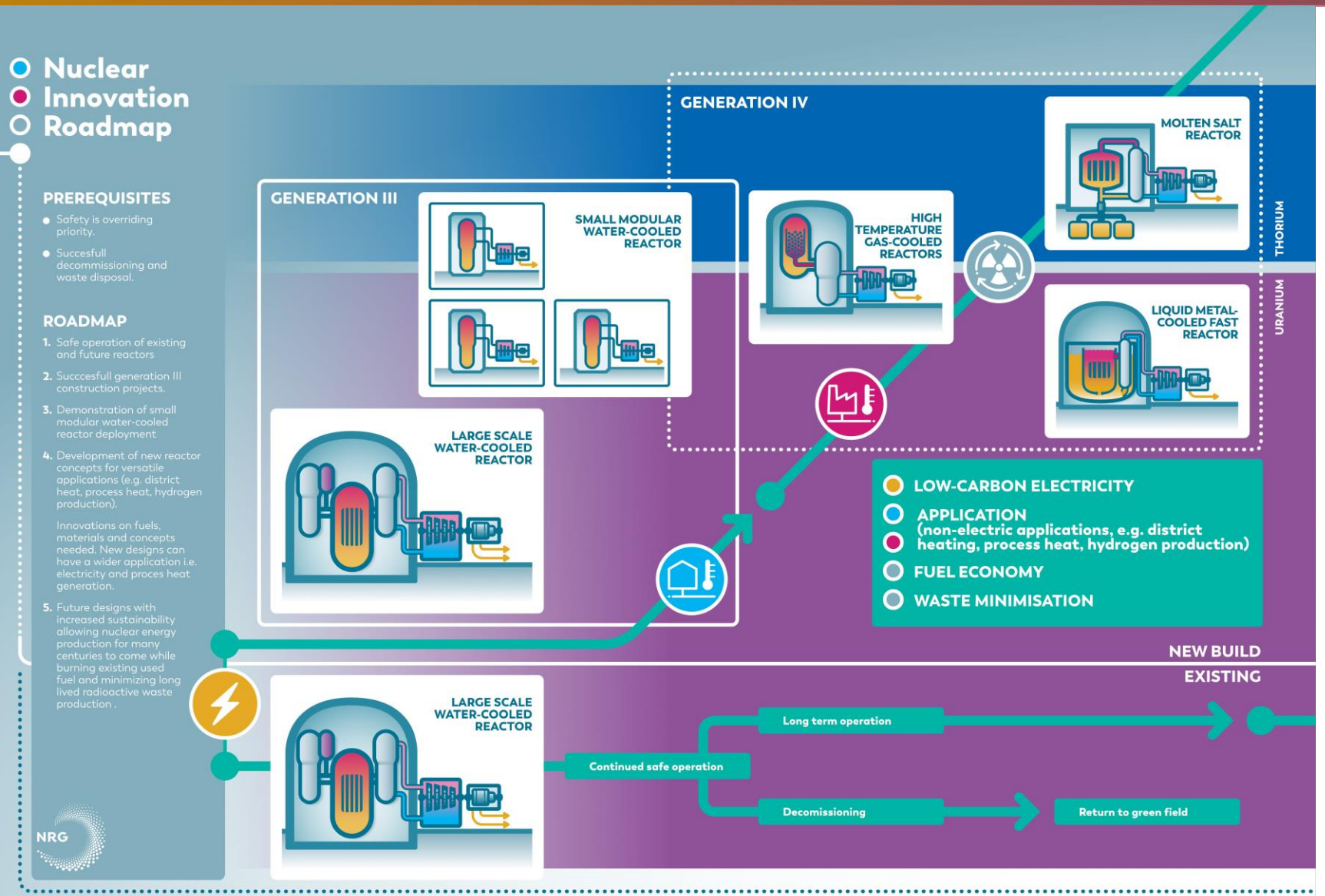
Energy research

Research programme commissioned by the Ministry of Economic Affairs and Climate policy.

- Contributing to safe operation of nuclear facilities, state-of-the-art knowledge base.
- Supporting policy-making processes – e.g. plans for newbuilt.
- Innovation – development of future advanced reactor technologies.



Nuclear Innovation Roadmap



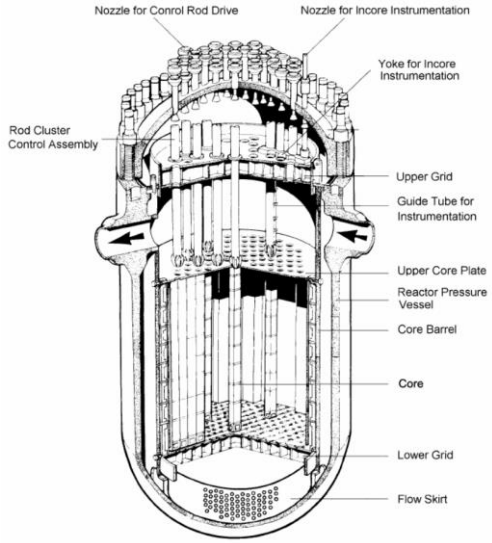
Energy research – Long term operation (LTO)

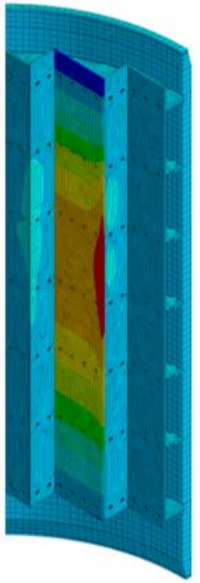
- Nuclear power plants have typically been designed for an operational lifetime of 40 years.
- Due to conservative design, the operating time of many nuclear reactors is longer than originally planned at the time of their construction: long term operation.
- Reactor fleet from 1970-1980's: lifetime extension from 40 to 60 years.
  - Borssele power plant: 1973 → 2013 → 2033
- Prerequisite: demonstration that the reactor can be operated beyond 40 years without compromising nuclear safety.
  - Safety assessment of the reactor and all reactor components.
  - Ageing management programme: continuous monitoring of the behaviour and properties of critical components

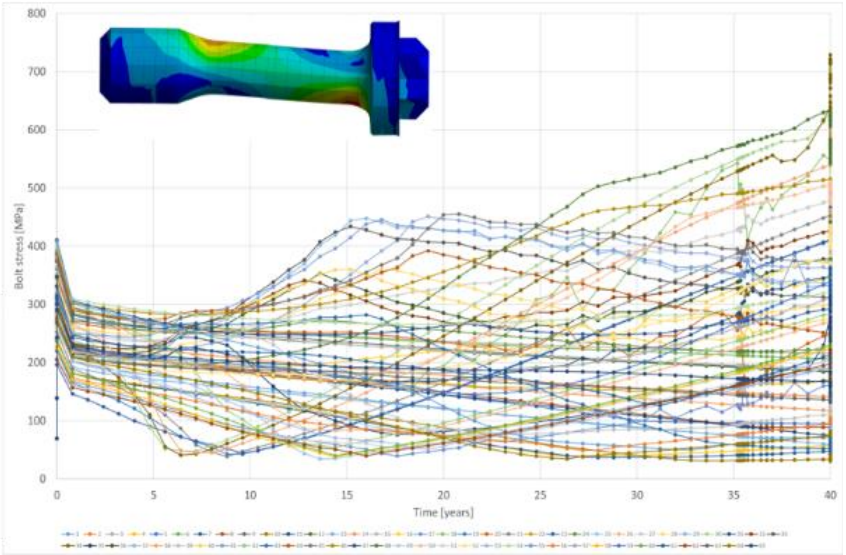
Energy research – Long term operation (LTO)

Irradiation-Assisted Stress Corrosion Cracking (IASCC)

- Reactor pressure vessel internals: development of models for structural integrity assessment of baffle - former bolts
- Material behaviour changes during operation under the influence of radiation and interaction with cooling water
- Multiphysics: neutronics (MCNP), cooling flow (CFD), material behaviour (FEM)
- Thermo-mechanical analyses including radiation-induced creep and swelling of bolts



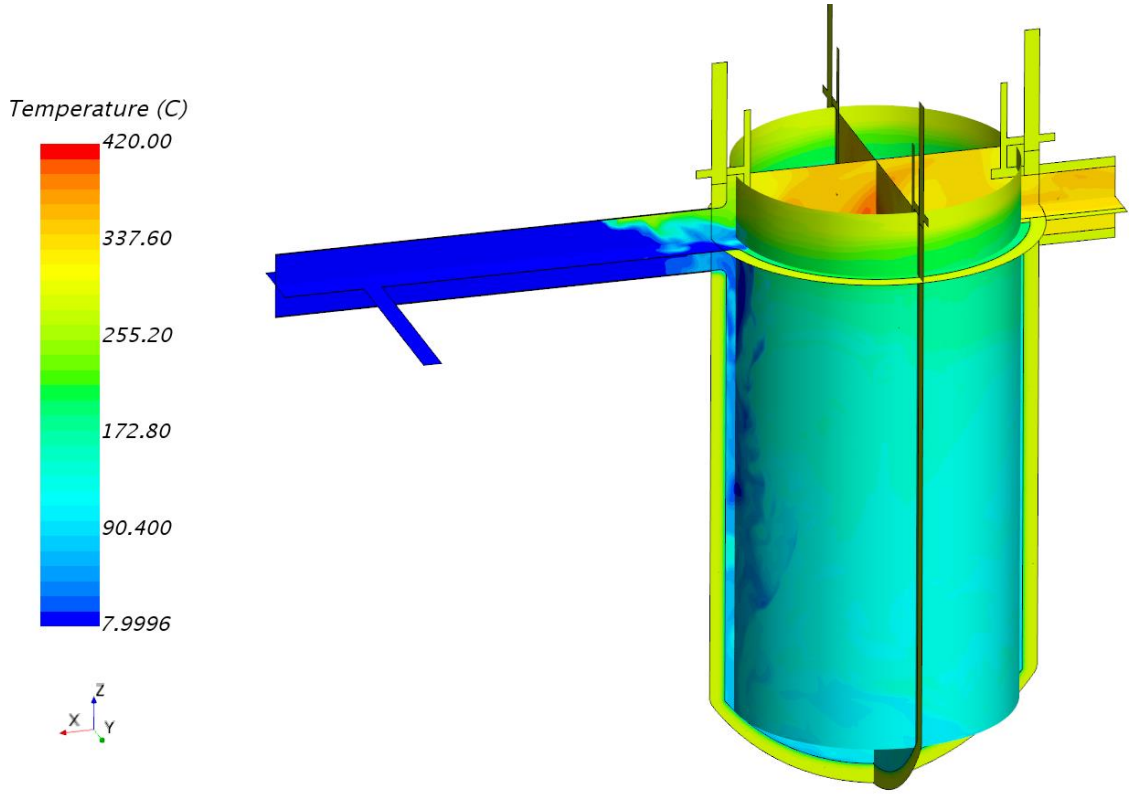




Energy research – Long term operation (LTO)

Pressurized thermal shock (PTS)

- Postulated accident scenario
- Sudden temperature change due to injection of cold (emergency) cooling water
- Improve structural integrity assessment of reactor pressure vessel
- Multiphysics: temperature load (CFD), structural integrity (FEM)
- Crack growth analysis



Energy research – Molten salt reactor

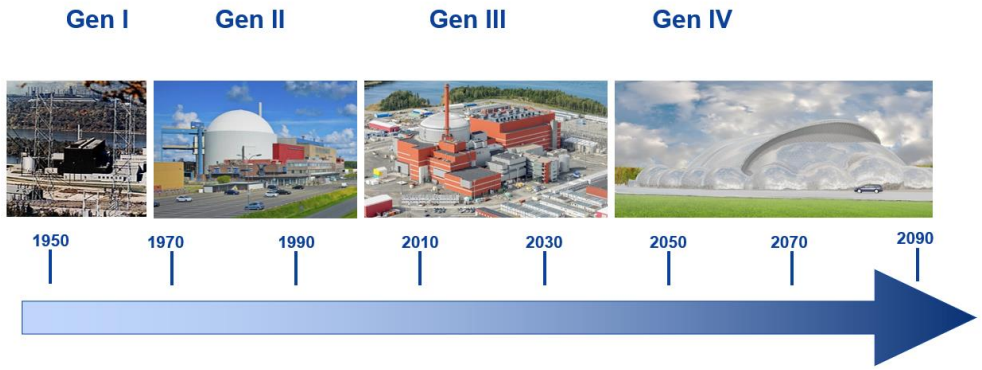
The molten salt reactor

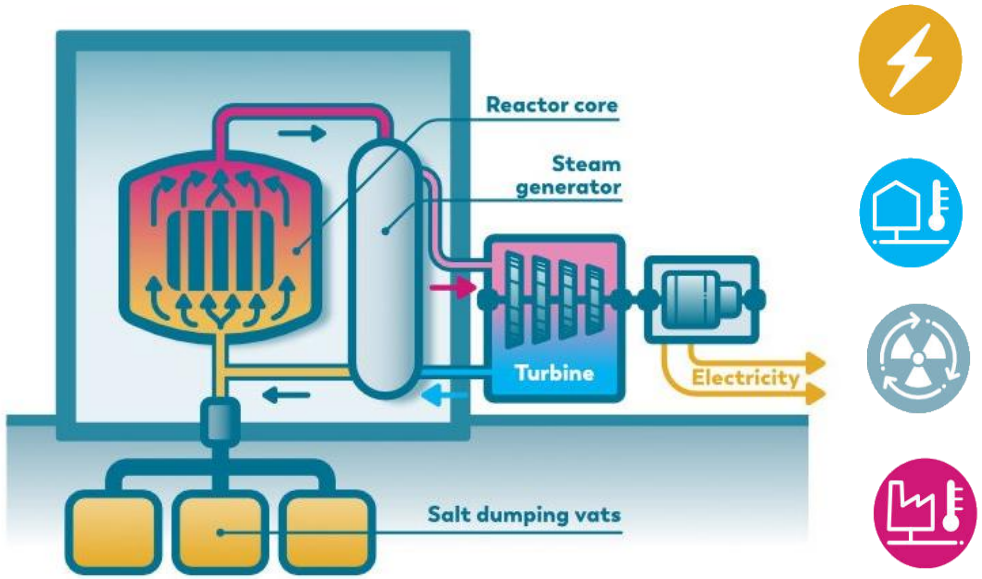
- Advanced reactor technology – Gen IV
- Prospects:
  - optimized utilization of resources
  - increased efficiency (higher T)
  - reduced amounts of radioactive waste
  - …. compared to current GenIII/water-cooled reactors
- Molten salt as cooling agent instead of water.
  - low pressure
  - fuel dissolved in molten salt – no damage built-up

Promising but challenging at the same time.

- manufacturing of fuel,
- high-temperature corrosion,
- processing, on-line cleaning of salt,
- …..

Key: experimental data!





Energy research – Molten salt reactor

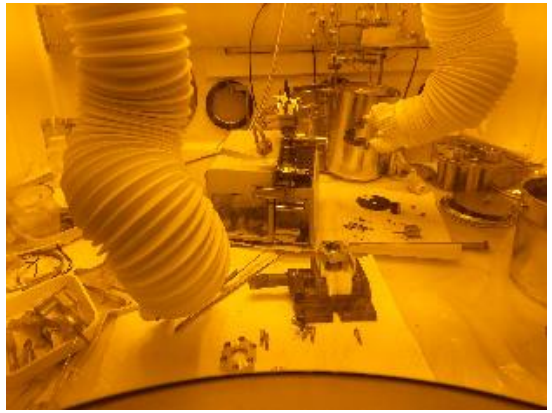
Building up experience with molten-salt fuel

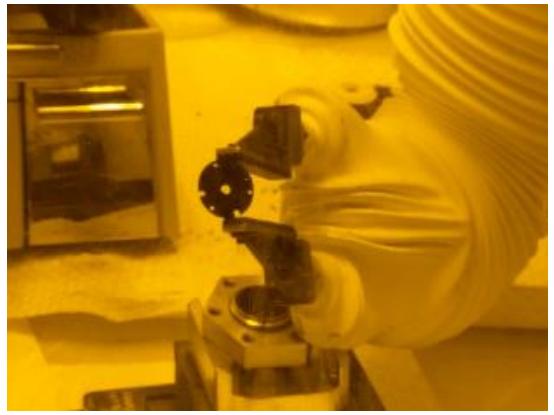
- Fabrication of fuelled salt mixtures
  - high purity
  - reducing conditions (no UO_2 formation)
- Irradiation of fuelled salt mixtures in controlled environment
  - how does the fuelled salt behave during irradiation

Energy research – Molten salt reactor

Building up experience with molten-salt fuel

- Fabrication of fuelled salt mixtures
  - high purity
  - reducing conditions (no UO_2 formation)
- Irradiation of fuelled salt mixtures in controlled environment
  - how does the fuelled salt behave during irradiation
- Post-irradiation examination
  - what is the composition of the fuelled salt after irradiation
  - composition of fission products
  - distribution of fission products
  - how to handle irradiated fuelled salt sample

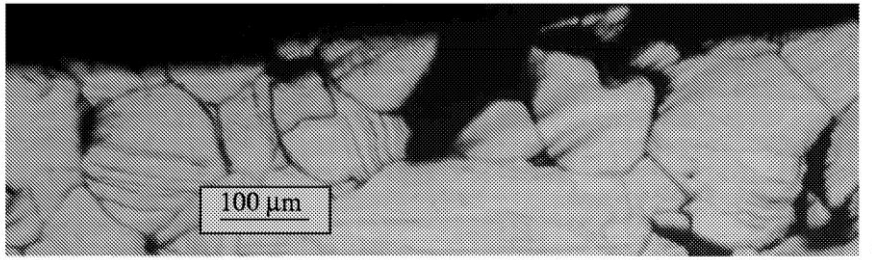


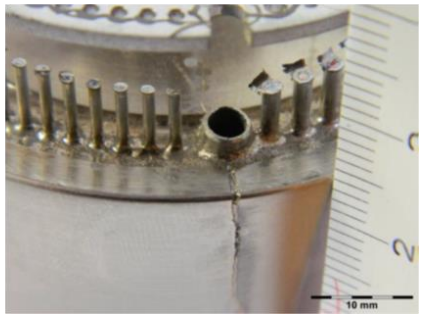


Energy research – Molten salt reactor

Corrosion

- Corrosion of metals due to dissolution of Cr and Fe in salt:
  - $Cr(s) + 2e^- \rightarrow Cr^{2-}$
  - $F_2 \rightarrow 2F^+ + 2e^-$
- In addition: fission product (Te) attack on grain boundaries
- Result: **loss of integrity** of the containment
- Question: what are suitable containment materials for future MSR reactors?
- Irradiation experiment under preparation:
  - various candidate-materials exposed to salt
  - on-line measurement of redox potential





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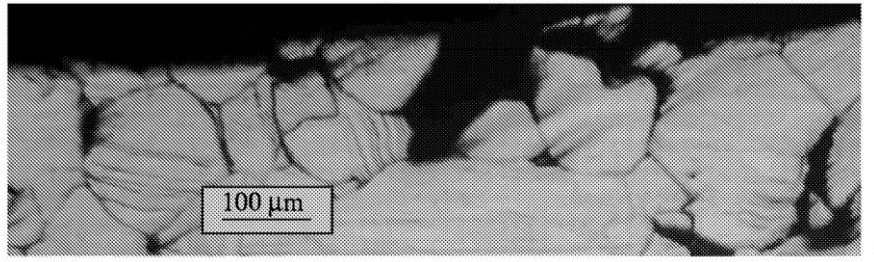
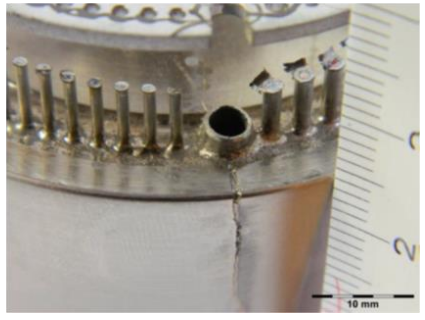
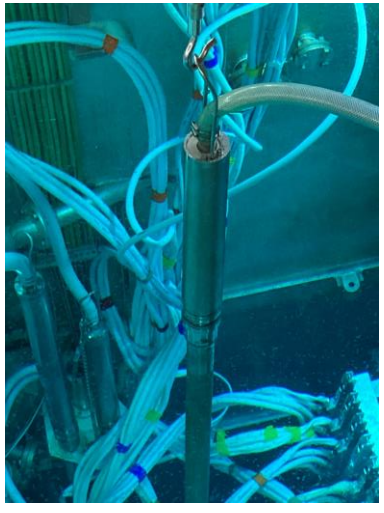
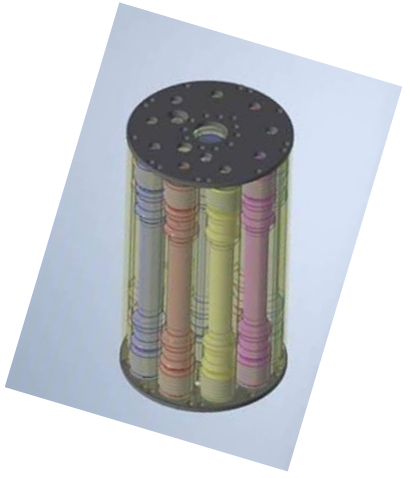
- Result: **loss of integrity** of the containment
- Question: what are suitable containment materials for future MSR reactors?
- Irradiation experiment under preparation:
  - various candidate-materials exposed to salt
  - Nickel-based alloys (hastelloy) are promising

- However: irradiation of nickel → formation of helium gass → embrittlement!
- Another experiment….what's the impact of He-release on the mechanical properties of Hastelloy





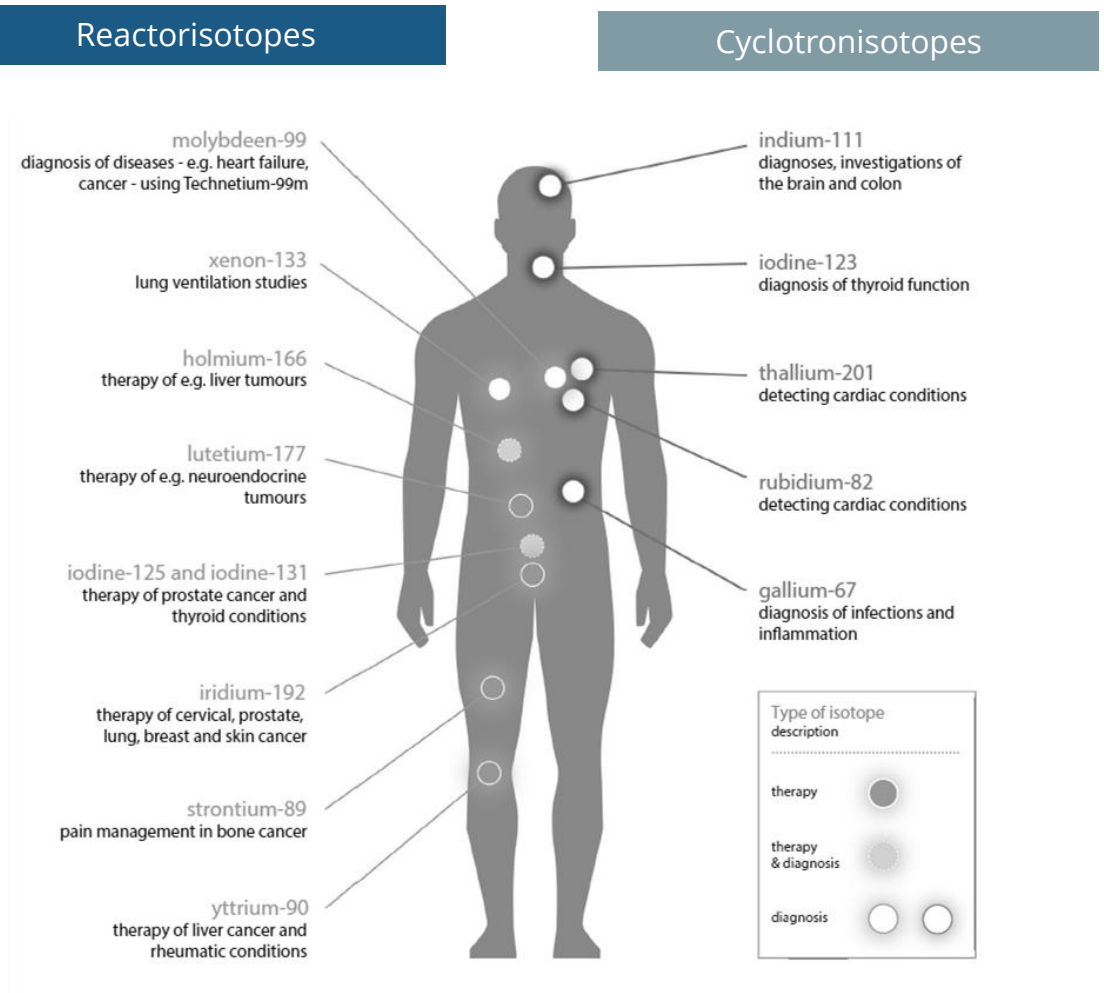




Nuclear medicine – medical radioisotopes

Application of medical isotopes:

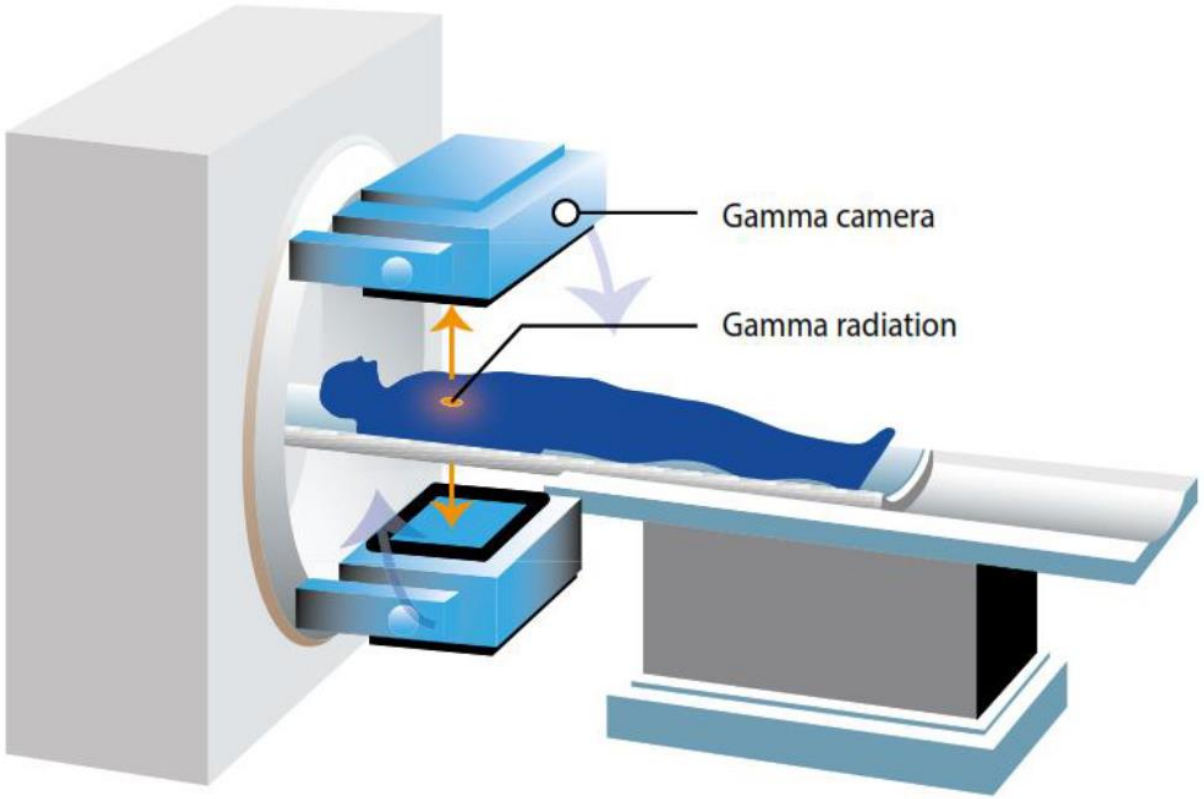
1. Diagnostics:
   - To determine whether organs are functioning properly
   - To detect cancerous growths, infections, brain diseases, or heart and lung diseases
2. Therapeutics
   - The radiation from medical isotopes is used to destroy cancer cells.
   - Transport of isotopes linked to ‘tracers’ to the right spot in the body to prevent damage to healthy tissue and organs.

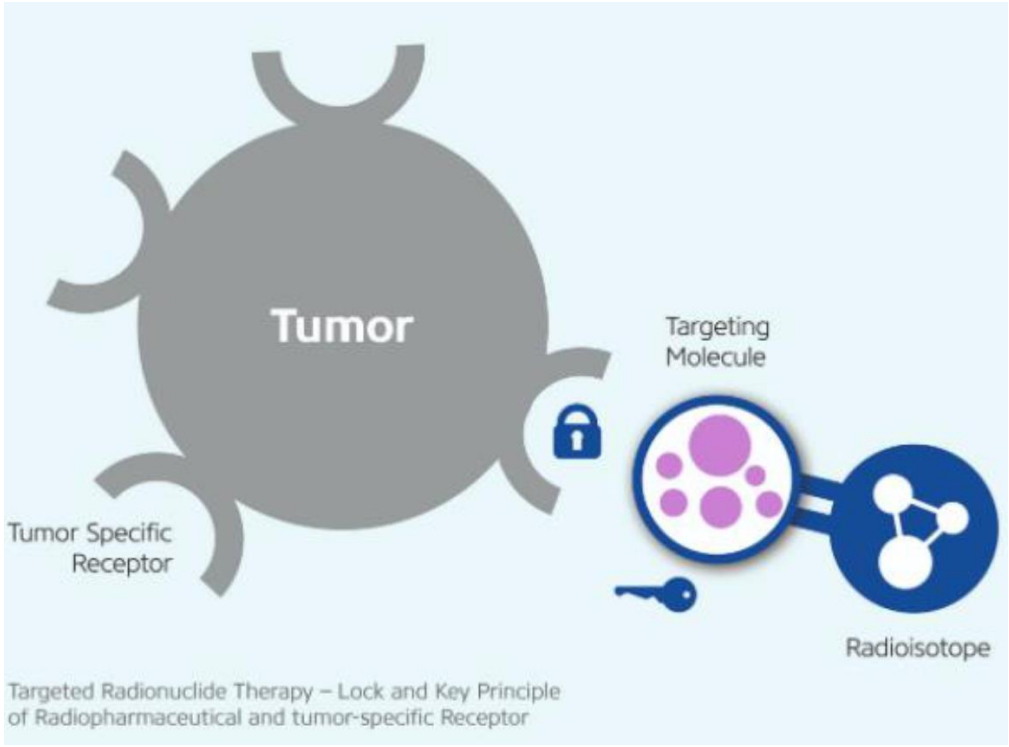


Bron | Slide Prof. Andor Glaudemans, voorzitter NVNG

Nuclear …

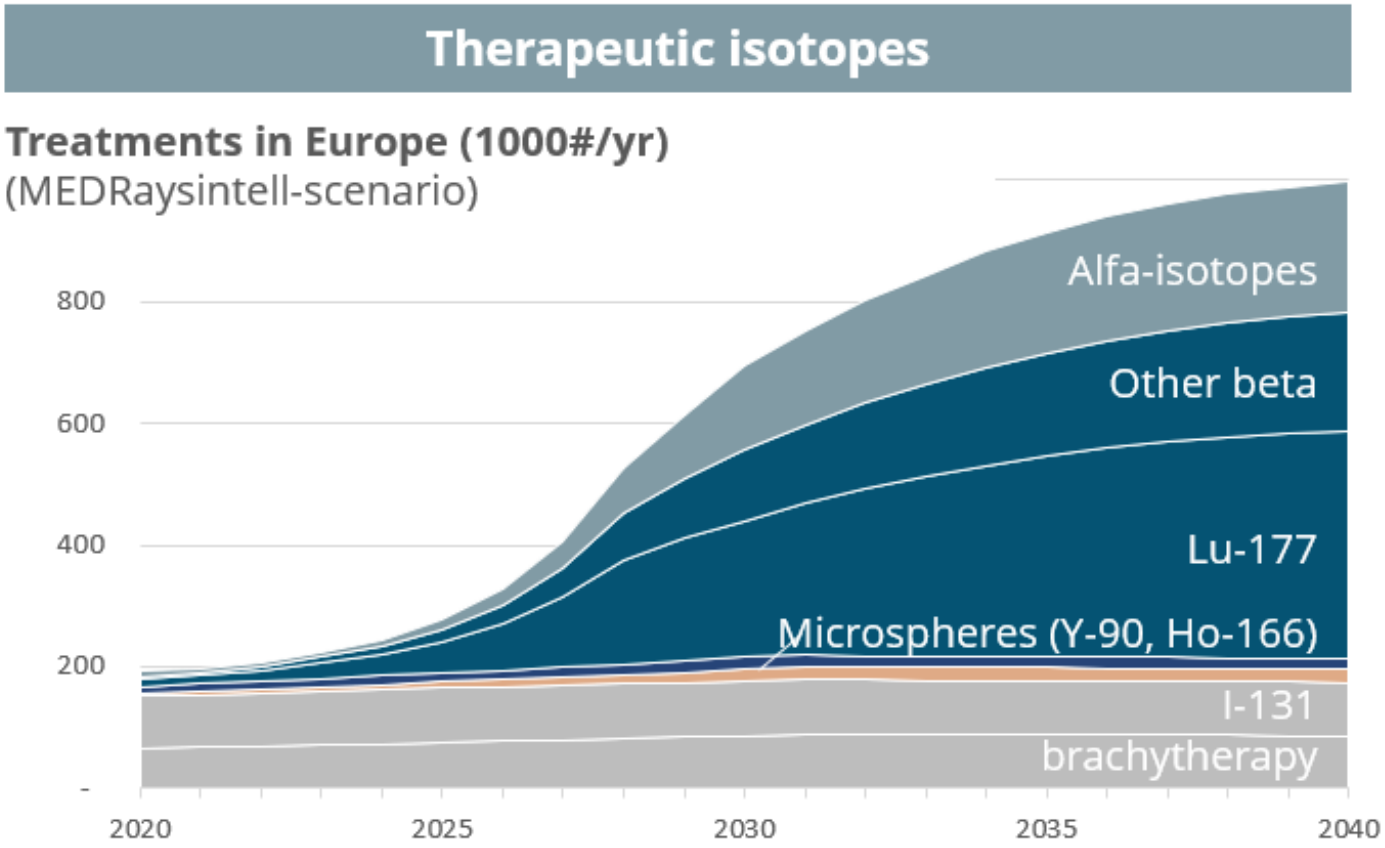
Single Photon Emission Computed Tomography (SPECT)





Targeted Radionuclide Therapy – Lock and Key Principle of Radiopharmaceutical and tumor-specific Receptor

Nuclear medicine – forecast



Production and innovation

PRODUCTION & INNOVATION IN PETTEN (NL), TOGETHER WITH PARTNERS

Security of supply of medical isotopes

Target producer → Source material → Cyclotron

or

IRRADIATION ↔ PROCESSING

Reactor → Isotopes → Processing plant

Partners

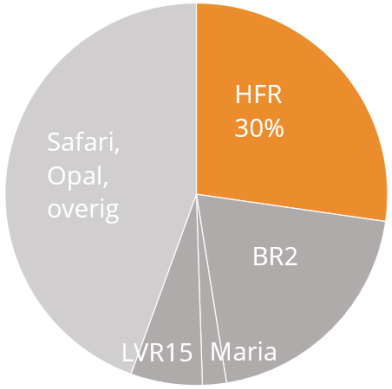
INNOVATION

Securing treatment for hospitals, doctors and patients

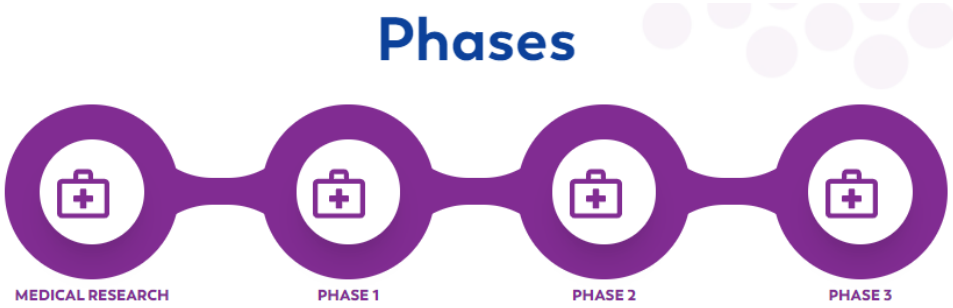
Processing plant → Active ingredients → Pharma → Medicine → Hospital → Patient doses → Patient

Global availability of affordable radionuclides

Innovation by providing accelerated development of new therapies in collaboration with partners



Innovation and resarch



Goal: Acceleration of the development of new nuclear medicine in phase I and phase II

- Innovation programme with academic hospitals and industry
- Medical isotope developments and infrastructure

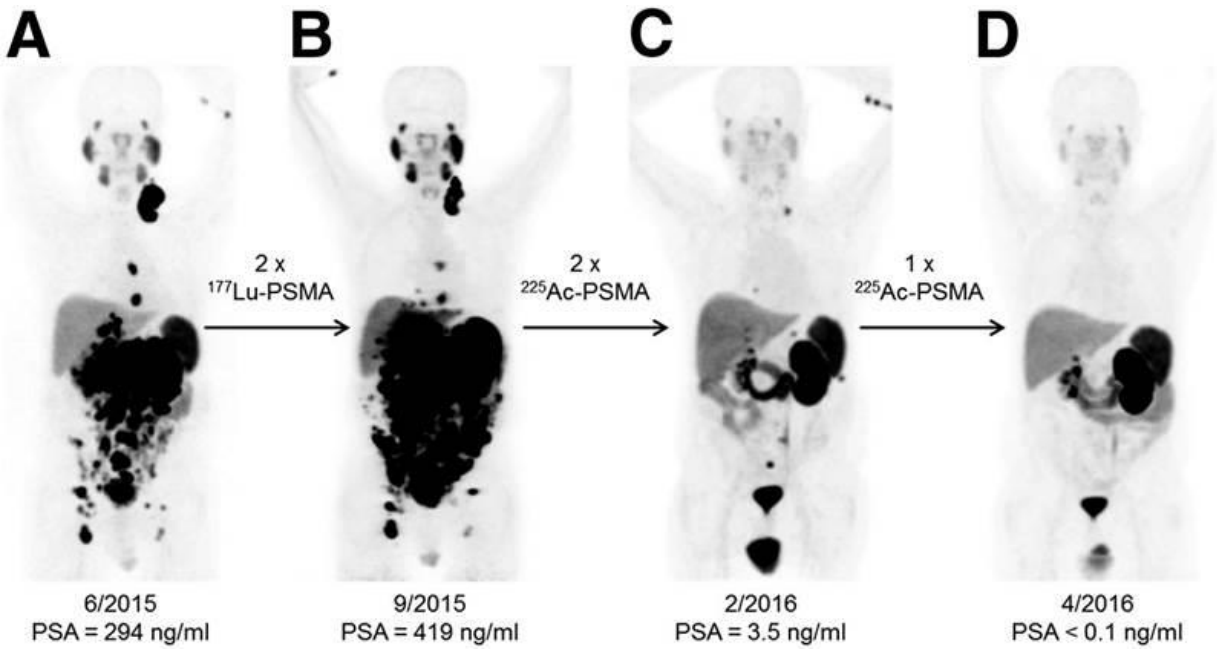
FIELD-LAB

Advancing Nuclear Medicine

Financially supported by

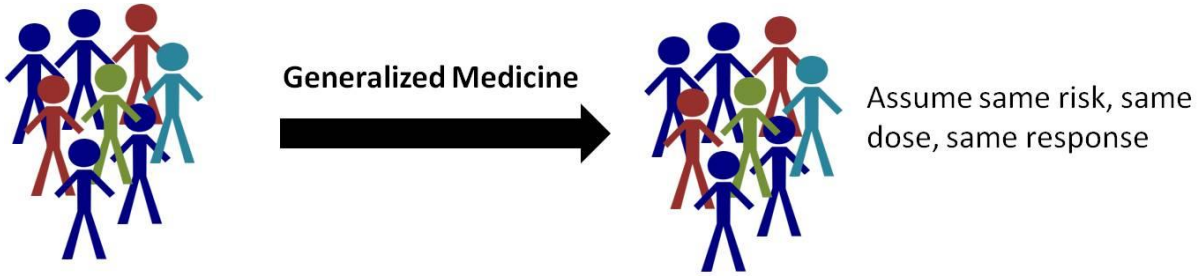
European Union
European Regional
Development Fund

A new therapy for prostate cancer with Lead-212



- Therapy with 177-Lutetium is not effective for all patients
- 225-Actinium seems promising but decay of 4 alpha particles might cause radiotoxicity
- 212-Lead is being developed with partners to minimize toxicity with only decay of 1 alpha particle

The case of Cisplatin with platinum-195m: a new tracer



- Chemotherapy
- Cisplatin is widely used for a large group of patients
- Less then 10% of lung cancer patients benefit
- Severe kidney toxicity may occur

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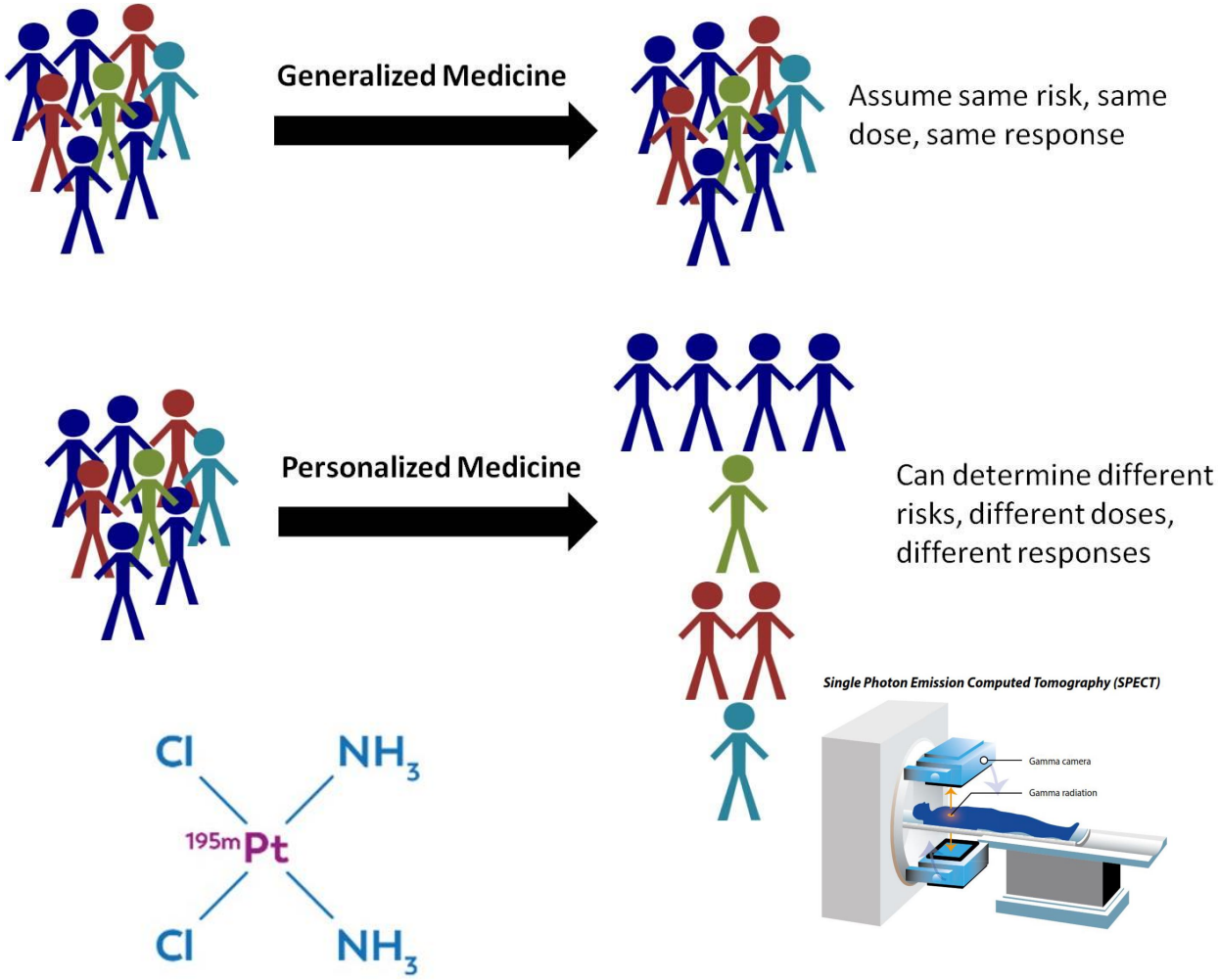
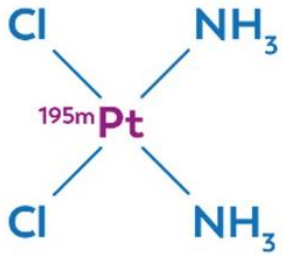
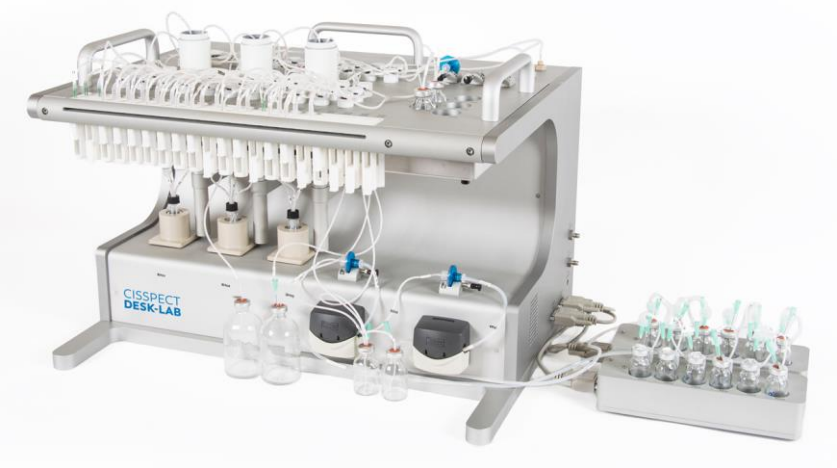


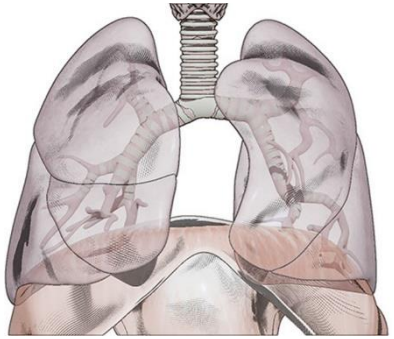
- Chemotherapy
- Cisplatin is widely used for a large group of patients
- Less then 10% of lung cancer patients benefit
- Severe kidney toxicity may occur

- Objective: increase of effectiveness, success rate
- Needed: information about the location of Cisplatin in body (place of deposition)
- Solution: small dose of Cisplatin, with the platinum replaced by radioactive platinum-195m
- Pt-195m → Pt-195 + γ
- Needed: Pt-195m, produced by irradiation of Pt-195

Radioactive Cisplatin: for imaging of Cisplatin



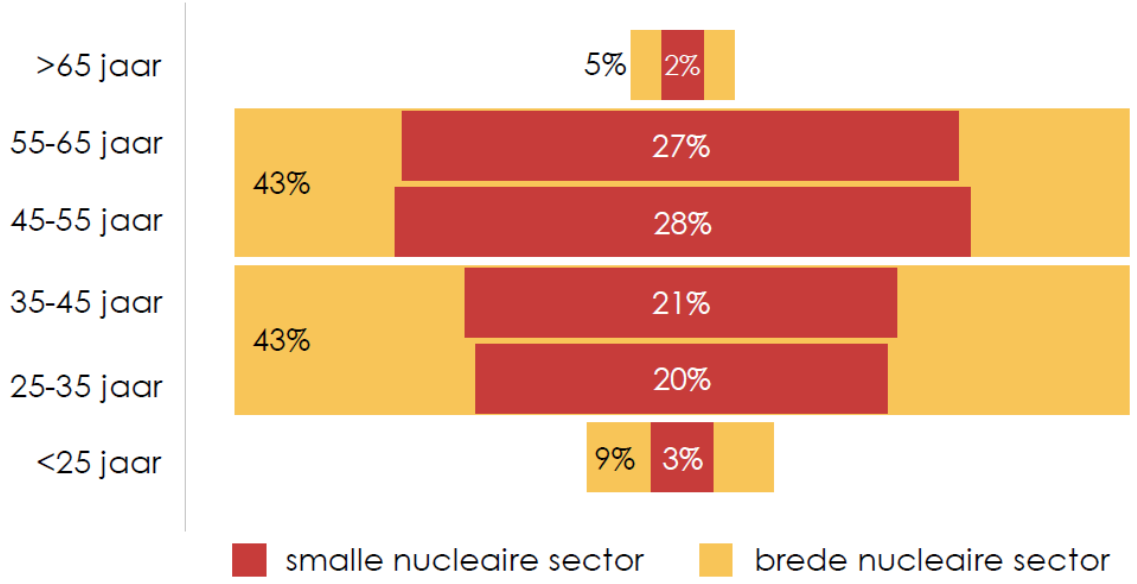




- NRG started development with NKI-AvL. Mice studies showed perspective → the deposition of radioactive Cisplatin can be located using gamma irradiation
- VUmc set-up the GMP production for human use.
- Good imaging quality in 4 patients and no toxic side effects.
- Phase II study is foreseen with partners for which product stability has to be improved and production needs to be optimized to assure delivery for clinical use.

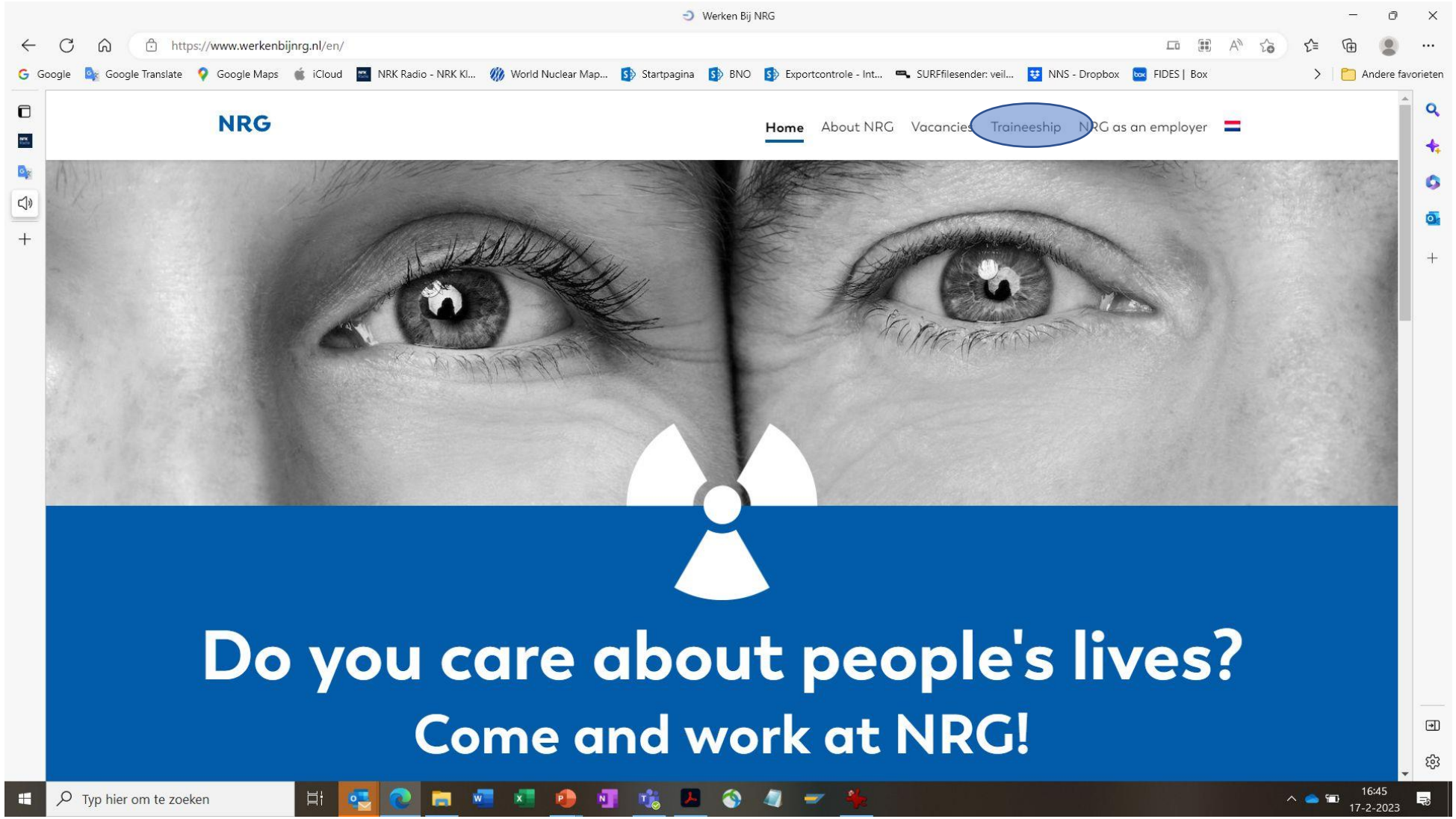
Prospects for students and young professionals

- The nuclear landscape of the Netherlands is on the move:
  - newbuilt of two power plans,
  - prolonged operation of Borssele power plant
  - construction of the PALLAS reactor
  - growth of nuclear medicine
- Needed: young people to secure realization of all plans and ambitions.
- Possibilities at NRG:
  - Internships,
  - BSc, MSc thesis
  - Young professionals: NRG trainee programme



- Doubling of the work force foreseen
- Taking into account that 30% of the current work force will be retired by 2035

Interested?



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HEALTH