Lithuania‘s Involvement in European Nuclear Energy Research

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Perspectives of nuclear energy development
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Vilnius Gediminas Technical University, Lithuania

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LITHUANIAN ENERGY INSTITUTE

Creation of nuclear infrastructure in Lithuania

- State Nuclear Power Safety Inspectorate (VATESI) was established by Government resolution in October 1991. Since 1991 till the closure VATESI has regulated Ignalina NPP operation by issuing annual operating permits.

- Ignalina Safety Analysis Group (ISAG) was established in March 1992 at the Lithuanian Energy Institute in Kaunas. Later this group overgrows into Laboratory of Nuclear Installation Safety.

- The other organizations also took income into creation of TSOs:
  - Kaunas University of Technology (KTU),
  - Vytautas Magnus University (VMU),
  - Faculty of Physics of Vilnius University (VU),
  - Center for Physical Sciences and Technology (CPST).

- In 2000 the Coordination Council of Technical Support Organisations of VATESI was established. The Council:
  - coordinates the TSO expertise assistance to VATESI,
  - promotes the development of nuclear energy research-industrial infrastructure,
  - upbringing of scientific technical potential in the country,
  - coordinates the training of nuclear energy specialists.

Nuclear energy research in Lithuanian Energy Institute

LABORATORY OF NUCLEAR INSTALLATION SAFETY

NUCLEAR ENGINEERING LABORATORY

LITHUANIAN ENERGY INSTITUTE

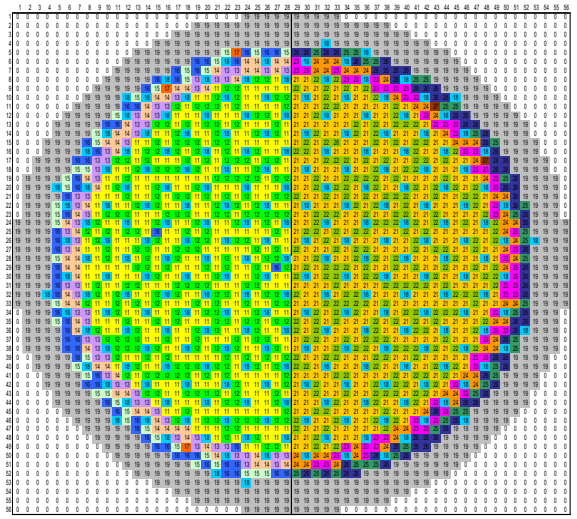
Nuclear energy research directions in LEI

- **Nuclear energy technologies research**
  - Safety and reliability assessment of operating NPPs
  - Advanced small modular reactors (SMR) technologies, safety and reliability
  - Nuclear installations decommissioning technologies safety and reliability
- **Nuclear fusion technologies and accelerators (CERN, etc.) research:**
  - Elementary particle transport processes and material activation
  - Nuclear fusion installation safety and reliability

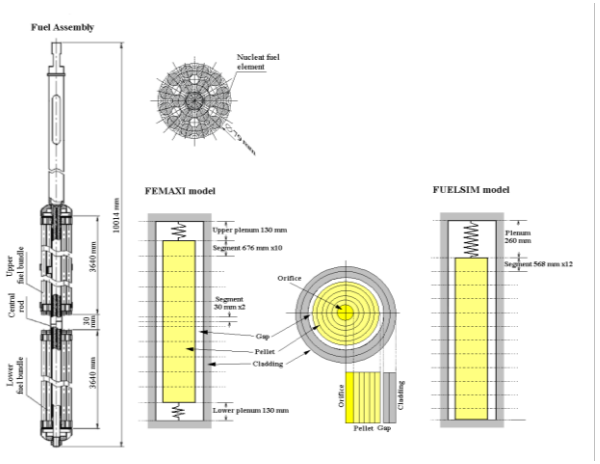
Ignalina NPP safety-related activities (1)

Analyses for Ignalina NPP licensing

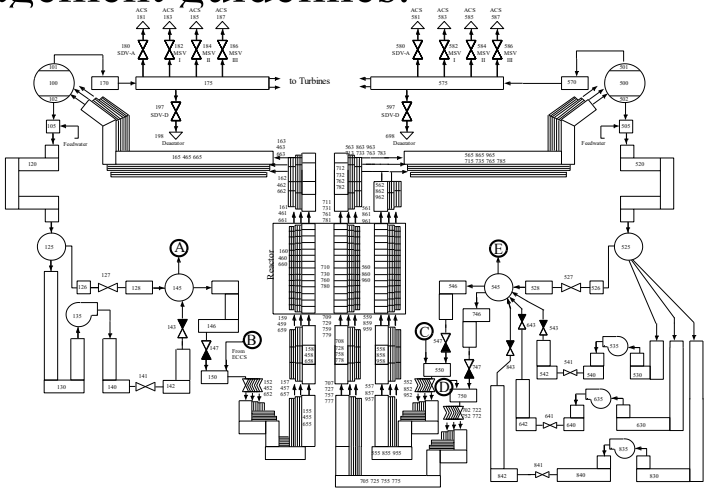
- Analysis of **neutron dynamic processes** in the reactor core using QUABOX/CUBBOX code.
- Assessment of reactor core modifications and analysis of postulated reactivity accidents.



- Analysis of **processes in fuel assembly** using FUELSIM code



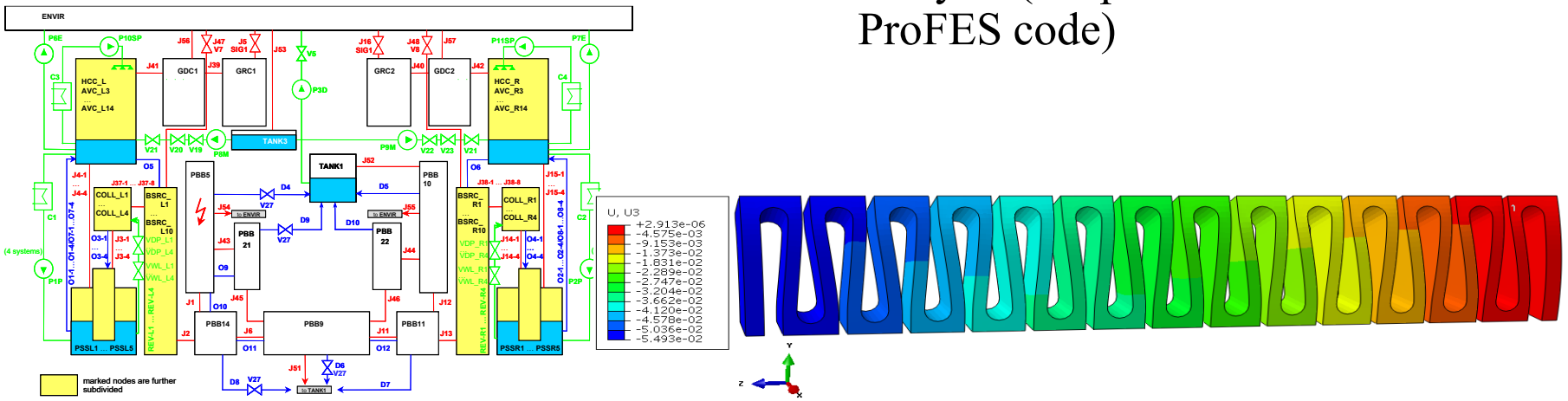
- Thermal-hydraulic analysis of **reactor cooling circuit** during accidents and operational transients using ATHLET (Germany) and RELAP5 (USA) codes.
- Modeling of severe accidents using RELAP5/SCDAPSIM, ASTEC, ATHLET-CD codes.
- Development of Severe accidents management guidelines.



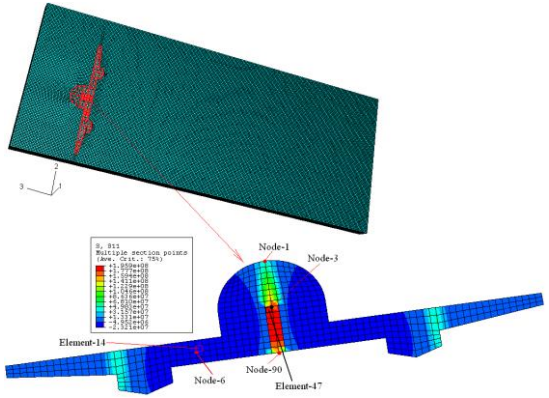
Ignalina NPP safety-related activities (2)

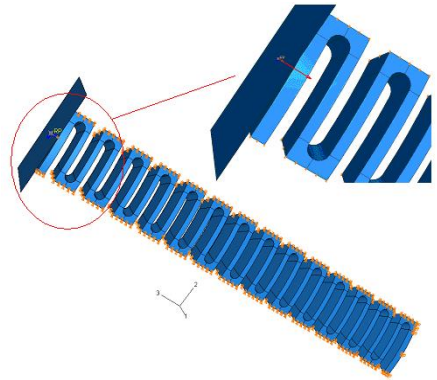
Analyses for Ignalina NPP licensing

- Simulation of T/H processes as well as radio nuclides and H_2 transport and distribution in Ignalina NPP **compartments** using COCOSYS (Germany) and ASTEC (France, Germany) codes.



- Linear and Non-linear analysis of **structural integrity of buildings and components** (FE code NEPTUNE and ABAQUS)
- Analysis of Aircraft Crash (Global and Local Levels)
- Contact Analysis Using FEM
- Probabilistic structural integrity analysis (coupled NEPTUNE – ProFES code)





Ignalina NPP safety-related activities (3)

Project “Reuse of Unit 1 Fuel in Unit 2 Reactor of Ignalina NPP”

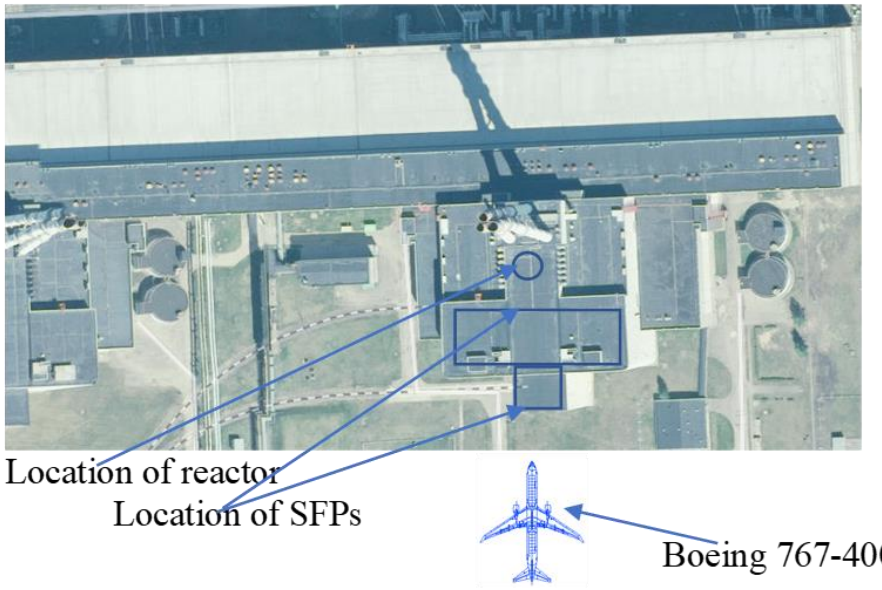
- “Turn key” project under the coordination of the LEI.
- Project includes:
  - Development of technology,
  - Safety justification report,
  - Design development of fuel transportation container, transport vehicle, protection shaft, buildings reconstruction, existing systems modifications
- Approximately 1000 irradiated fuel assemblies from Unit 1 were safely transported and reused in the reactor of Unit 2 before the final shutdown of the Unit 2 reactor in 2009.
- This allowed NPP to spare about 600 fresh fuel assemblies.

Ignalina NPP safety-related activities (4)

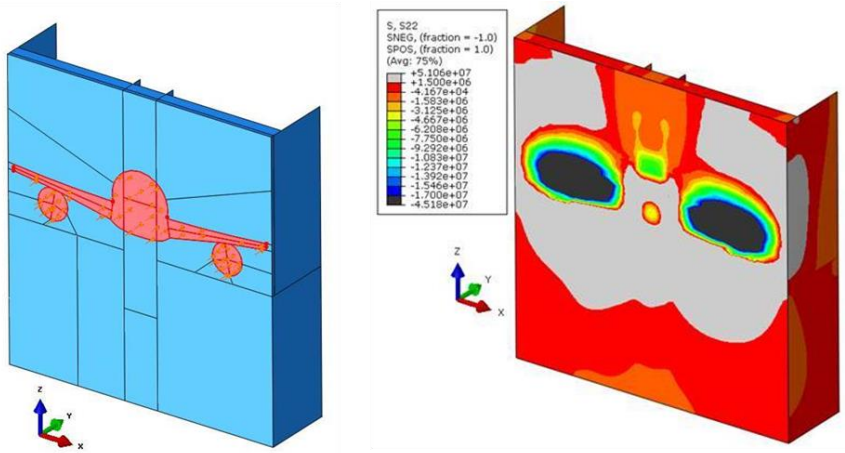
Analysis of the consequences of possible nuclear and radiological accidents at the Ignalina NPP facility

1. Identification of hazardous objects at RBMK reactor site during plant decommissioning:
   - storage pools with SNF assemblies;
   - reactor core graphite stack;
   - bitumen compound stored in facilities for treated combustible waste;
   - storage facilities for raw combustible waste.

2. Postulated events:
   - Extreme earthquake
   - Airplane crash



Project „Analysis of the consequences of possible nuclear and radiological accidents at the Ignalina NPP facility“ performed in 2019

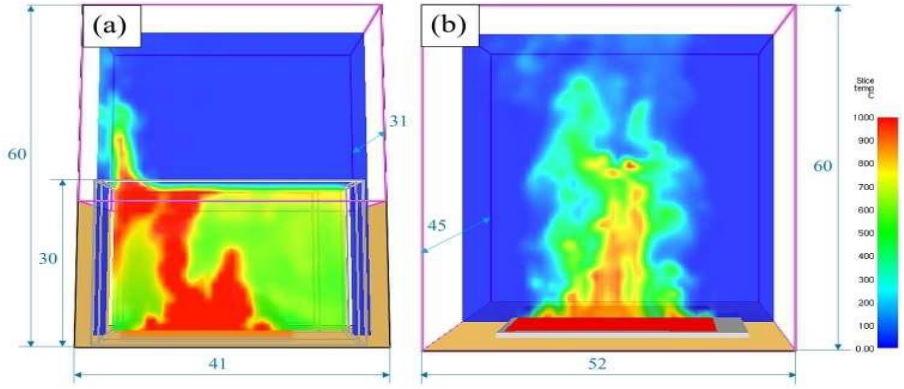


The performed structural analysis of Boeing 767-400 crash on the SFP of RBMK-1500 showed that airplane may affect the integrity of one or two pools. Falling parts of airplane and construction debris may destroy SNF storage scheme which keeps nuclear fuel under sub-critical conditions.

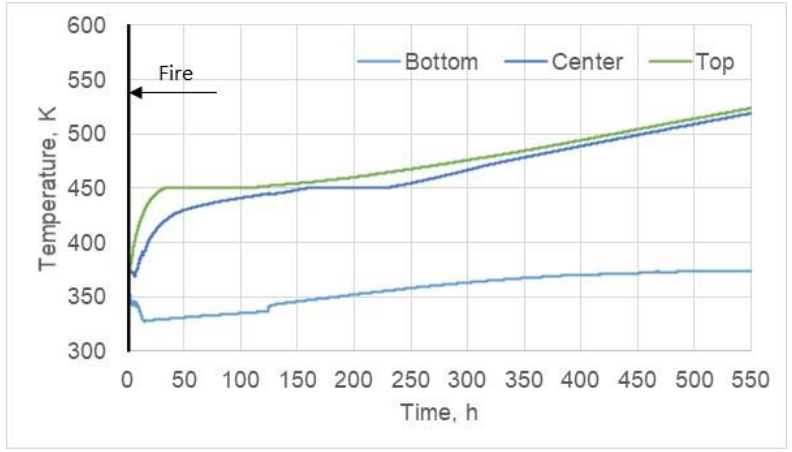
Ignalina NPP safety-related activities (5)

Analysis of the consequences of possible nuclear and radiological accidents at the Ignalina NPP facility

Assessment of Jet Fuel Fire Impact



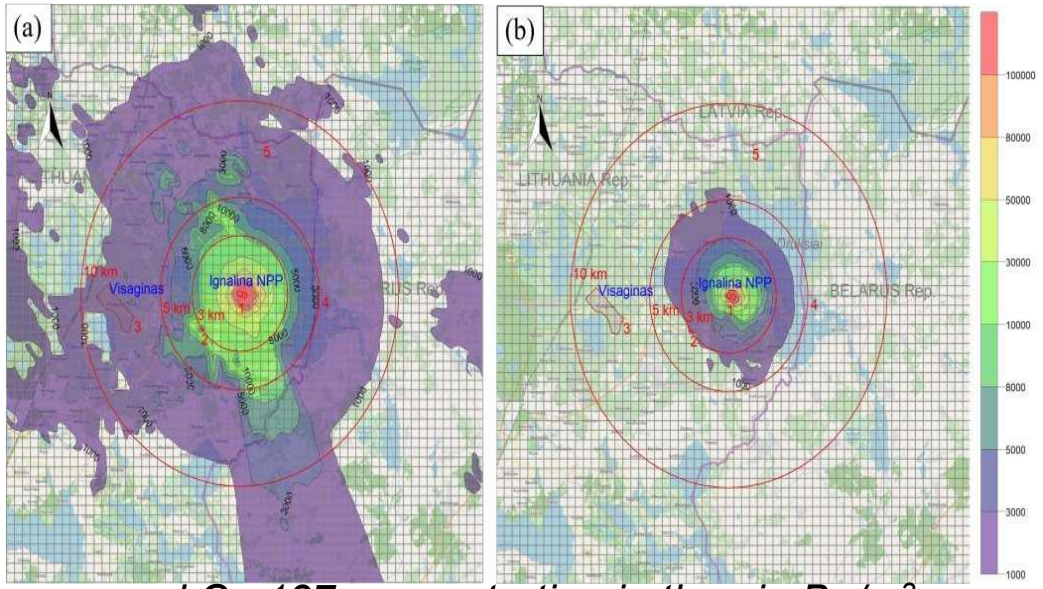
Jet fuel fire temperature field above the SNF storage pools: (a) the case with partially damaged roof structure (b) the case with damaged building walls and roof



Behavior of SNF cladding temp. in damaged pool

SNF rods will not overheat to the temperature causing fuel damage and secondary release of activity will not occur

Assessment of Radionuclide Release, Dispersion and Public Dose



Hourly averaged Cs-137 concentration in the air, Bq/m³:
(a) 99.7th percentile values and
(b) 95.5th percentile values in the region of 30×30 km

Assessment of the public doses showed, that all accident conditions will not cause determined health effects. It is expected, that the annual effective dose for population at the distance of 5 km from the plant will be 0.4 mSv or less.

Ignalina NPP safety-related activities (6)

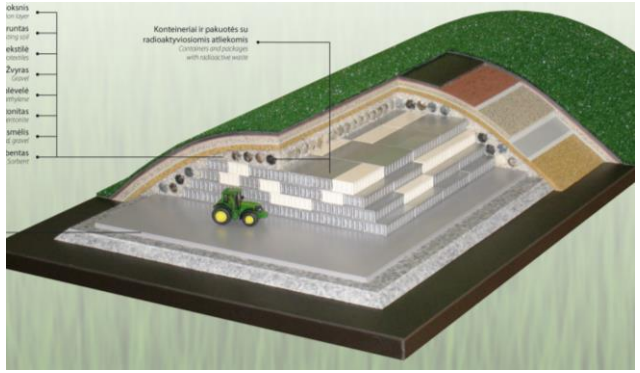
Safety of spent nuclear fuel (SNF) management

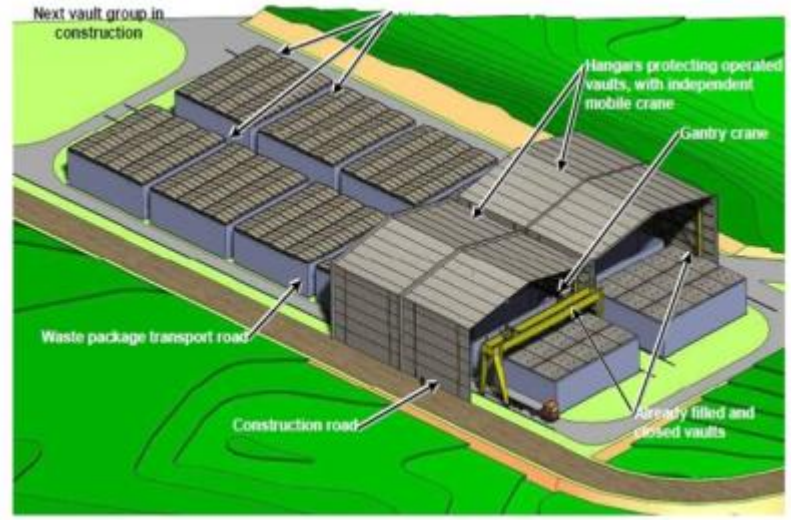
- Modelling of SNF characteristics;
- Criticality modelling;
- Dose rates modelling and dose assessment;
- Radionuclide migration modelling;
- Environmental impact assessment of storage and geological (DGR) disposal facilities;
- Safety assessment of storage and disposal facilities.

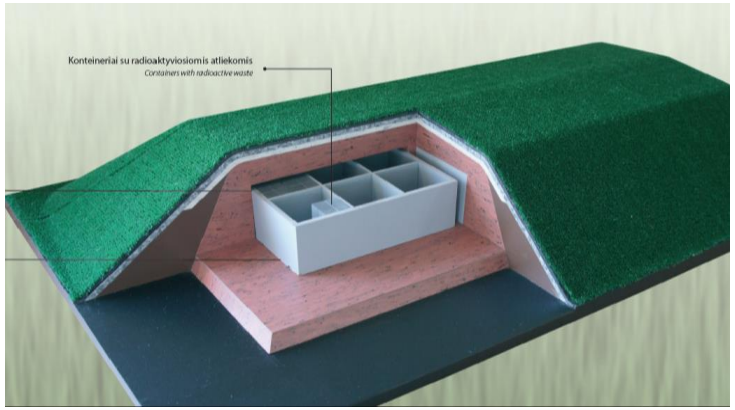
Ignalina NPP safety-related activities (7)

Safety of radioactive waste (RW) management

- Modelling of RW characteristics;
- Radionuclide migration modelling;
- Doses to workers and public;
- Environmental impact assessment of treatment, storage, and disposal (Landfill, NSR, DGR) facilities;
- Safety assessment of treatment, storage and disposal facilities.



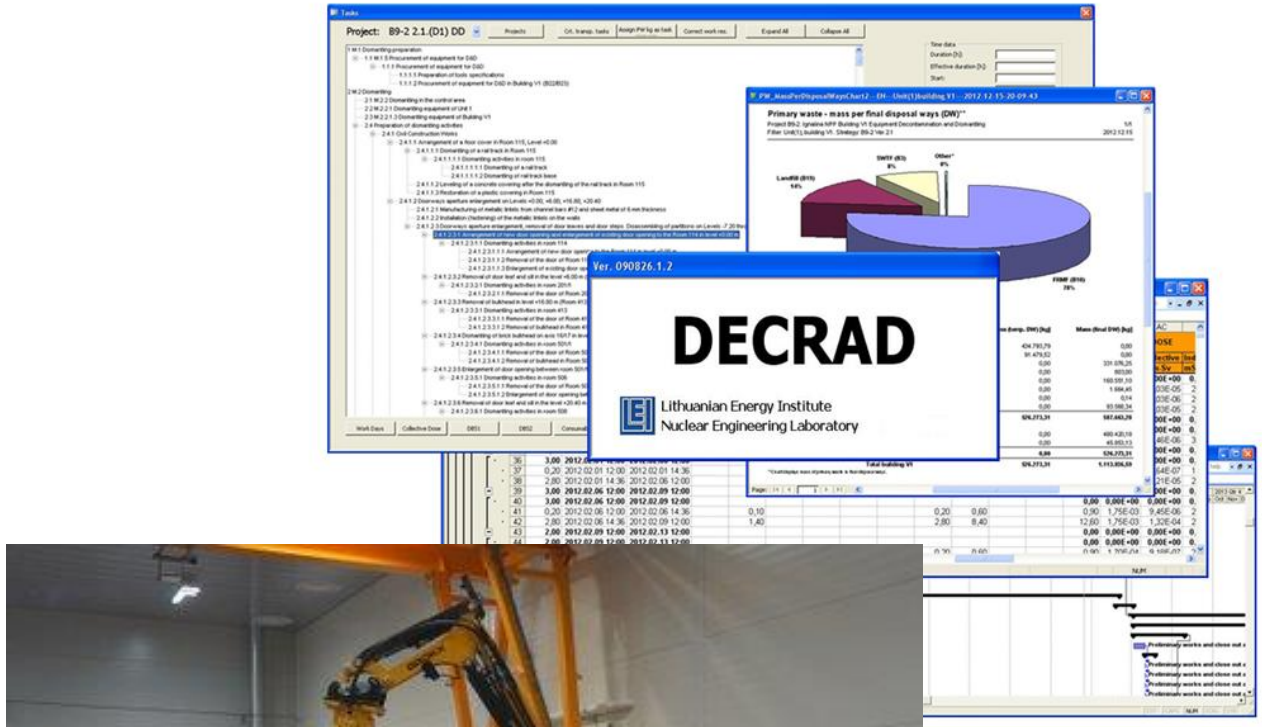




Ignalina NPP safety-related activities (8)

Evaluation of different factors related to decommissioning of nuclear facilities

- Selection of the decommissioning strategy;
- Planning and cost estimation of decommissioning and dismantling activities (LEI code DECRAD);
- Modelling of the radiological contamination of the systems and components;
- Reactor components activation modelling;
- Safety and environmental impact assessment during decommissioning and dismantling.



LEI in the EU research programmes

SNETP
Sustainable Nuclear Energy Technology Platform

NUGENIA
NUclear GENeration II & III Association

igd·tp
safe solutions for radioactive waste

FuseNet
The European Fusion Education Network

ETSON
EUROPEAN TECHNICAL SAFETY ORGANISATIONS NETWORK

IAEA Technical and Scientific Support Organization Forum

European Industrial Alliance on SMRs

EUROSAFE
Towards Convergence of Technical Nuclear Safety Practices in Europe

enstti
TRAINING & TUTORING NUCLEAR SAFETY

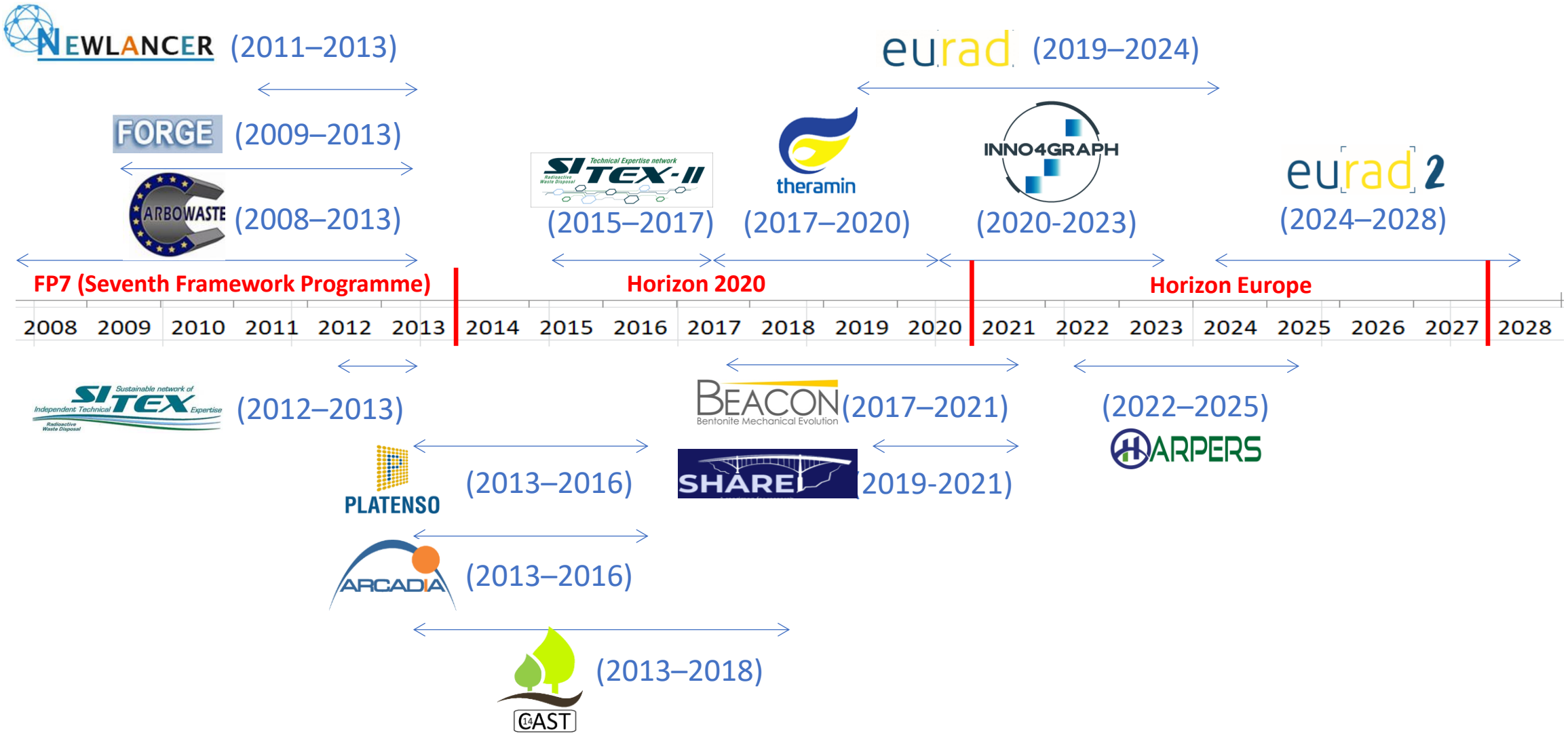
Junior Staff Programme ETSON

Main networks, where LEI is participating

Ongoing nuclear research projects of EU “Horizon Europe” EURATOM programme

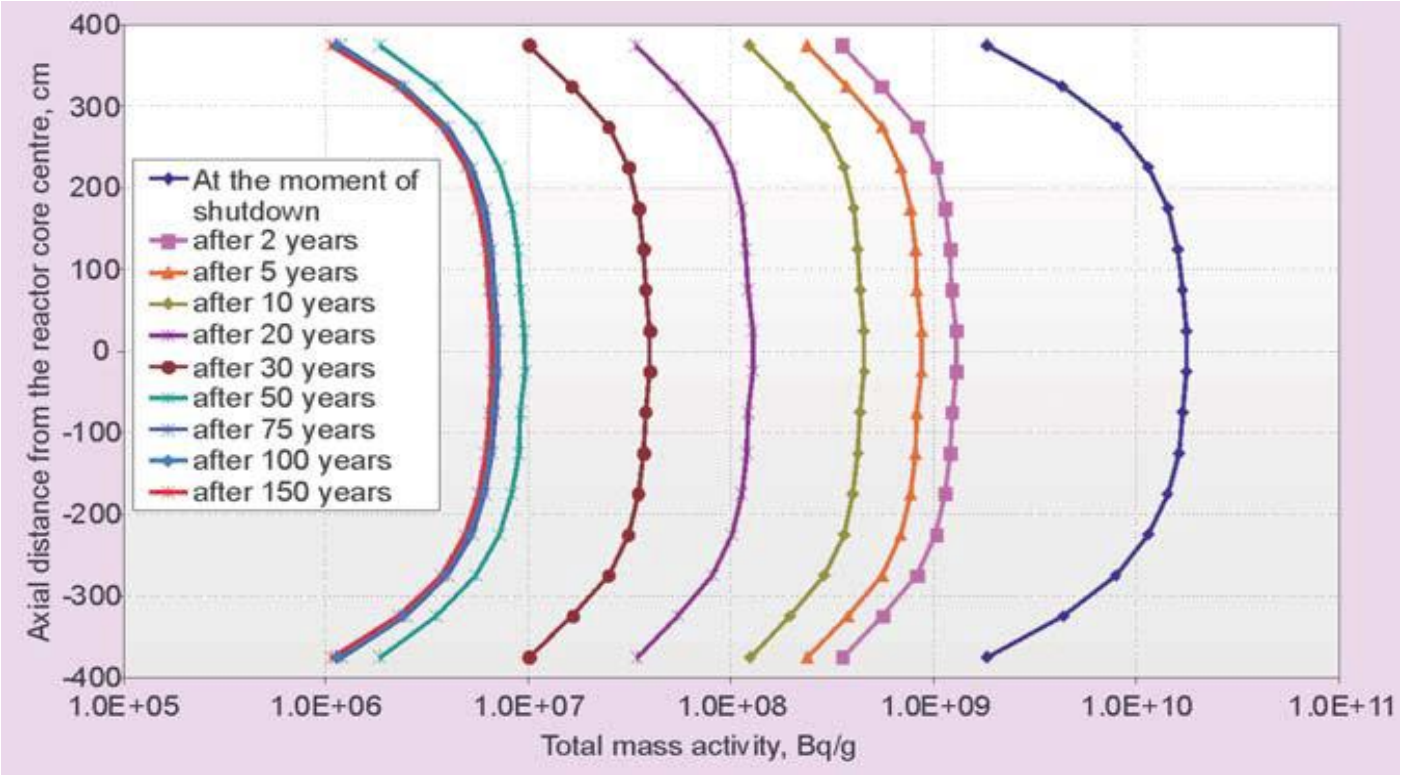
- **HARMONISE** - Towards harmonisation in licensing of future nuclear power technologies in Europe:
  - Project under coordination by the LEI
  - HARMONISE address issues related to the preliminary safety assessments and licensing needs of innovative fission and fusion installations
- **EASI-SMR - Ensuring Assessment of Safety Innovations for SMR**
  - LEI leads task dedicated to the approach to licensing of LW SMR, also participates in input-deck development and code benchmark exercises
  - LEI works together with AC2 code developer (Germany) GRS and provides code validation against two experimental facilities (IVR Ex Vessel cooling, condensation in SACO tube, COSAC).
- **SASPAM-SA -** Safety Analysis of SMR with PAssive Mitigation strategies – Severe Accident:
  - LEI contributes to the iPWR severe accident modeling and IVMR strategy application
- **OPERA HPC** - OPEn HPC theRmomechanical tools for the development of eAtf fuels
  - LEI contributes to the modeling of the BWR and VVER fuel rods during normal operation and transient situation
- **EUROfusion** - Implementation of Activities Described in the Roadmap to Fusion during Horizon Europe through a Joint Programme of the Members of the Eurofusion Consortium under Horizon Europe

Ongoing nuclear research projects of EU EURATOM programme, related to radioactive waste management



PhD thesis in nuclear safety area defended in LEI (1)

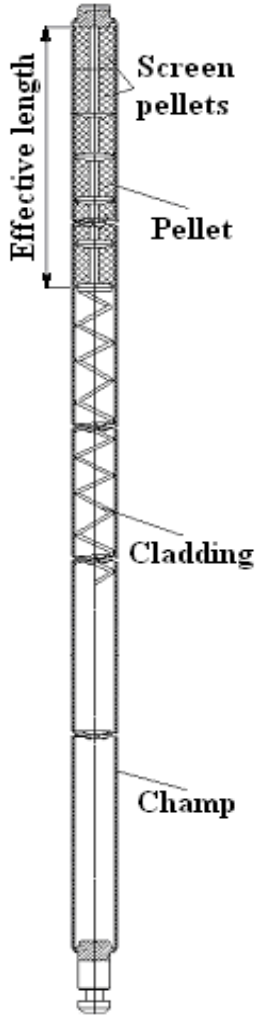
- Ernestas Narkūnas **"Investigations of the Change of Nuclides' Content in the RBMK-1500 Reactor Structural Components"** (2009)

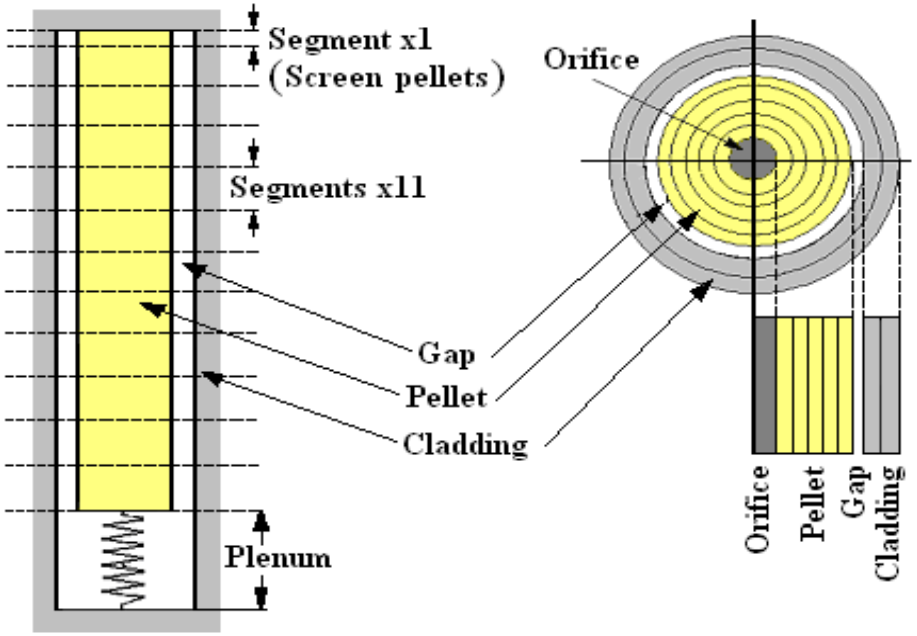


The calculated mass activity distribution in axial direction of RBMK-1500 fuel channel and its variation in 150 years after the final reactor shutdown

PhD thesis in nuclear safety area defended in LEI (2)

- Aušra Marao **"Simulation of Processes in Fuel Rods of RBMK Type Reactors"** (2010)



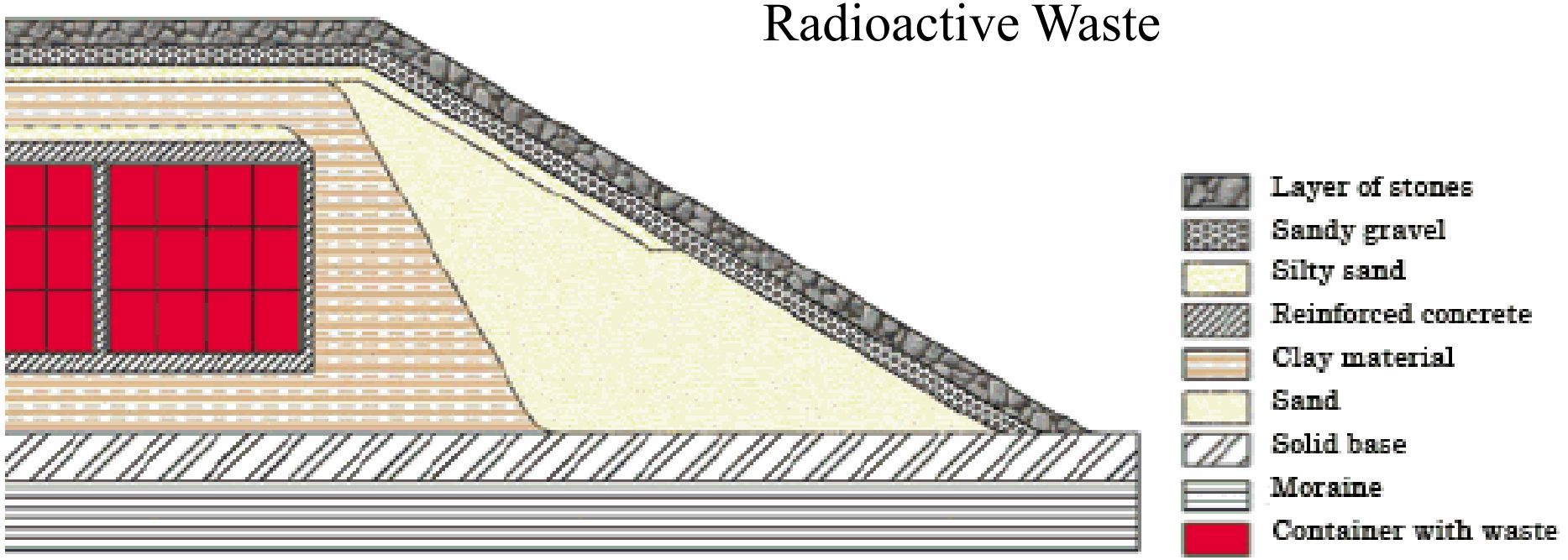


Model of RBMK-1500 fuel rod (bottom bundle), developed using FEMAXI-6 code

PhD thesis in nuclear safety area defended in LEI (3)

- Raimondas Kilda **"Analysis of Radionuclide Migration from Near-Surface Repositories for Radioactive Waste"** (2010)

Near Surface Repository for Low and Intermediate Level Short Lived Radioactive Waste

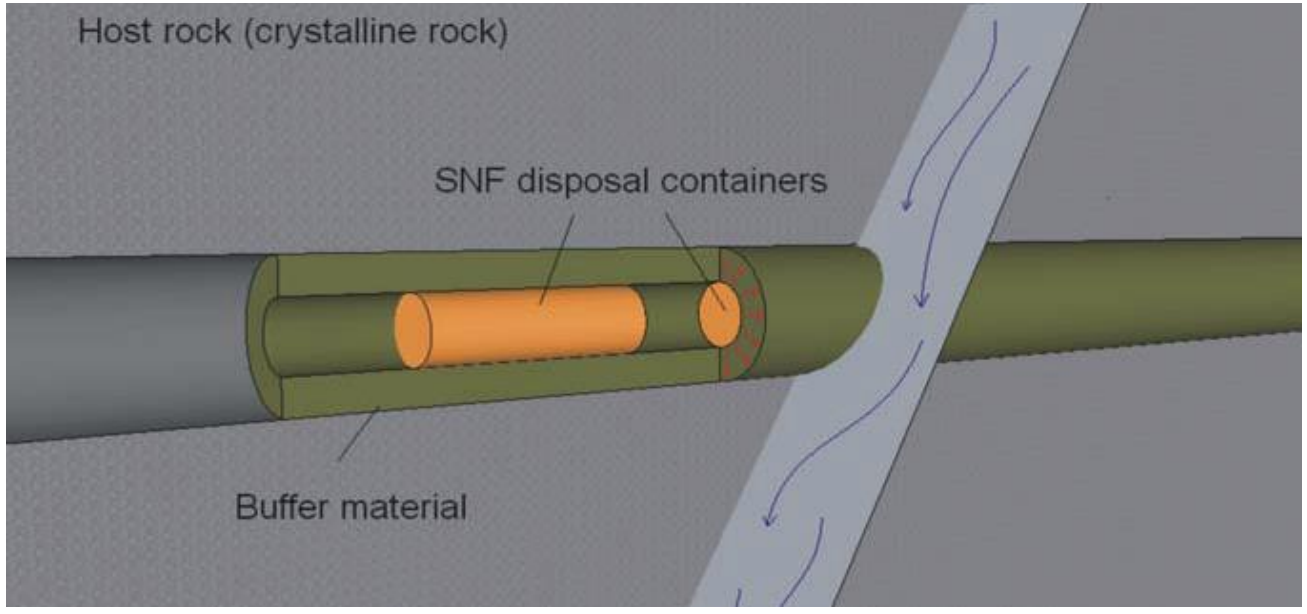


PhD thesis in nuclear safety area defended in LEI (4)

- Asta Narkūniene **"The Investigation of Radionuclide Release from the Hypothetical Repository for RBMK Spent Nuclear Fuel Disposal"** (2011)

The objective of the research is to investigate the potential radionuclide release from the hypothetical repository for RBMK-1500 SNF disposal in the crystalline rock in Lithuania, to analyse the possibilities of radionuclide release, their distribution area, as well as radiological consequences, to determine the regularities of radionuclide transport, and to evaluate the impact of various factors of nuclide migration.

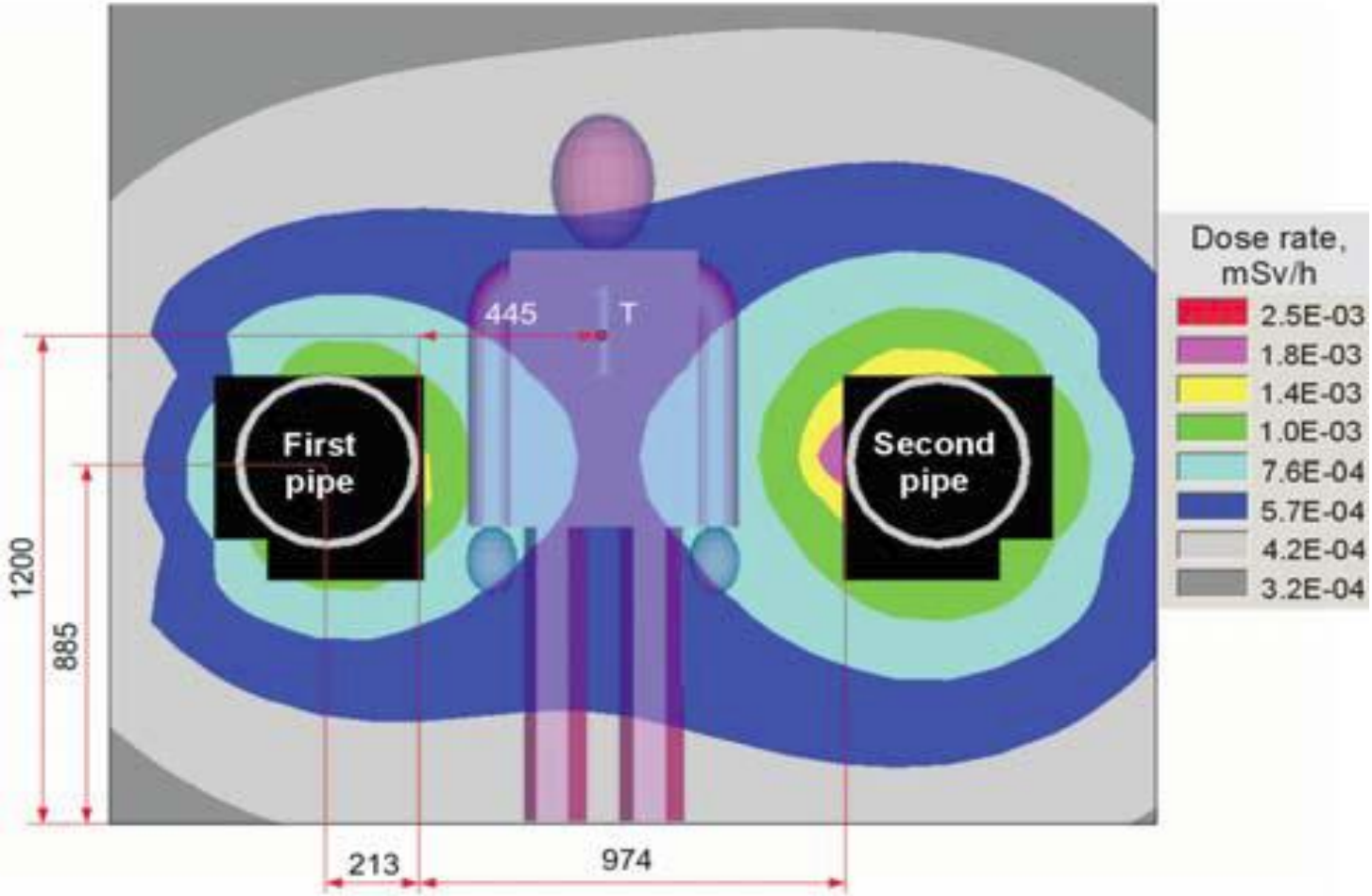
Scientific novelty. The main parameters, determining the maximal release of the most relevant radionuclides in the near field flux, have been analysed using deterministic and probabilistic analysis methods. Systematic analysis of radionuclides transport from the hypothetic repository for RBMK-1500 SNF disposal has been carried out and the regularities of radionuclide transport through engineered barriers have been determined.



Spent nuclear fuel disposal model

PhD thesis in nuclear safety area defended in LEI (5)

- Audrius Šimonis **"Investigation of Personnel Exposure During Dismantling of Nuclear Facilities"** (2011)



Radiation fields during dismantling of Ignalina NPP 117/1 building reactor emergency cooling system large diameter pipeline

PhD thesis in nuclear safety area defended in LEI (6)

- Darius Justinavičius **"Investigation of Gas Migration in Geological Repository"** (2014)

The objective of the research is to perform a numerical analysis of gas migration and determine regularities of gas migration in the geological repository situated in clay formation, evaluate the impact of various factors on gas migration and gas impact on long-term safety of the geological repository.

Scientific novelty. Advective fluid flow through thin interfaces (primary transport pathways for gas) in the tunnels (disposal, access and main) has been taken into account for the first time in the modelling of gas migration in the geological repository. Factors influencing peak pressure in the repository and possibly influencing its mechanical stability and functionality have been determined.

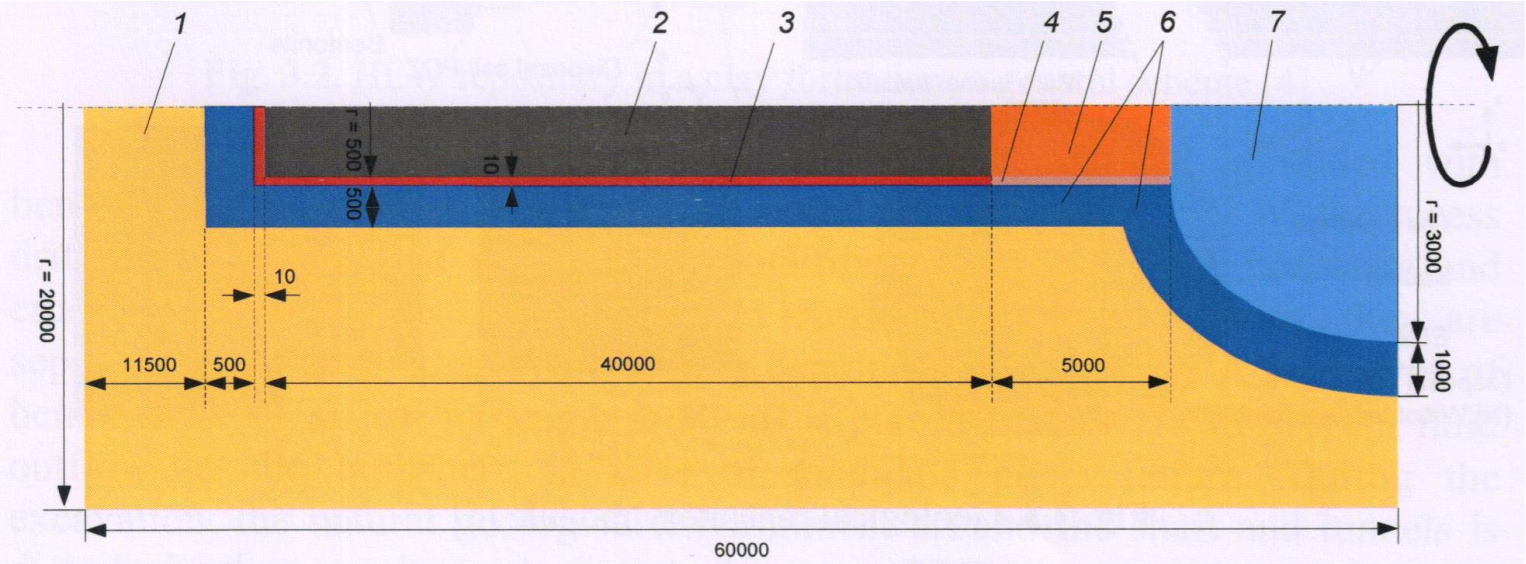


Fig. 3.4. Model of single disposal cell: 1 – undisturbed clay formation; 2 – HLW containers; 3 – waste interface; 4 – bentonite plug interface; 5 – bentonite plug; 6 – engineered disturbed zone (EDZ); 7 – access drift

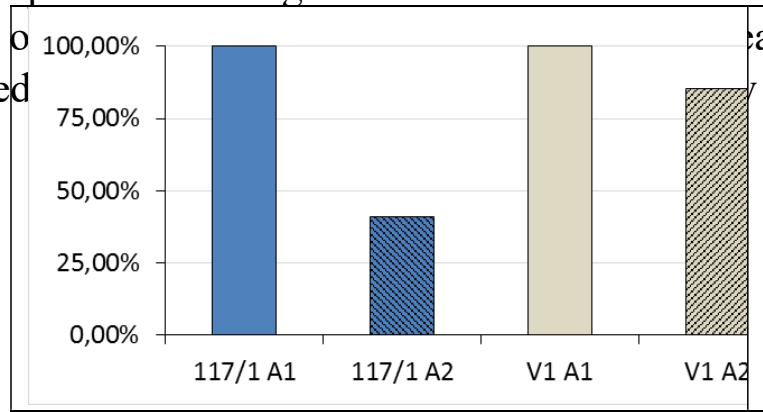
PhD thesis in nuclear safety area defended in LEI (7)

- Gintautas Poškas **"Modelling of the Radiological Contamination and Dismantling Process of the Nuclear Reactor Technological Systems"** (2017)

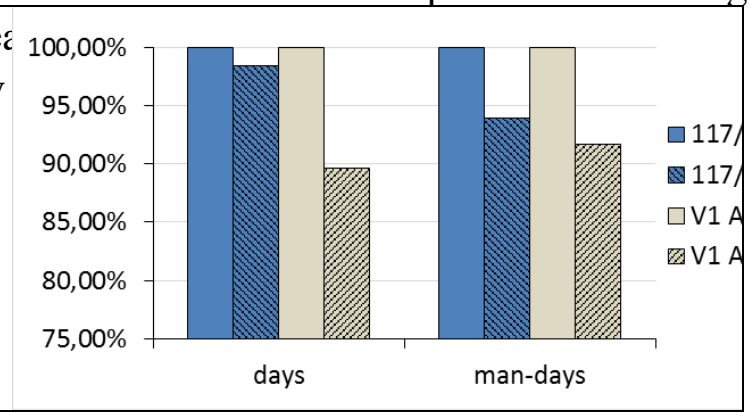
The work aims at extending the functionality of numerical modelling software and performing assessment of radiological contamination of RBMK-1500 nuclear reactor water systems and analysis of dismantling process for low contaminated systems.

Scientific novelty. Extension of functionality of numerical modelling software for radioactive contamination of nuclear reactor systems and their dismantling process and their application for analysis of nuclear reactor systems expand and improve the method of nuclear power plant decommissioning. Regularities of the radiological contamination of the RBMK-1500 reactor water systems has been defined and factors determining the uncertainty of the contamination results and selection of the dismantling strategy alternatives have been determined by applying probabilistic methods.

Practical value. Developed methodologies and software can be used for determination of optimal dismantling strategies for systems o[illegible] and software were used [illegible] reactor.



Comparison of collective doses for workers for different alternatives



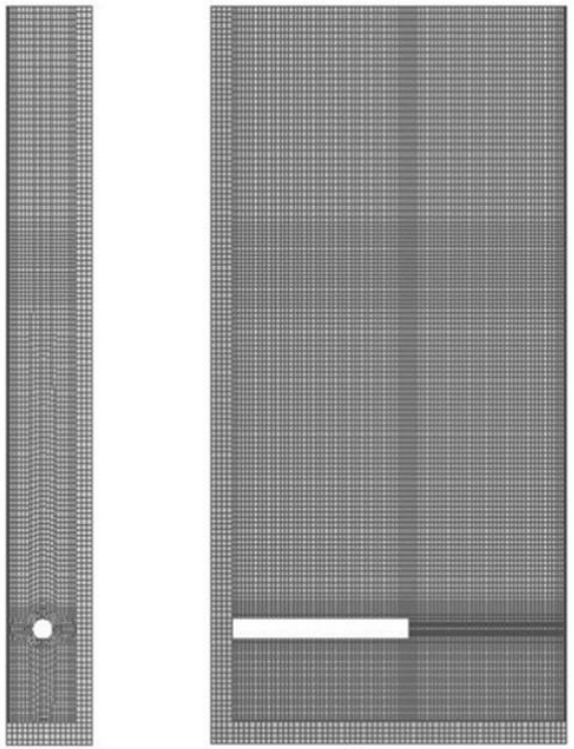
Comparison of project duration for different alternatives

PhD thesis in nuclear safety area defended in LEI (8)

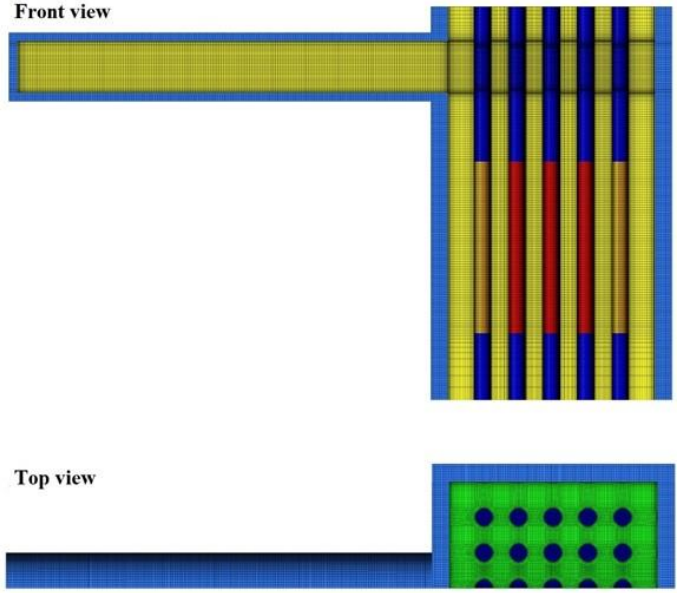
- Audrius Graževičius **“Numerical investigation of two-component two-phase natural convection and thermal stratification phenomena”** (2020)

The aim of work is to develop the methodology for modelling of two-component two-phase natural convection and thermal stratification phenomena in thermal installations using CFD software.

KAERI



Osaka University



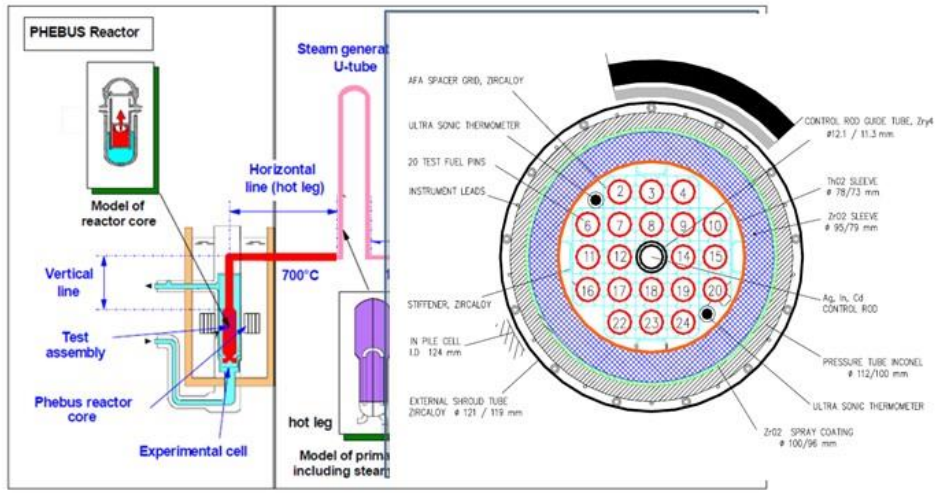
PhD thesis in nuclear safety area defended in LEI (9)

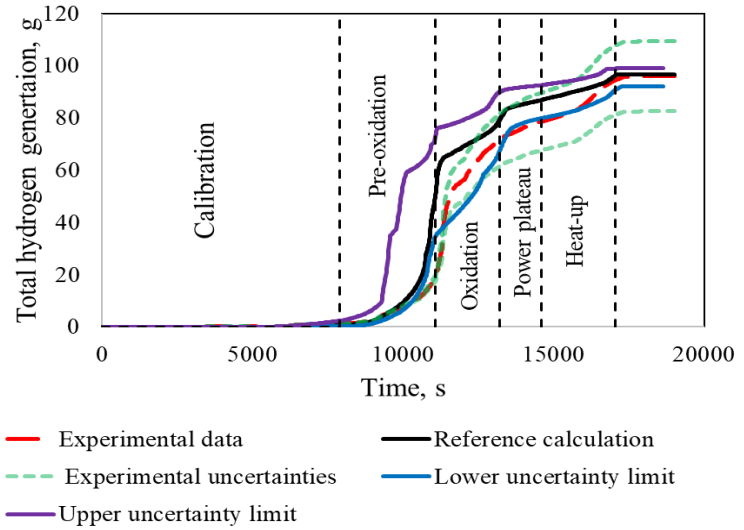
- Noura Elsalamouny **“Analysis of Severe Accidents leading to partial core melting in Light Water Reactors using best estimate approach”** (2025)

The aim of work is:

- To improve the understanding and accuracy of severe accident simulations in light water reactors by quantifying uncertainties and improving modeling techniques based on experimental data of fuel rod degradation during the partial meltdown.
- To develop the research methodology for the numerical investigation with quantifying calculation uncertainties of severe accidents leading to a partial core meltdown.
- To propose recommendations for the numerical investigation of physical processes in nuclear facilities with symmetric and asymmetric geometry.

Uncertainty analysis of PHEBUS FPT-1 test





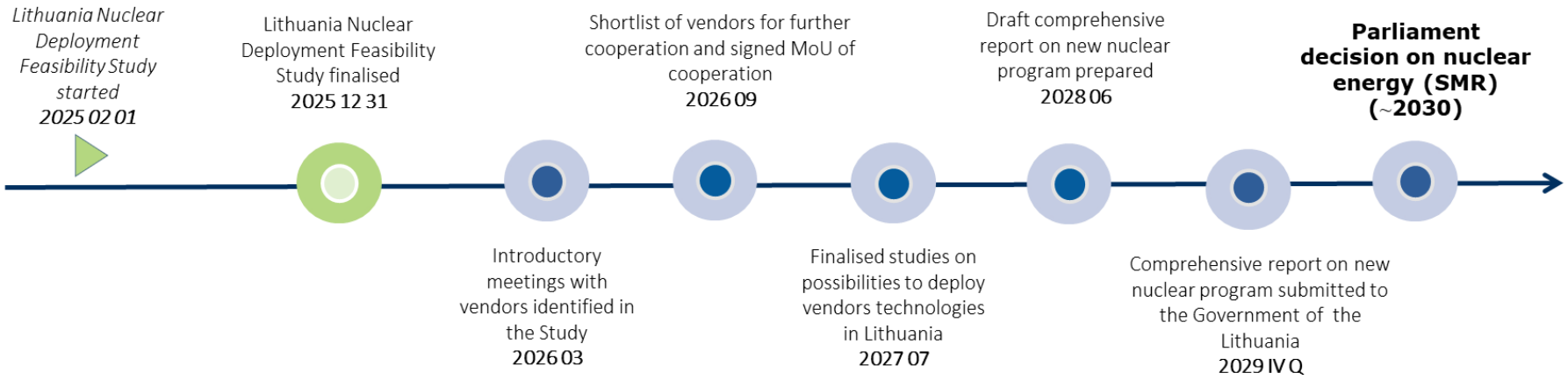
New trends. SMRs

New trends in Europe and in Lithuania

- In May 2024, the European Industrial Alliance on Small Modular Reactors (SMRs), which aims to facilitate and accelerate the development, demonstration, and deployment of SMRs in Europe by the early 2030s was created.

- In June 2024, Lithuania's parliament adopted the new National Energy Independence Strategy that includes nuclear power as a strategic option.
- According to this strategy, a Parllament decision on deployment of small modular reactors (SMRs) should be taken by ~ 2030 and a first unit of about 500 MWe should be start in operation after 2038.
- It is planned that in Lithuania SMRs will reach 1.5 GWe capacity in total by 2050.

MINISTRY OF ENERGY
OF THE REPUBLIC OF LITHUANIA



New trends in Lithuania

- In November 2024, Lithuania and the USA signed an intergovernmental agreement on cooperation in Lithuania's civil nuclear programme, under which the US Department of Energy would prepare a technology assessment.

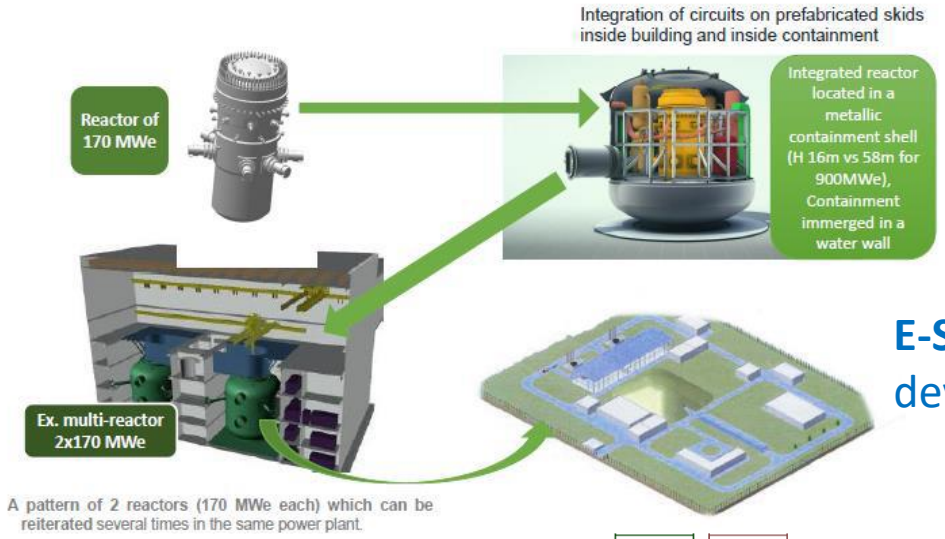
- In July 2025, SE Ignalina Nuclear Power Plant signed a memorandum of understanding with France-based NEWCLEO to assess potential deployment of its lead-cooled fast reactor technology in Lithuania.

- In February 2026, in Washington, D.C., the Ignalina Nuclear Power Plant, operating under the name ALTRA, together with the US company GE Vernova Hitachi Nuclear Energy (GVH) and the Polish company SGE S.A. (SGE), signed a trilateral memorandum of cooperation. It envisages assessing the potential of the advanced small modular reactor (SMR) technology – BWRX-300 – in Lithuania.

LEI research in the field of SMRs (1)

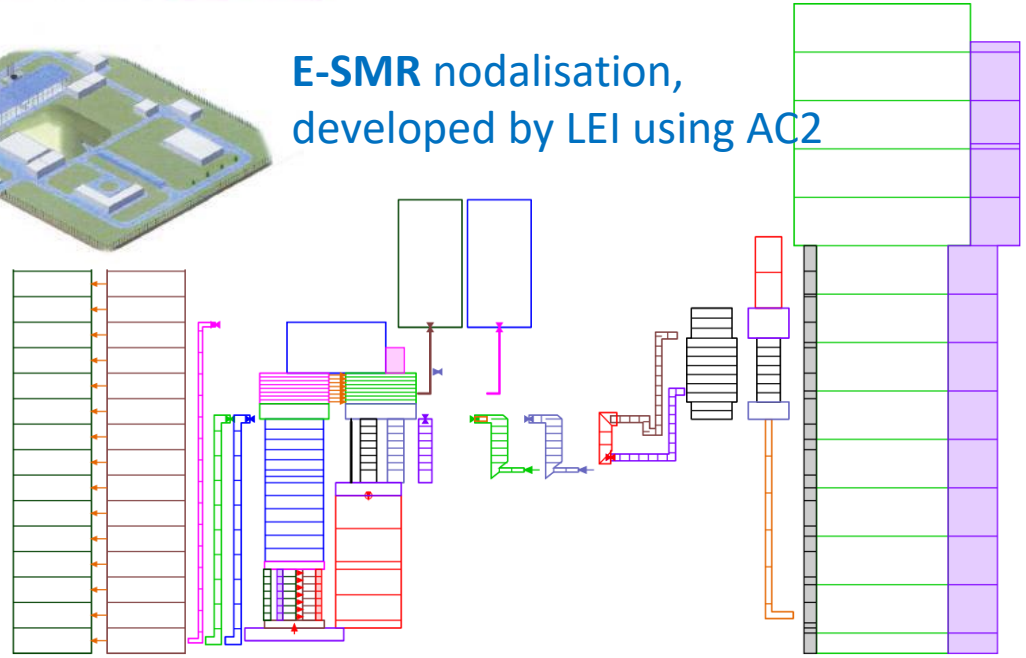
- **(ELSMOR)** Towards European Lisencing of Small MOdular Reactors)
- 2019 - 2023

ELSMOR
Towards European Licensing of Small Modular Reactors

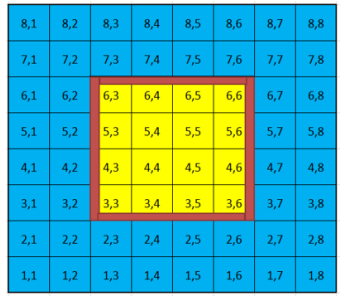


European **E-SMR** scheme

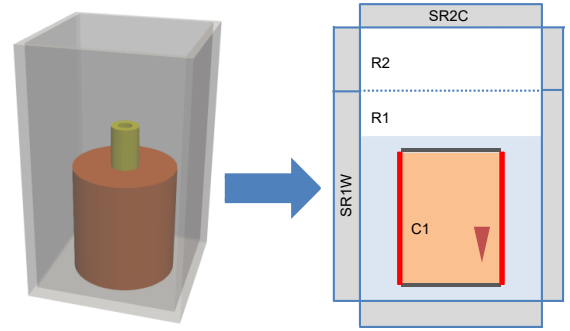
E-SMR nodalisation, developed by LEI using AC2



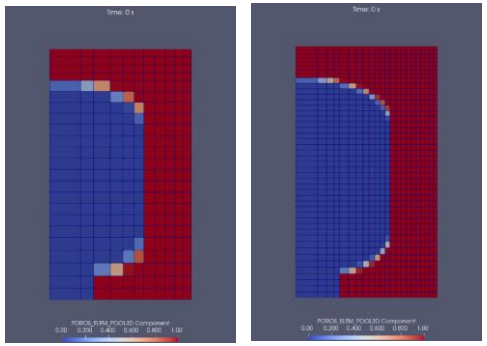
LEI (ATHLET-3D)



GRS (CoPool/COCOSYS, ANSYS)

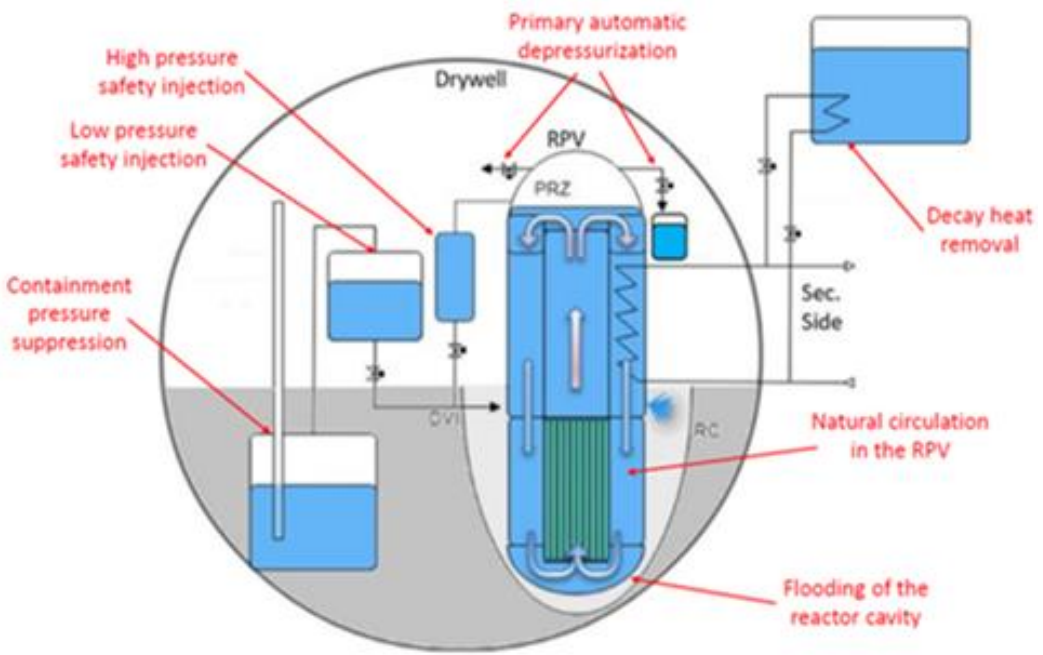


CEA (CATHARE)

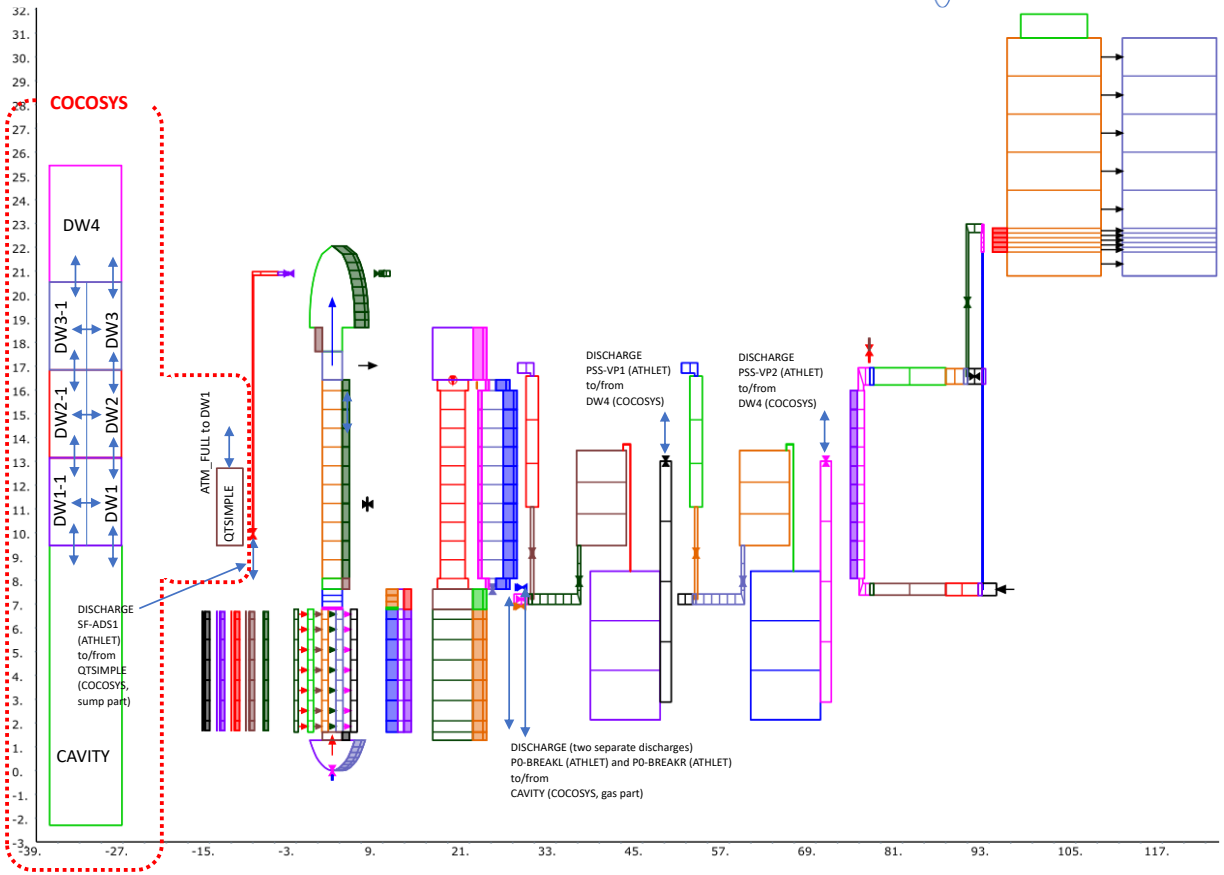


LEI research in the field of SMRs (2)

- **(SASPAM-SA)** Safety Analysis of SMR with PAssive Mitigation strategies – Severe Accident
- 2022 - 2026



iPWR scheme

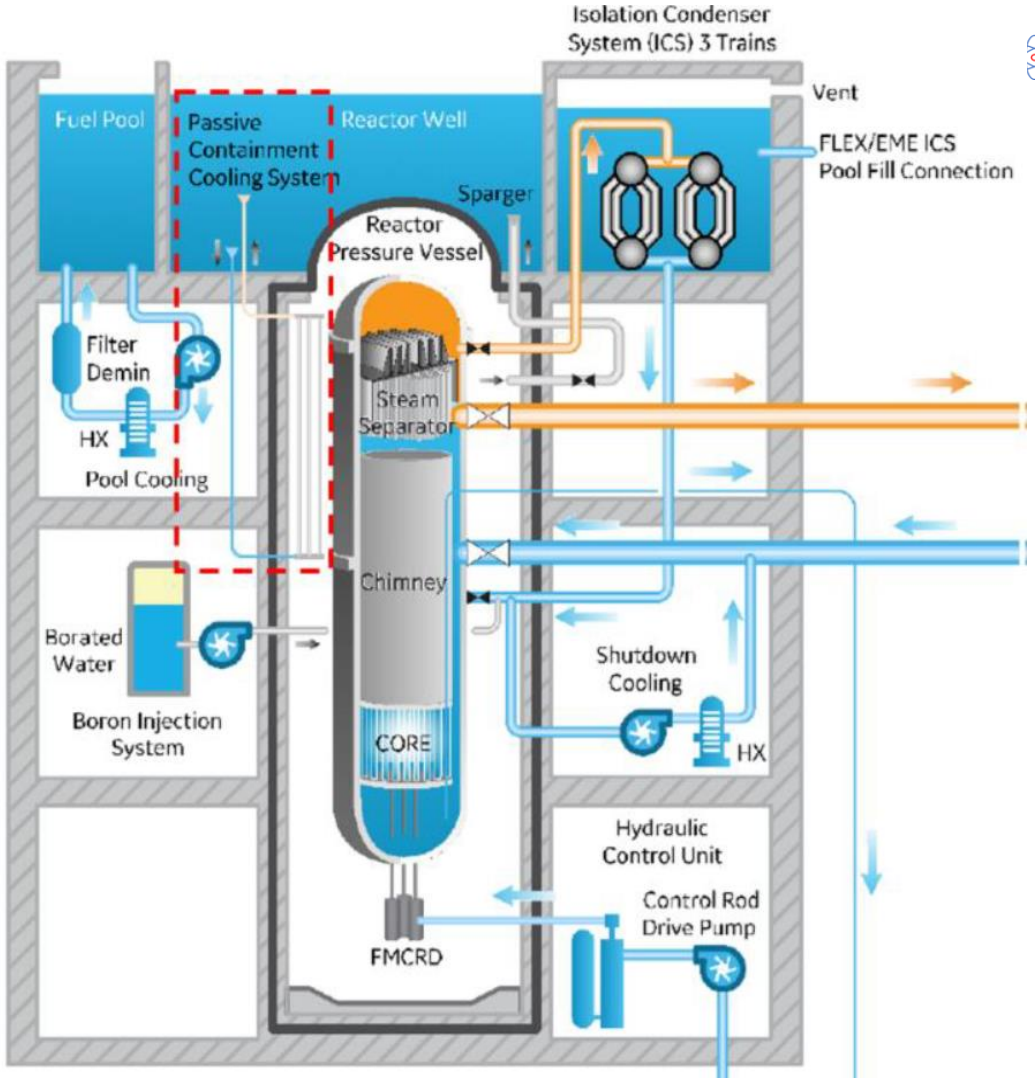


LEI contributes to the iPWR severe accident modeling and IVMR strategy application using ATHLET-CD and COCOSYS codes

LEI research in the field of SMRs (3)

- **(SASPAM-SA)** Safety Analysis of SMR with PAssive Mitigation strategies – Severe Accident
- 2022 - 2026

BWRX300 schematic diagram

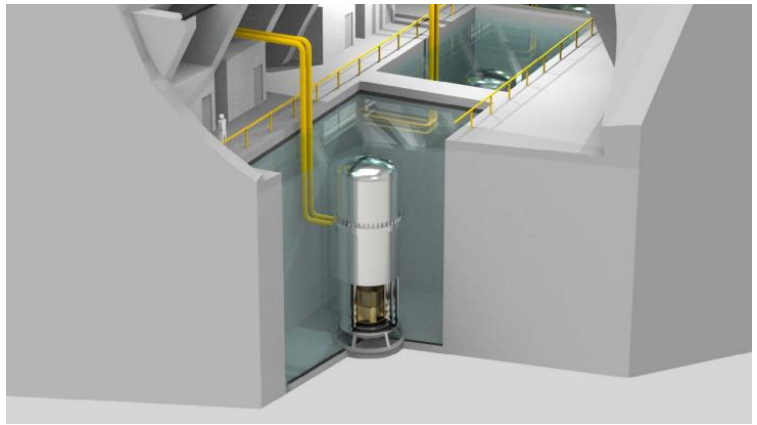


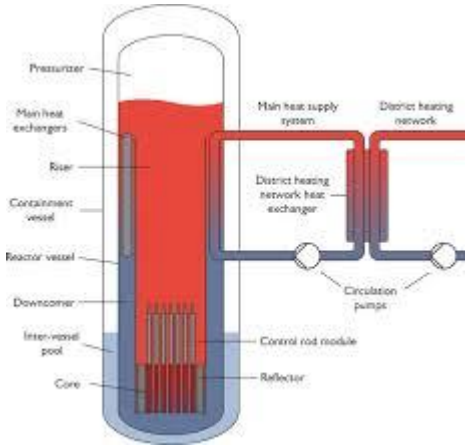
In 2025, CNL (Canadian Nuclear Laboratories LTD) joined the SASPAM-SA project team, which has developed a BWRX300 principle model using the MELCOR software package.

The goal of the SASPAM-SA project is to master this model and develop its own model using the European software package (AC2). This work is being carried out by LEI (Lithuania) and GRS (Germany).

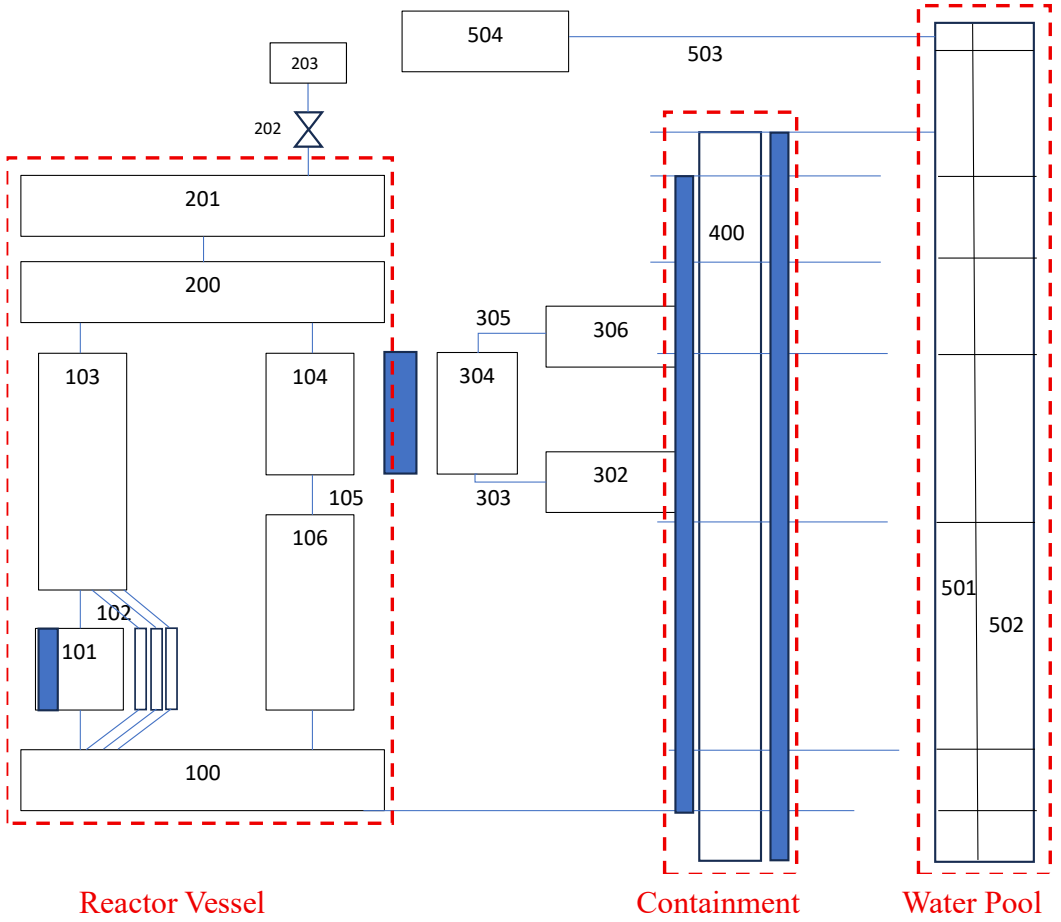
LEI research in the field of SMRs (4)

- **(EASI-SMR)** Ensuring Assessment of Safety Innovations for SMR
- 2024 - 2028





LDR-50 scheme



LEI created a nodalization scheme for the LDR lite model using the RELAP5 computer code

LEI research in the field of SMRs (5)

EURAD-2 – European Partnership on Radioactive Waste Management

LEI participates in the activities of WP4 "WM for SMRs and future fuels (FORSAFF)" of this project, which analyzes the management of spent nuclear fuel and radioactive waste from small modular reactors.

Conclusions

- Over more than 30 years of operation, Lithuanian researchers (LEI) has gained the necessary experience in deterministic and probabilistic safety analyses of the Nuclear Power Plants and in solution of NPP decommissioning and Radioactive Waste Management issues

- LEI researchers has all the required tools to perform necessary analysis

- LEI scientists actively participate in EU-led scientific research in the nuclear energy area

LITHUANIAN ENERGY INSTITUTE

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