Neutronics Analysis of EU DEMO Conducted at the Lithuanian Energy Institute

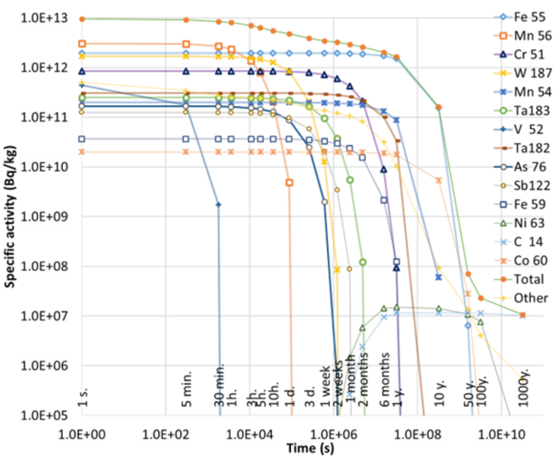
Simona Breidokaite, Gediminas Stankunas, Andrius Tidikas

Lithuanian Energy Institute Breslaujos g. 3, LT-44403 Kaunas, Lithuania
Corresponding Author Email: simona.breidokaite@lei.lt

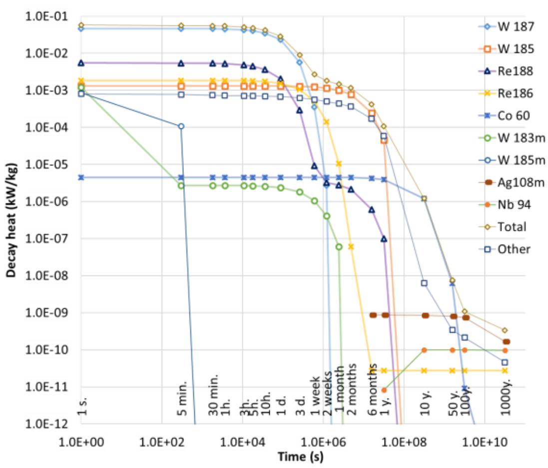
Growing demand for sustainable, low-carbon energy has increased interest in nuclear fusion. In the European Union, fusion research is led by the EUROfusion program, which aims to develop fusion-based energy production. A key initiative in this effort is the European Demonstration Fusion Power Plant (EU DEMO**)**, designed to bridge the gap between experimental reactors and commercial fusion energy. Neutronics calculations ensure EU DEMO's safety, efficiency, and feasibility. The Lithuanian Energy Institute (LEI) contributes to EUROfusion research by performing neutronics and inventory calculations for EU DEMO. This study presents key findings from these calculations. The study conducted a series of neutron transport and radiological analyses to evaluate the impact of neutron interactions in the EU DEMO fusion reactor. Using advanced numerical models and updated nuclear reaction cross-section databases, the calculations assessed neutron-induced activation, decay heat, and waste classification of key reactor components, including the divertor, vacuum vessel, and breeding blanket (both WCLL and HCPB concepts).

Neutron flux calculations were performed using the MCNP6 code with JEFF-3.2 or FENDL-3.2 nuclear data, while activation and decay heat calculations were conducted with FISPACT-II using the TENDL-2017 library. Breeding blanket calculations were based on the 2018 MCNP model and operating conditions from the early years of the reactor's operation. The 2017 model and the same early operational conditions were applied to the divertor, while the 2015 MCNP model and, later, prolonged operational phase were used for the vacuum vessel. The results of this work could be divided into three subsections, covering radionuclide analysis, waste classification, and the differences of neutron flux and decay heat using HCPB and WCLL breeding blankets.

The neutron transport simulations were used to examine the interactions of neutrons with 5 structural and 3 functional materials, determining dominant activation products. The study identified the most contributing radionuclides, such as ^{56}Mn in stainless steels, ^{187}W in tungsten, and ^{52}V in Inconel**.** Additionally, long-term activation was analyzed, revealing the formation of long-lived isotopes, including ^{91}Nb, ^{108m}Ag, ^{205}Pb, and ^{14}C from impurities. For example, see Fig. 1



a)



b)

Fig. 1 Examples of radionuclide analysis results. a-EUROFER- specific activity, b- tungsten decay heat.

The calculations were used to compare neutron flux, activity, and decay heat in different breeding blanket types. Results showed up to 40% variation in neutron flux and activation parameters for plasma-facing components and 20 times for components behind the first wall, highlighting the role of neutron absorption and breeding material composition.

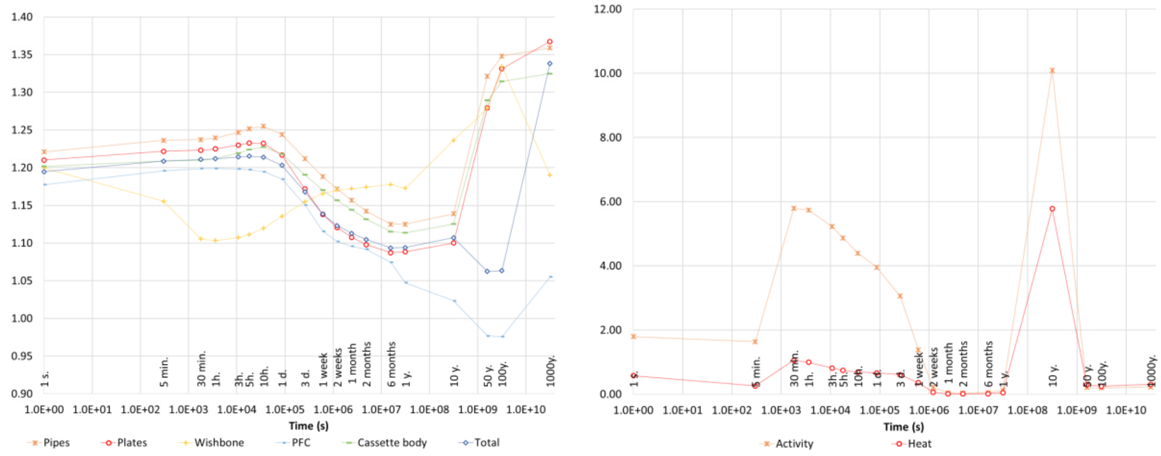


Fig. 2. WCLL/HCPB ratio of total activity values in divertor and activity and heat densities in breeding materials.

Finally, waste classification calculations were used to determine reactor components' radiation levels and decay timelines. Most parts were classified as ILW at shutdown due to high activity and decay heat values. Over time, materials like tungsten and EUROFER in the EU DEMO divertor would degrade to LLW within 50–100 years. HCPB breeding materials and many others would take over 1000 years to reach LLW status. These findings highlight the need for long-term waste management strategies to ensure fusion reactor sustainability.

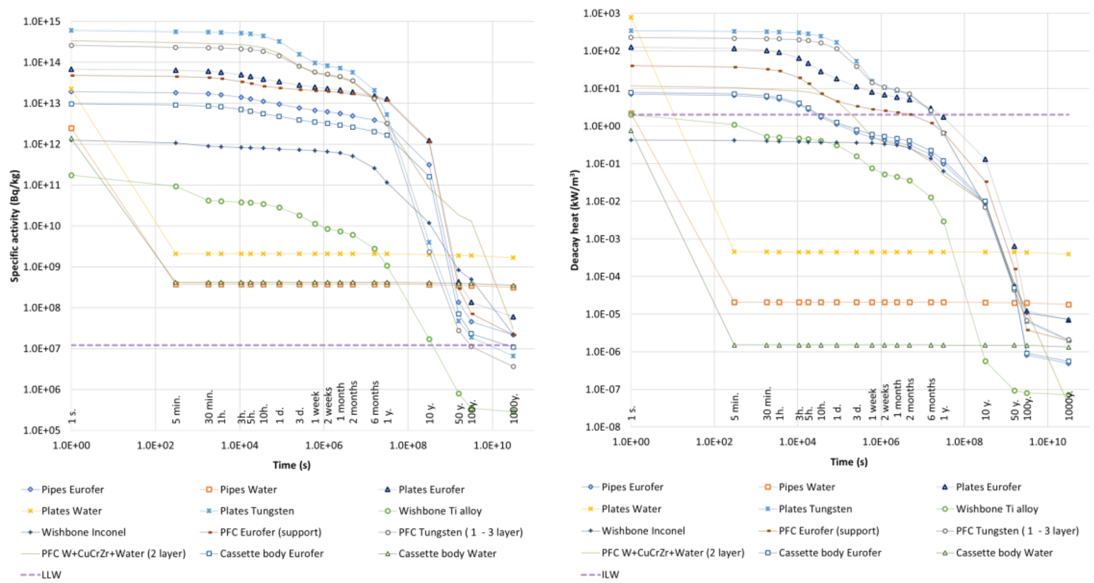


Fig. 3. Averaged decay heat and specific activity in different parts and materials in the divertor (HCPB model)