LITHUANIAN ENERGY INSTITUTE

ADMISSION TO PHD STUDIES FOR THE YEAR 2026

DOCTORAL RESEARCH TOPIC:

## Synthesis and performance of transformed waste-based geopolymer material for energy application

RESEARCH FIELD:

Energetics and Power Engineering (T 006)

BRIEF DESCRIPTION OF RESEARCH TOPIC:

The European Union's strategic objectives include achieving energy efficiency, energy independence, and a transition toward zero emissions in the industrial and construction sectors. However, non-biodegradable and non-recyclable wastes continue to be generated across various industries and technological processes. The potential availability, valorization routes, and added value of these wastes for new construction and industrial applications remain insufficiently investigated and rarely implemented in practice.

Efficient and innovative utilization of industrial waste can significantly reduce dependence on primary raw materials, lower the environmental impacts associated with extraction and processing, and contribute to achieving climate neutrality. Sustainable and environmentally friendly technologies, such as geopolymerization, enable the conversion of multiple waste streams and by-products into thermally stable alternative binders, supporting the EU's zero-emission and circular economy goals.

The physicochemical composition of industrial residues varies and is strongly influenced by the changing technological parameters of energy and manufacturing processes. As a result, the effective use of these heterogeneous waste materials in developing geopolymer-based products remains a significant scientific and technological challenge. Furthermore, the relationship between waste composition, geopolymerization kinetics, and the resulting micro- and nanostructural properties of the materials is still insufficiently understood.

Both the geopolymerization process parameters and the physicochemical characteristics of waste feedstocks determine the nano- and mesoscale structural evolution of the resulting material. The combination of different types of waste (e.g., organic and mineral) may induce synergistic effects that enhance porosity control, thermal and mechanical stability, and long-term durability under extreme temperature, humidity, or chemically aggressive conditions.

The origin and chemical composition of waste influence reaction pathways and phase formation during geopolymerization. These processes can be optimized using geochemical modeling supported by thermodynamic simulations of heterogeneous systems. Such modeling involves analyzing mineral phase metastability, dispersion, and solid–liquid equilibria through Gibbs free energy minimization. Integrating thermodynamic predictions with experimental data will enable a deeper understanding of phase evolution mechanisms and allow reliable assessment of material stability and performance under specific environmental conditions.

This research aims to identify the correlations between waste composition, geopolymerization conditions, and resulting structural transformations, leading to the development of waste-derived materials with tailored nano- and mesostructures and enhanced functional properties. The study will combine experimental synthesis and structural characterization with geochemical and thermodynamic modeling to establish predictive relationships for material design.

The expected outcome is the development of special-purpose geopolymeric materials exhibiting improved thermal stability, durability, and catalytic or sorptive functionality. These materials will be suitable for use in energy-efficient and environmentally sustainable technologies, contributing to the reduction of greenhouse gas emissions and supporting the transition to a circular, low-carbon economy.

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