In the face of rising energy prices and increasingly stringent environmental standards, buildings must become significantly more energy-efficient. One of the key elements affecting energy consumption is the design of external walls, which are responsible for a substantial portion of heat loss. Proper selection of materials and layer thicknesses in building envelopes can reduce annual energy demand by several dozen percent. New construction and insulation materials with increasingly attractive and diverse performance characteristics are constantly being introduced to the market. However, choosing the optimal solution from among a vast number of possible combinations is a major challenge- especially when it requires balancing factors such as cost, thermal insulation, durability, and environmental impact. Additionally, the local climatic conditions, which have a significant influence on building performance, should also be taken into account in the envelope design process.

The aim of this project is to develop an intelligent design support tool for external wall assemblies that will enable rapid and objective selection of the most efficient material-structural variants in terms of energy, economics, and environmental impact. To achieve this, an Adaptive Neuro-Fuzzy Inference System (ANFIS) model will be used. This model combines the advantages of artificial neural networks and fuzzy logic, and will be capable of instantly predicting energy consumption for new wall configurations without the need for time-consuming simulations. To train and validate the ANFIS model, energy simulations will be carried out using the EnergyPlus software environment. These will be based on a simplified test cell model located in various European climate zones (e.g., Madrid, Warsaw, Stockholm). Dozens of material and geometric wall variants will be analyzed, generating over 500 simulation datasets.

In the next stage, the model will be integrated with a multi-criteria optimization algorithm that considers heating energy demand, construction costs, and the global warming potential (GWP). The result will be a set of optimal wall configurations that meet predefined technical and environmental constraints. The output will be presented as a pareto-optimal solution set, illustrating trade-offs between performance and cost. Furthermore, a recommendation algorithm will be developed to automatically select the optimal wall design based on the user's chosen project priority (e.g., minimum thickness, lowest cost, or highest energy performance).

For testing, the ANFIS model will also be compared with real-world energy data obtained from pilot or experimental buildings. In the absence of such data, an extended validation phase will be conducted using additional, previously unused simulation sets. In the final phase, sensitivity analysis using the Sobol method will be performed to identify the most influential parameters affecting the energy performance of building envelopes across different climate conditions.

This interdisciplinary project bridges the fields of construction, energy, and artificial intelligence. Its result will be an innovative design tool that supports rational decision-making in the selection of building materials and technologies, paving the way for more energy-efficient construction in the future.