The high penetration of intermittent renewable energy sources has created a great need for increased flexibility that would allow an electrical power system to adapt to dynamic and changing energy demand and supply conditions. To support the transition to a renewable energy future with intermittent and fluctuating power generation, a change is needed, where demand can be adjusted to the available power by incorporating energy flexible systems. The building sector accounts for approximately 40% of global energy usage and offers great opportunities for energy flexibility. The energy flexibility of a building is the ability to manage its demand and generation according to local climate conditions, user needs and energy network requirements. Buildings can supply flexible services in different ways such as utilisation of building thermal mass, changes of the operating schedules and setpoints of heating, ventilation and air conditioning systems, optimisation of charging and discharging of electric storage and thermal energy storage, and shifting of plug loads. Building energy flexibility can, therefore, provide unique opportunities for effective demand side management and thermal comfort of occupants in particular under extreme weather conditions. It also can provide flexible grid services and accelerate the transition to a low carbon energy future.

Investigations on the energy flexibility of electrical grids from the supply side have been extensively carried out. However, research on exploring opportunities from the building demand side, discovering the mechanisms governing building energy flexibility, and examining how the energy flexibility in buildings can facilitate the penetration of renewable energy sources and provide flexible grid services **is still in the very early stages**. The primary aim of this project is to develop a unique platform that can explore and quantify the opportunities of building energy flexibility, and a new control framework that can facilitate building demand side management, in order to reduce building operational cost, increase the security of energy supply and improve building resilience to extreme weather conditions. The specific objectives of the proposed project include:

- To unlock the mechanisms governing building energy flexibility through dynamic building simulation, advanced data analytics and deep learning;
- To develop a data driven platform to characterise and quantify building energy flexibility, and explore and optimise energy flexibility opportunities for a wide range of scenarios and;
- To develop and demonstrate an innovative control framework that integrates reinforcement learning and model predictive control to facilitate optimal utilisation of building energy flexibility for demand side management, and improvement of thermal comfort and grid optimisation.

This project offers multiple contributions in Poland's national interest. Firstly, being responsible for about 40% of global energy usage, reducing building energy usage is of vital importance to the nation's social, economic and environmental outcomes. Secondly, energy infrastructures form the backbone of modern society. High penetration of renewable energy in buildings can significantly reduce the need to reinforce the current power grid infrastructure and enhance the resilience of electric grids. The novel toolkit and control framework developed can enable buildings to effectively participate as distributed energy resources in support of seamless integration and optimisation of renewable energy in buildings and grid optimisation. Lastly, the new IP generated through this project will open up commercial opportunities in low carbon energy technologies, data analytics and ancillary services, and allow the Polish industry to achieve economic profits and earn energy market revenue.