Aim of the project:

Today's social and technological developments are driving global energy demand at an unprecedented rate. Therefore, with the current drastic shortage or increase in the price of fossil primary energy sources, the need to use previously unavailable regenerative thermal energy reservoirs is growing. Systems that allow for the recovery of thermal energy are required even at low temperature differences or low temperature levels. The project is addressing this topic.

The scientific goal is to increase the thermal performance of phase-change probes by *in situ* coating the evaporator surface. Earlier research at Wroclaw Tech delivered evidence that boiling suspensions containing particles between 10 and 100 nm in size alter the evaporator surfaces and allow the achievement of this goal. The results obtained show changes in wettability and a significant reduction in superheat, which open the possibility of pool-boiling heat transfer with high efficiency under otherwise impossible conditions. However, the underlying physics of boiling on porous surfaces is complex and complicated. More research is necessary, and these open questions lead to Ph.D. worthy scientific research tasks that form the basis of this proposal.

The earlier results showed that, instead of improving the thermodynamic properties of the fluid**, the nanoparticles rather deposit on the boiling surface and affect its properties**. The profound finding was that with some nanomaterials **the effect appears to be permanent**, which fact sparked our interest in the creation of a new *in situ* coating method, which is addressed in this proposal.

Research carried out in the project:

We are going to study three especially selected nanoparticle suspensions: silicon dioxide (SiO2) and two other suspensions that will be determined in the first year of research. SiO2 was chosen because it exhibits hydrophilicity, leading to the formation of a porous layer on the heater surface and improves the heat transfer coefficient during boiling. The quality of the layer depends on boiling conditions, and to produce repeatable high-quality porous surfaces, it is necessary to determine ways to control the boiling process.

The experiments will be conducted with an especially designed thermosyphon. In previous research, we have studied the boiling process in a similar device. We have developed maps that can now be used to navigate between stable and pseudo-stable boiling regimes. Now, the plan is to use this information to control the occurring process and potentially obtain the highest possible quality of the layer. Before and after boiling, each suspension will be characterized to evaluate differences in properties and nanoparticle content. The device itself will be dismantled, and its internal surfaces will be carefully characterized at different scales (from standard microscope observation, through confocal microscope scanning, to SEM photography) to check the status of the evaporator surface and the character of nanoparticle layer. Additionally, boiling of nanoparticle suspensions will be followed by boiling a pure base liquid, to check if (and to what degree) heat transfer enhancement caused by nanoparticle agglomeration prevails.

The first series of experiments will allow one to form a list of control and noise factors and to design the experimental plan. The second series of experiments, in combination with statistical analysis (the Taguchi method) will produce the quantitative and qualitative understanding of the new *in situ* coating method.

Reasons for choosing the research topic:

Nanoparticle deposition, if properly controlled, would allow for improved thermal device operation in ways otherwise impossible. The general adoption of such thermal systems would have a significant impact on economic and social development through substantial energy savings. Savings that translate into reduced equipment size, improved efficiency, a broader range of operating temperatures, and, as a result, reduced environmental impact. High-performance thermal systems enhanced with nanoparticles offer opportunities for development and innovation in many areas, especially those that have high energy demands (e.g., HVAC, food storage). The *in situ* process and coatings that we intend to develop and research in this project offer a low-cost approach to effectively coat any evaporator geometry. The consequence will be the reduction of investment and operating costs, as well as reduced usage and better allocation of non-renewable resources, such as fossil fuels. The results of our work will significantly contribute to the development of a balanced and more environmentally conscious society powered by highly efficient green energy systems aligned with the principles outlined in the UN Sustainable Development Goals.