Thermodynamics is undeniably one of the most important theory in physics at all. Surprisingly, this extremely powerful and universal framework was developed in 19th century during theoretical studies of thermal machines like heat engines. The object of interest at that time may look boring and trivial, however the results which were obtained, immediately revolutionized the whole science for the next two centuries. Today, thermodynamics is an ABC-book for any engineer and is essential for studies of condensed matter (like finding a new materials), however it is also a corner stone for big questions about the beginning of the Universe, properties of black holes or answering the fundamental question "what is life?".

On the other hand, 20th century brings us another revolution in physics which is the emergence of quantum mechanics, a theory which properly describes microscopic world composed of electrons, atoms, molecules and other elementary particles. After about one hundred years of triumphs of the quantum mechanics, today most of physicists is convinced that our Universe is fully quantum-mechanical for any scale, despite that only for microscopic systems quantum effects can play a relevant role. This is the reason why in a theoretical physics have been arised a need to formulate the general framework of thermodynamics by means of the quantum theory, such that classical thermodynamics in macroscopic domain will be just a boundary case. On the other hand in last decades we were observing a huge progress in a nano-scale technology, what includes also microscopic machines. In this case quantum effects are not negligible and that is why a new theory, called quantum thermodynamics, is necessary to describe such thermal machines in a microscopic regime.

Today, in 21th century, we enter a new path which is an emergence of quantum thermodynamics. Once again physicist around the world study basic thermodynamic processes like how thermal energy can be converted into the useful work, however, in this case the objects of interest are thermal machines belonging to the microscopic domain. Many new and very interesting systems already have been proposed on a paper, like the concept of a quantum batteries, and it is only a matter of time when our energetic technology will became essentially quantum.

We would like to participate in this great project of formation of the quantum thermodynamics. Particularly in this research, we will study a new paradigm of a quantum work extraction (from a thermal energy) which is able to operate more efficiently than in a classical domain, and also provide a basic theoretical studies in order to better understand the quantum thermodynamics at the fundamental level.