Innovative system using wet steam to convert waste heat into electricity

The overall objective of the project is to empirically confirm the possibility of effective utilization of an innovative Wet Steam Cycle (WSC) for Waste Heat Recovery (WHR).
The research team is planning to develop WHR system with:
- implementation of not yet used WSC, with water/steam as a working fluid,
- wet steam tolerate expander,
- the ability to utilize waste heat temperature range: 150 °C to approx. 450 °C,
- possibility to utilize up 200 kW thermal energy to produce electricity.

The most modern WHR devices currently in use can be connected to almost any flue pipe or chimney by means of a heat exchanger in which hot flue gases are cooled and waste heat extracted from them. These exhaust gases would otherwise be released into the environment. This makes these technologies very versatile and has great potential to affect CO_2 savings. However, current state-of-the-art WHR systems fall short of expectations because they fail to achieve high efficiency at an acceptable cost. The vast majority of waste heat recovery systems in use utilize the well-known ORCs. The ORC is widely described in the literature (Fig. 2).
The ORC technology is well-suited for low input temperatures up to about 150°C as found in geothermal applications, however, the thermodynamic advantage of higher temperature levels cannot be exploited because organic working media tend to decompose at temperatures above ~180°C (apart from Toluene). It should be noted that refrigerants/low-boiling fluids are used in ORC installations. The refrigerants currently in use are being replaced with fluids that have less impact on the environment. The replacements have low global warming potential (GWP), but some of them have harmful, flammable, poisonous properties. In the planned project, the working fluid is water/steam, which does not have the unfavourable characteristics of refrigerants.

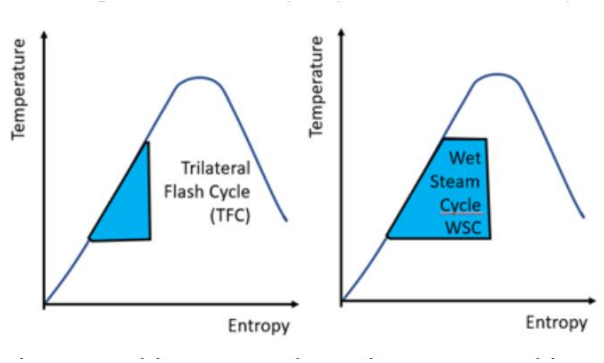

Fig. 1 Thermodynamic cycle: *a*) triangular flash cycle, *b*) wet steam cycle

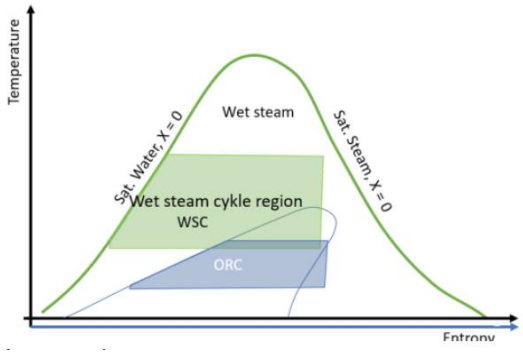

Fig.2 Pictorial T-s diagram

The project will adapt and modifying (to increase energy efficiency) a screw expander. Accurate recognition of the applicability (to the conditions specified in the requirements of the proposed research project) will allow to select one type of the expander for modification and application. The most likely (for specific requirements) seems to be a screw compressor with a reverse duty cycle. In the original version, the compressor is of course used to increase the pressure of the gas at the expense of the supplied mechanical energy (e.g. an electric motor). As part of the modification, this machine will be powered by wet steam and will generate mechanical energy used to drive an electric generator. This will require a number of structural and material modifications as well as the implementation of e.g. new compressor timing system, lubrication system, etc.
The project idea is based on the already known TFC (Fig. 1a) that feeds boiling water to the expander, where flash evaporation takes place during the expansion process.
The present proposal develops the TFC for WHR technology beyond the state-of-the-art regarding:
- Wet Steam Cycle (Fig. 1b) for wide range of wet steam quality,
- Trilateral Flash Cycle enhancement by wet steam supply,
- Wet steam tolerant expander.