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Micro-scale organic Rankine cycle units for industrial waste heat recovery

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A combination of different strategies should be pursued in order to develop a more sustainable energy system. Great attention is now devoted to the study of renewable sources, but it is also necessary to focus on the already existing technologies in order to increase the overall effectiveness of thermodynamic cycles and to investigate novel solutions to economically exploit freely available heat sources. In this context, a recent study carried out at DTU Mechanical Engineering has shown that around 266 PJ of heat is wasted every year in the Danish business sectors [1]. The low temperature and dispersed nature of this waste heat makes it challenging to convert it into power in an economical way. Nevertheless, this heat represents a freely available hot source whose exploitation could enable to decrease the fossil fuel consumptions.

This project, carried out in collaboration with Innogie ApS, aims at modeling, developing and testing a micro-scale organic Rankine cycle (ORC) unit (1-5 kW_{el}) able to perform an efficient and economical conversion of industry low temperature (80 – 120 °C) waste heat into power. The ORC is thermodynamic cycle suitable for the conversion into power of low temperature heat sources. Its main advantage compared to the traditional steam Rankine cycle lies in the possibility to choose a proper working fluid in order to obtain a good thermal match between the cycle and the heat source. The final objective of the project is to ensure the economical profitability of these micro-scale systems and to make them suitable for commercial purposes. The main tasks to be carried out include the development and validation of detailed numerical models of the cycle and its component, experimental tests and the economical assessment of the integration of the unit in real industrial processes.

An already available ORC prototype comprising a scroll expander will be tested soon. The scroll expander is a rotative volumetric expander usually employed in low temperature – low capacity ORC power plants [2]. The scroll is a reliable technology that has been widely used as a compressor in the field of air conditioning and refrigeration. Its main advantages include the high reliability, the good isentropic efficiency and the tolerance toward the presence of a liquid phase during the expansion process. The first scroll expander prototypes are now being commercialized but, in most of the cases, they are derived from existing scroll compressors and are thus not optimized for expander operation.

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[2] P. Song, M. Wei, L. Shi, S. N. Danish, C. Ma, "A review of Scroll expanders for organic Rankine cycle systems", Applied Thermal Engineering, Vol 75, pp. 54-64, 2015.