

## Developments on Small-Scale Organic Rankine Cycle (ORC) Systems

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### Editorial

The organic Rankine cycle (ORC) technology is perhaps the most suitable technology for heat recovery applications from sources of low temperature (even lower than 100°C) [1], while it can also be used for temperatures up to about 300°C with a variety of scale (from the kW up to the MW scale). At low temperatures its efficiency is usually in the range of 4-6 %, but still there are cases where it can be cost effective, especially for waste heat recovery thus improving the overall process/system energy efficiency. The main advantage at this low temperature range is the simple and low-cost heat source circuit and simple ORC configuration [2,3] (i.e. single expansion machine and no internal heat exchangers).

There are numerous studies especially for solar thermal energy applications, proving the importance, flexibility and potential cost-effectiveness of such energy systems [4-8]. Most of them focus on the power production from the ORC part, which is then converted to electricity, with the aim to maximize net power production. Some priority aspects of the researchers dealing with such systems is the design of the ORC [2], the organic fluid selection [9,10], the control and possible thermal storage unit [11], and the appropriate expansion machine [12-14]. The Renewable Energy Systems Group (RES Group) at the Agricultural University of Athens (AUA), ([www.renewables.aua.gr](http://www.renewables.aua.gr)) focuses on two major issues relevant to ORC technology, which are mentioned next:

1. Optimization of solar conversion to electricity through advanced design and control.
2. Development of unique expanders, included in a variety of ORC units (for different applications).

### Research on Solar ORC Units

Various solar ORC units have been developed in the past. Most of them use conventional solar collectors (either flat type or with evacuated tube ones) or collectors with reflectors (such as parabolic troughs), for conversion of the incident solar radiation to usable heat [6,7]. Recently, an alternative configuration has been developed and tested, which is based on concentrating PV/thermal collectors, which produce both heat and electricity. The key parameter of the hybrid concentrating photovoltaic/thermal (CPV/T) system design is the temperature of the heat transfer fluid, transferring heat from the CPV/T to the ORC unit, through the evaporator, having a major effect on the performance of both the PV cells and the ORC engine. The motivation is the utilization of solar thermal energy from the CPV/T by an ORC unit for producing additional electricity. By doing so, the total electricity production of such hybrid systems can be significantly increased, contributing also to the increase of their flexibility. Finally, such system can also operate at CHP mode, which is currently being examined. This system has a combined capacity of 13 kW (10 from PV

part and 3 kW from ORC part) and has been tested at AUA field with promising results in the framework of a EU-funded project (CPV/Rankine: [www.cpvrankine.aua.gr](http://www.cpvrankine.aua.gr)). The ORC housing and a part of the solar field are shown in Figure 1.

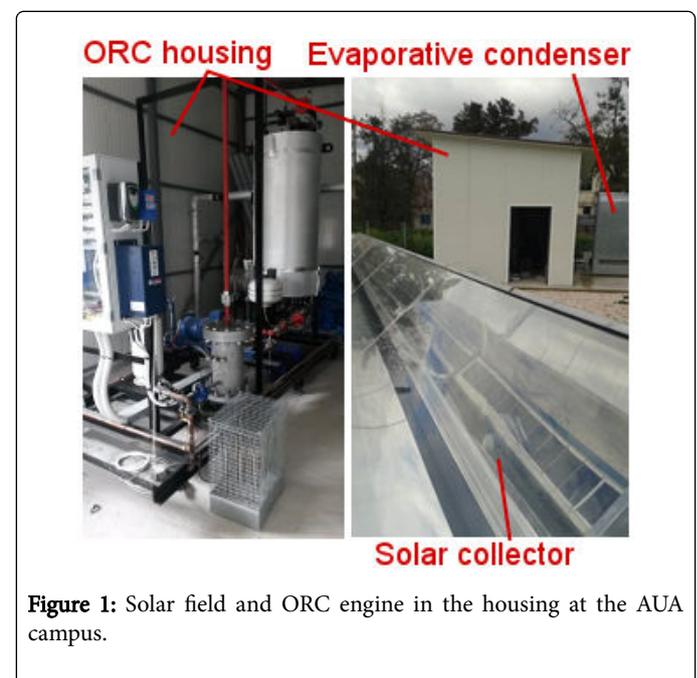


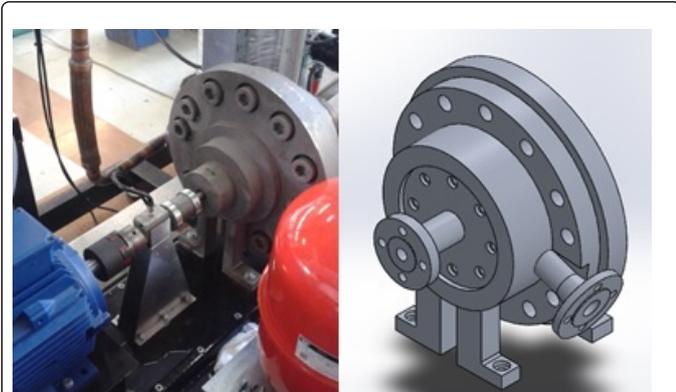
Figure 1: Solar field and ORC engine in the housing at the AUA campus.

### Research on Expander Development

For small-scale systems with power production lower than around 20 kW, scroll expanders are widely used and show adequate performance and expansion efficiency [15]. The authors have used such expansion expanders (both open-drive and hermetic ones) and reached good performance at a wide range of pressure ratios [1], from about 2 up to 8. However, scroll expanders are not commercially available and most of the times converted scroll compressors in reverse operation (obtained from refrigeration and HVAC industry) are used.

Recently, the RES Group has focused its efforts on developing new open-drive scroll expanders from scratch, by designing, optimizing, manufacturing and testing them for the specific conditions of each case. In this way confidence will be obtained that such expanders will operate according to the design criteria (i.e. pressure ratio, flow rate), showing superior expansion efficiency, and thus increasing the overall cycle efficiency. Such effort is at its early stages, already having manufactured and tested the first prototype, which demonstrated its potential. But at the same time some critical issues (such as leakages) have been identified, which are under further investigation.

This prototype is shown in Figure 2, designed for a supercritical ORC, operating at pressure up to 40 bar.



**Figure 2:** Left hand side: Scroll expander coupled with asynchronous motor/generator. Right hand side: Design of open-drive scroll expander.

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2. Supercritical-ORC, partly funded by the Greek General Secretary of Research and Technology (GSRT), grant agreement no 11SYN\_7\_278, [www.supercritical-orc.aua.gr](http://www.supercritical-orc.aua.gr).

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