Experimental retrofit of an organic Rankine cycle towards its integration into a Carnot battery

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Domestic energy storage options remain expensive for users and require strategic materials

The Carnot battery can offer a **reduced cost** per kWh stored, a long lifetime, scalability and does not require strategic materials [1]

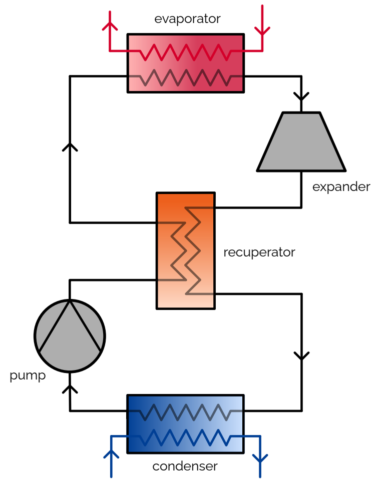
However **its efficiency is low** compared to other solutions (e.g. lithium batteries)

To ensure **decent performance** of the machine, the organic Rankine cycle (ORC) responsible for the discharge of the Carnot battery must have a **stable efficiency** along its operating range

In this study, we operated and characterized a micro-scale ORC (< 1 kWe) in off-design conditions and mapped its performance at part load to assess its potential in a domestic, low temperature (< 100°C), Carnot battery

The ORC is a thermal engine

It is able to produce work out of a **low temperature** heat source (< 400°C) such as waste heat, solar, geothermal or biomass [2]



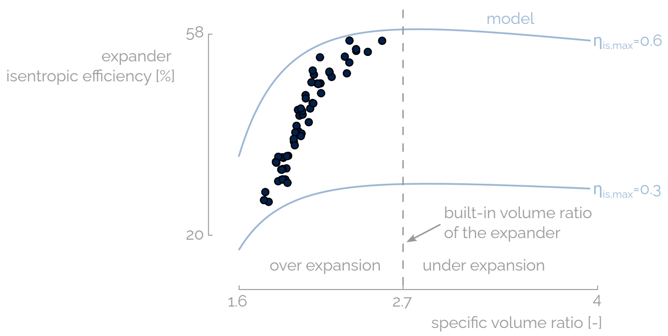
A new working fluid was chosen to suit the new operating temperatures

Isopentane (R601a) was originally present in the ORC designed for a heat source of **110°C** and a sink of **50°C**

It has been replaced with **isobutane** (R600a) to operate with a heat source of **70°C** and a sink of **15°C**

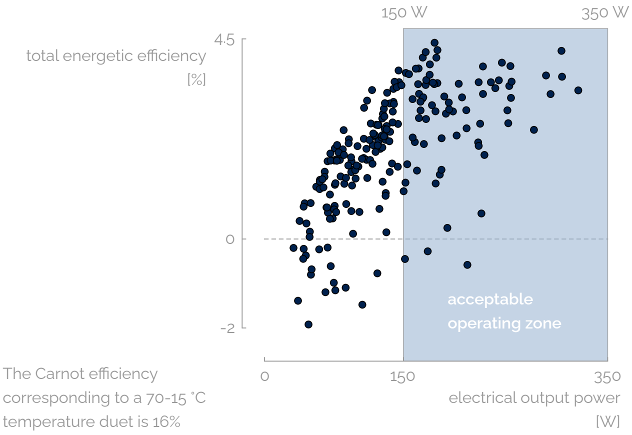
With isobutane at these new temperatures, the specific **volume ratio** seen by the **expander** was expected to match its built-in volume ratio to expect the most performance out of it

At a source of 70°C and a sink of 15°C, the expander constantly operated suboptimally



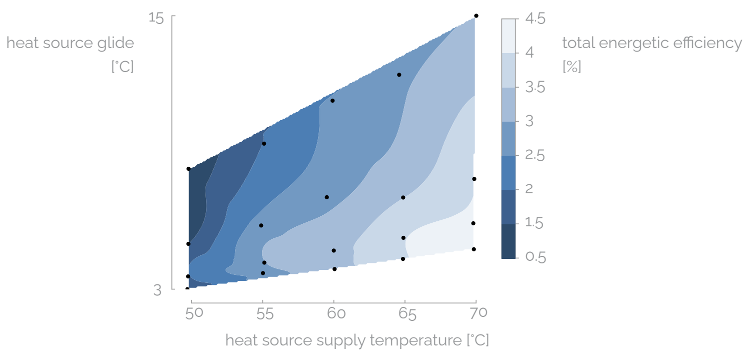
expander model: $\eta_{is} = f(\eta_{is,max}, BVR)$ — built-in volume ratio of the expander; maximum isentropic efficiency

From 150 W and less, maximum energetic efficiency drop significantly



The Carnot efficiency corresponding to a 70-15 °C temperature duet is 16%

A trade-off between the ORC efficiency and the thermal storage density must be found to suit a Carnot battery application



A **large glide** at the evaporator (= heat source) **favours the storage density** of the sensible thermal storage but is **detrimental for the ORC efficiency**

The **maximum** evaporator glide reachable while maintaining a **decent efficiency** is **proportional** to the **supply temperature**

Perspectives

The upcoming work will consist in experimentally coupling the ORC with a low temperature sensible thermal energy storage and investigating the best control strategy to extract the stored energy in the most efficient way

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References

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[2] Rahbar, K. et al. (2017) 'Review of Organic Rankine cycle for small-scale applications', Energy Conversion and Management, 134, pp. 135–155.