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Carnot battery integration in a geothermal power plant: study case of Zorlu Enerji

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SEHRENE

Context and case study introduction

Carnot battery integration in the **industrial sector**, **generating** a lot of **waste heat**, can improve energy efficiency and reduce greenhouse gases emissions.

This study case, part of the **SEHRENE EU project, aims to implement a Carnot battery** in the 80MW Kızıldere-II geothermal plant of Zorlu Enerji **in Türkiye**.

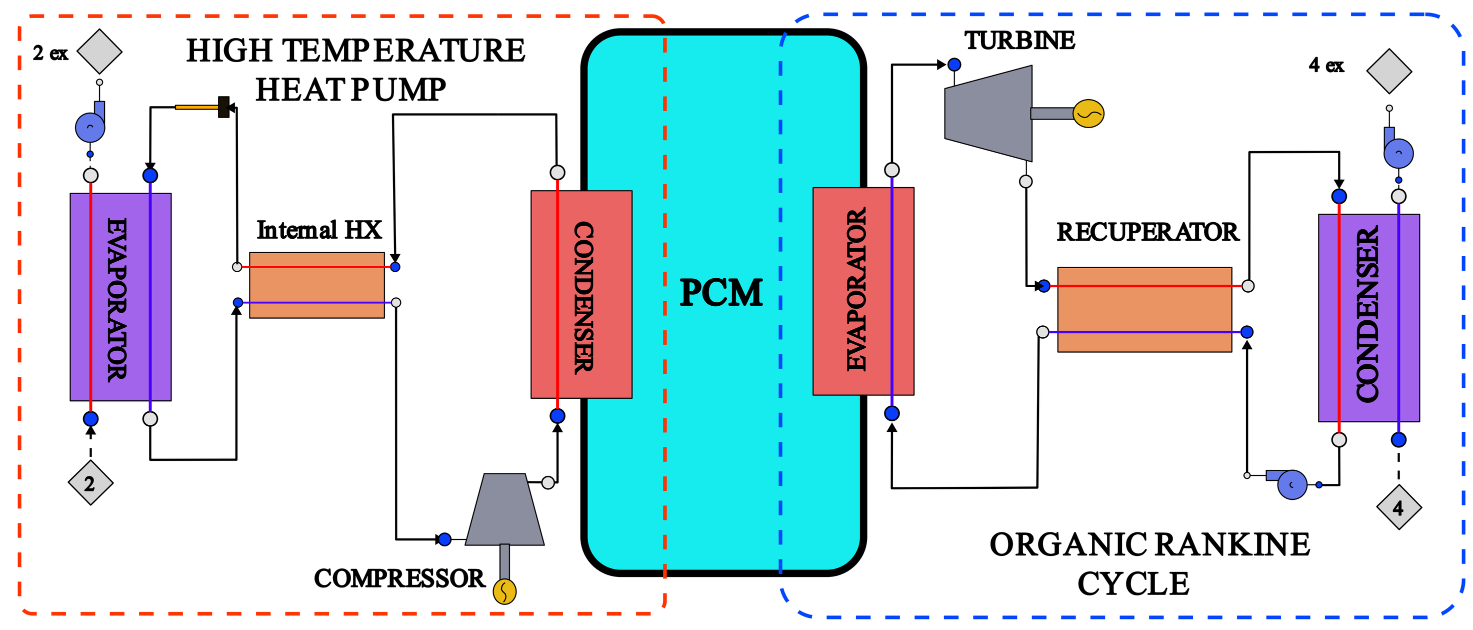
This Electro-Thermal Energy Storage (**ETES**) **includes** a High-Temperature Heat Pump (**HTHP**) with an internal heat exchanger, a Phase Change Material (**PCM**) storage and an Organic Rankine Cycle (**ORC**) with a recuperator.

Re-injection wells brine at 113.1°C from the plant is chosen as the waste heat source, supplied **to the Heat Pump evaporator** at a flow rate of 857.9kg/s.

Cooling water at 24°C from the plant **supplies the ORC condenser** at a flow rate of 2500kg/s.

Reference parameters and architecture

Parameter	$\Delta T_{pp,cd}$ / $\Delta T_{pp,ev}$	η_{HX}	$\eta_{s,cp}$, $\eta_{s,tu}$ $\eta_{s,pp}$	$\eta_{v,cp}$ $\eta_{v,pp}$	T_{PCM}	$t_{discharge}$/ $t_{discharge}$	V_{PCM}
Value	3	0.8	0.65	0.95	160	4 / 2	322.2
Unit	K	-	-	-	°C	h	m^3

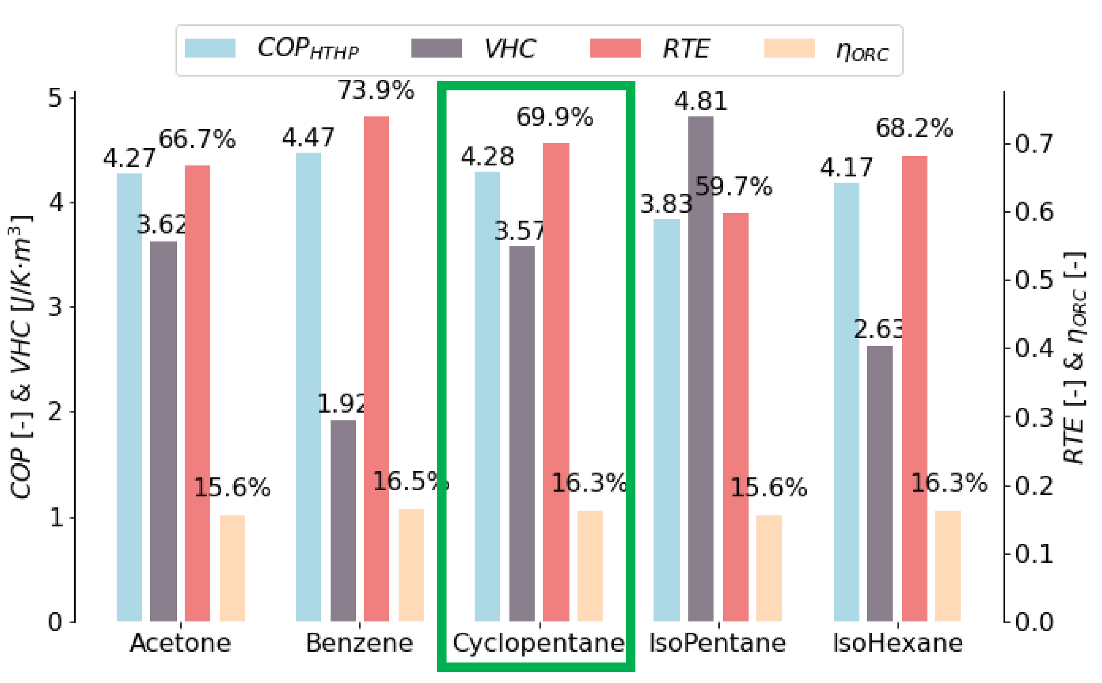


Refrigerant selection

Some pre-selected **refrigerants** are **not suitable** because of:

- **Too low critical pressure**: R1234ze(Z), R245fa, R600 and R1233zd(E)
- **Too low saturation pressure** in the ORC condenser, highering the risks of leakage: ethanol, methanol, cyclohexane, and toluene

Remaining **candidates are compared** by Heat Pump **COP**, ORC efficiency (η_{ORC}), Round Trip Efficiency (**RTE**) and Volumetric Heat Capacity (**VHC**):



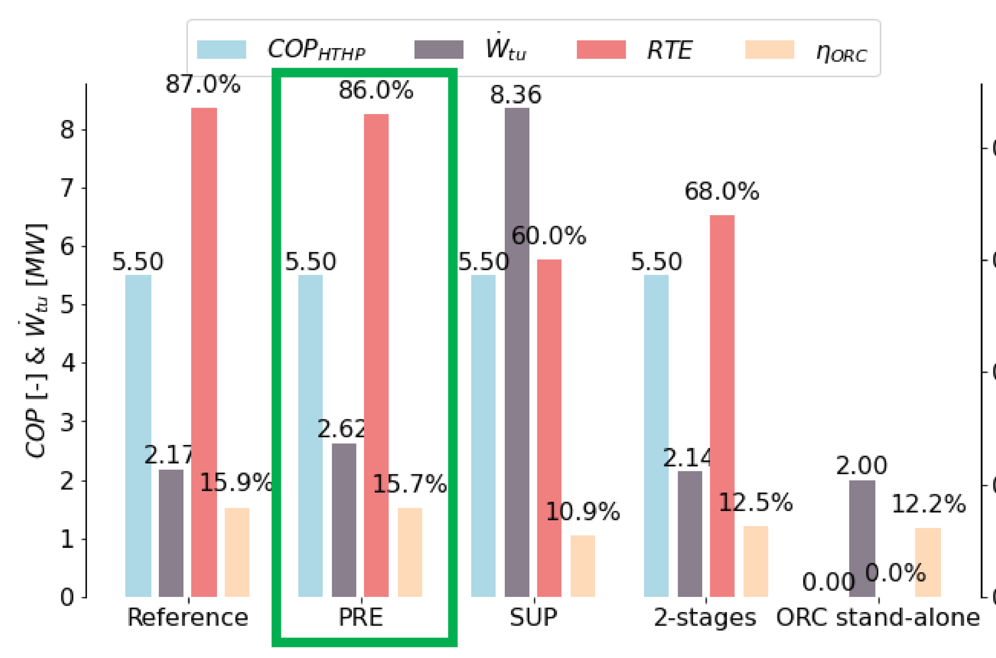
Benzene has the best performances, but its low VHC leads to larger components so higher investment costs.

Finally, **cyclopentane is chosen**.

Architecture selection

As it is possible to supply **Waste Heat** (WH) **to the ORC** during the Carnot battery discharge, **new architectures are imagined** (with T_{PCM}=150°C):

- PRE: Integration of a **preheater** fed with WH before the PCM
- SUP: Evaporator fed by WH and PCM as a **superheater**
- 2-stages: Integration of a **2-stages ORC**. High-pressure turbine supplied by the PCM and low-pressure turbine by WH
- ORC standalone: **Only an ORC**, directly fed with WH



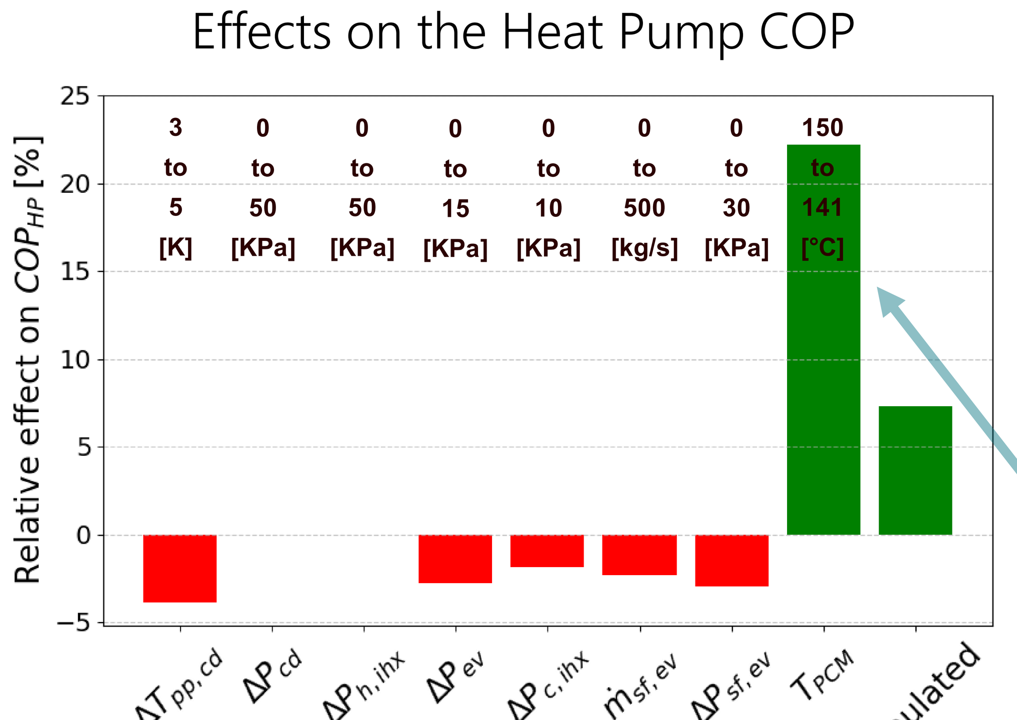
Architectures are compared.

SUP has a high output power ($\dot{W}_{tu}$) but a low ORC efficiency.

PRE is chosen as it shows the best trade-off between Round-Trip Efficiency (RTE) and **output power**.

Parameters refinements through a sensitivity study

Effects on the Heat Pump COP



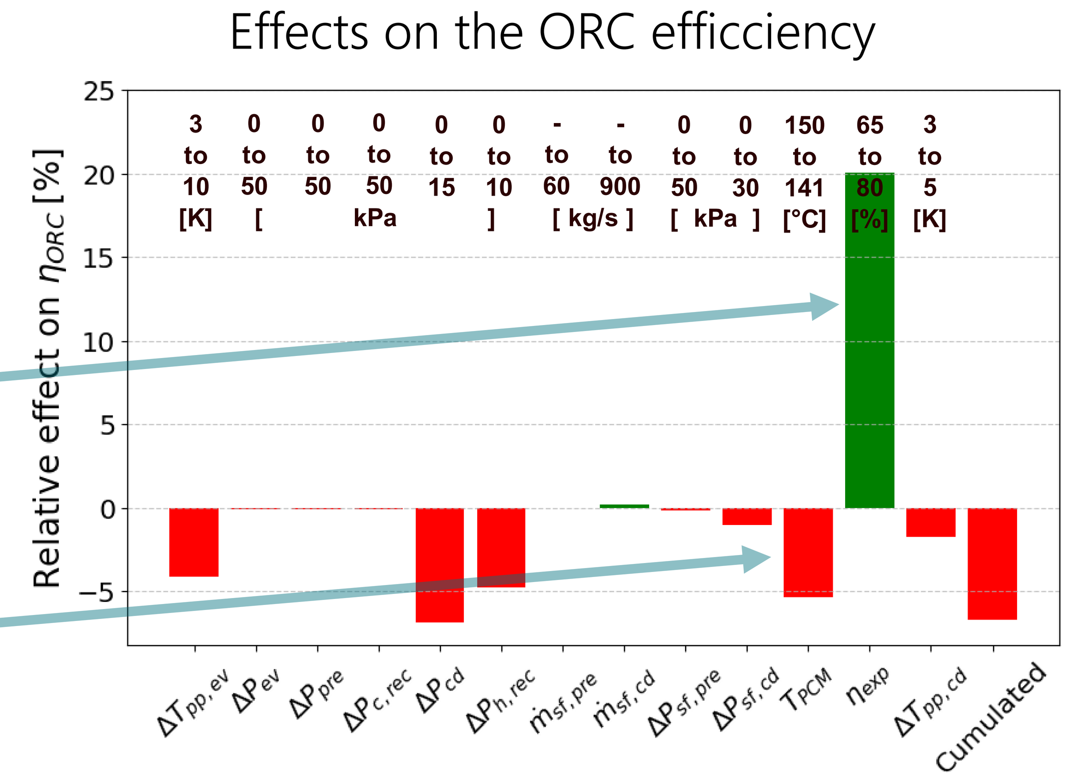
Pressure drops and **auxiliaries** are included, and **pinch points** are adapted, **decreasing performances**.

The objective is to **keep a similar RTE**.

Turbine efficiency of the ORC was **increased** to a still realistic value.

PCM temperature was **decreased**. This **affect positively** the HTHP COP and **negatively** the **ORC efficiency**. The overall effect **benefits** for the **RTE**.

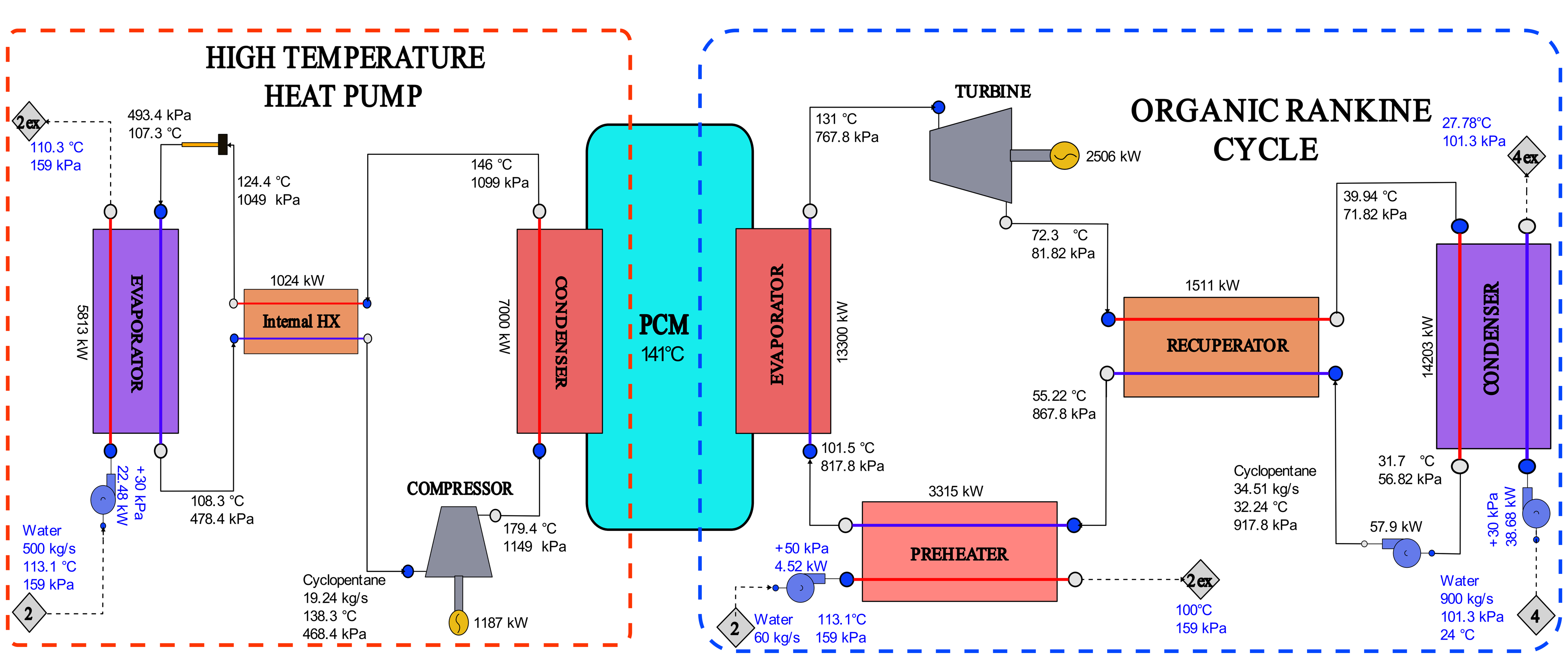
Effects on the ORC efficiency



Results before (B) and after (A) refinement shows similar RTE

	B	A
η_{orc} [%]	15.7	14.4
COP [-]	5.5	5.9
RTE [%]	86.3	85.0
$\dot{W}_{cp}$ [MW]	1.23	1.19
$\dot{W}_{net}$ [MW]	2.62	2.51
T_{PCM} [°C]	150	141

Final architecture and thermodynamic states



Heat exchanger areas

Heat exchanger areas are computed thanks to the F-LMTD method and with typical heat transfer coefficients values.

Heat Exchanger	HTHP Evaporator	HTHP IHX	HTHP Condenser	ORC Evaporator	ORC Preheater	ORC Recuperator	ORC Condenser
A [m²]	1103	262.6	1525	1618	147.9	374.1	1081

Future work

- Detailed sizing of the components
- Dynamic study and charge optimization of the whole system
- Study of an energy management system which features this machine

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