Modelisation of an Organic Rankine Cycle with R245fa as working fluid

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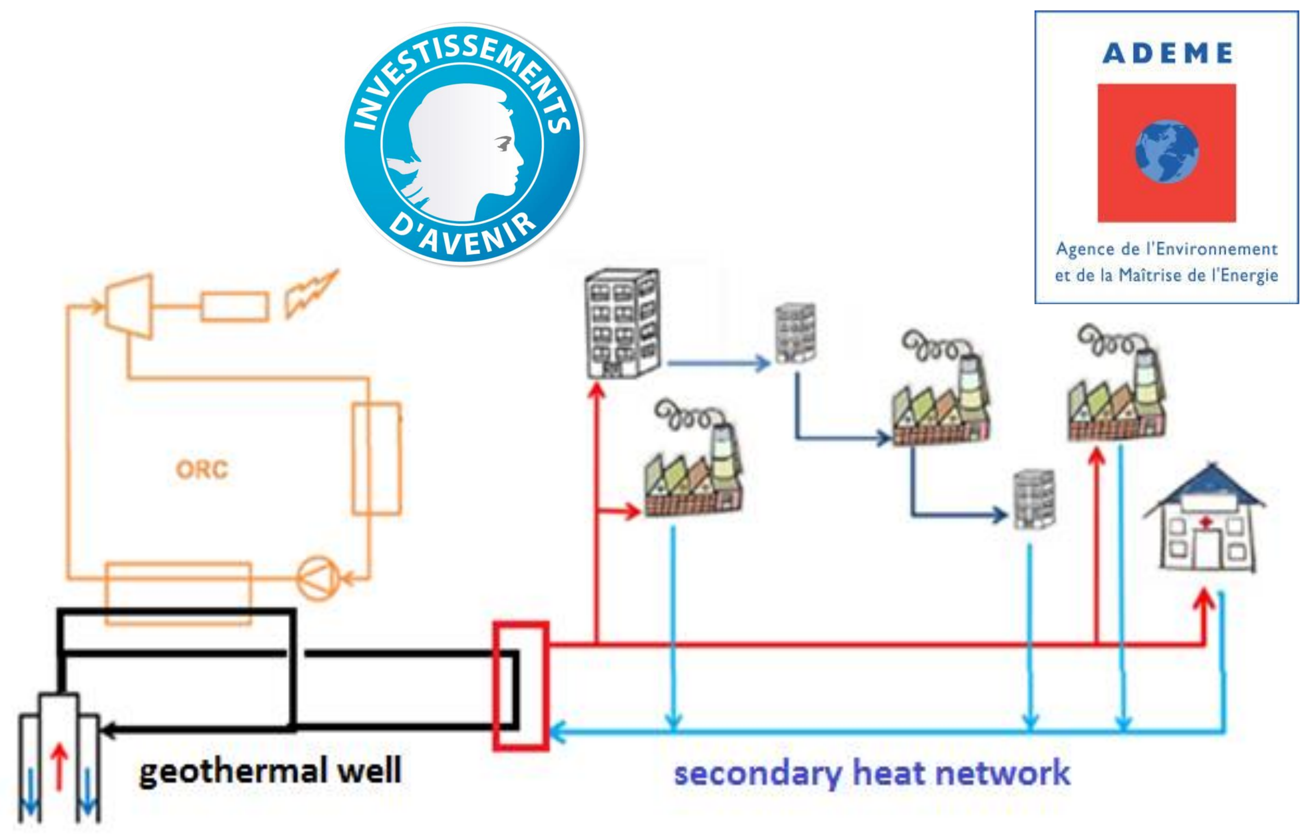
Context & Project Objective

A consortium (10 partners including the Latep), led by FONROCHE Géothermie, works on the FONGEOSEC project, an "Investissements d'Avenir" organized by the French Agency for Environment and Energy – ADEME.
To meet the French and International energetics needs, the aim of this project is to design and create an innovative demonstrator of a high energy geothermal power plant. Within this project, the LaTEP is responsible for a software development that helps to find the optimal design of secondary heat distribution network (district heating) of the geothermal power plant. An Organic Rankine Cycle (ORC), included in the optimization, is used to transform geothermal power into electricity and heat.

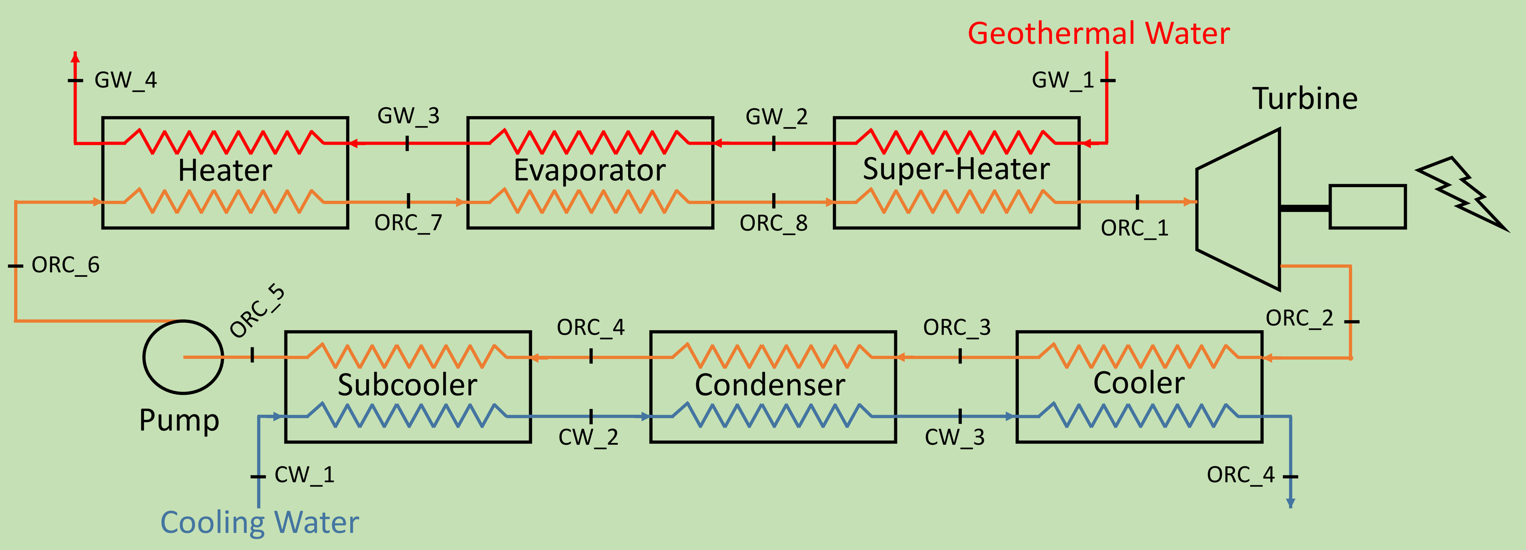


Modelisation

Methodology

- The optimization will be done using GAMS® software. Unfortunately, thermodynamics is unknown for it. Thus, two thermodynamics models (Equations Of State (EOS) SRK and Peng-Robinson) were developed in FORTRAN and were added to GAMS libraries.
- The two equations of state were compared to the NIST database REFPROP for R245fa fluid.
- Finally, a simple ORC model was solved in different configuration.

ORC Diagram



Nomenclature :

$\dot{m}$	mass flow
T	Temperature
P	Pressure
h	enthapy
s	entropy
f	fugacity
η	efficiency

Subscripts :

ORC_i	ORC positions
GW_i	Geothermal Water positions
CW_i	Cooling Water positions
gen	generator

Exposants :

is	isentropic
l	liquid
v	vapor

Equations

In first approximation, pressure losses are neglected :

$$P_{ORC\_6} = P_{ORC\_7} = P_{ORC\_8} = P_{ORC\_1} = \text{High Pressure}$$

$$P_{ORC\_2} = P_{ORC\_3} = P_{ORC\_4} = P_{ORC\_5} = \text{low Pressure}$$

For each position in ORC :

$$h_{ORC\_i} = h\,(T_{ORC\_i}, P_{ORC\_i})$$

Change of state in evaporator and condenser :

$$T_{ORC\_i} = T_{ORC\_i+1} \qquad \text{for} \qquad i = 3 \text{ and } 7$$

$$f^{l}\,(T_{ORC\_i}, P_{ORC\_i}) = f^{v}\,(T_{ORC\_i}, P_{ORC\_i})$$

Use of isentropic evolution in turbine and pump :

$$h^{is}_{ORC\_i+1} = h\,(T^{is}_{ORC\_i+1}, P_{ORC\_i+1}) \qquad \text{for} \qquad i = 1 \text{ and } 5$$

$$s\,(T_{ORC\_i}, P_{ORC\_i}) = s\,(T^{is}_{ORC\_i+1}, P_{ORC\_i+1})$$

Power and heat calculation :

- Turbine $W_{turb} = \dot{m}_{ORC} \cdot (h^{is}_{ORC\_2} - h_{ORC\_1}) \cdot \eta^{is}_{turb}$
- Pump $W_{pump} = \dot{m}_{ORC} \cdot (h^{is}_{ORC\_5} - h_{ORC\_4}) \,/\, \eta^{is}_{pump}$
- Evaporator

$$Q_{evap} = \dot{m}_{ORC} \cdot (h_{ORC\_1} - h_{ORC\_6}) = \dot{m}_{GW} \cdot (h_{GW\_4} - h_{GW\_1})$$

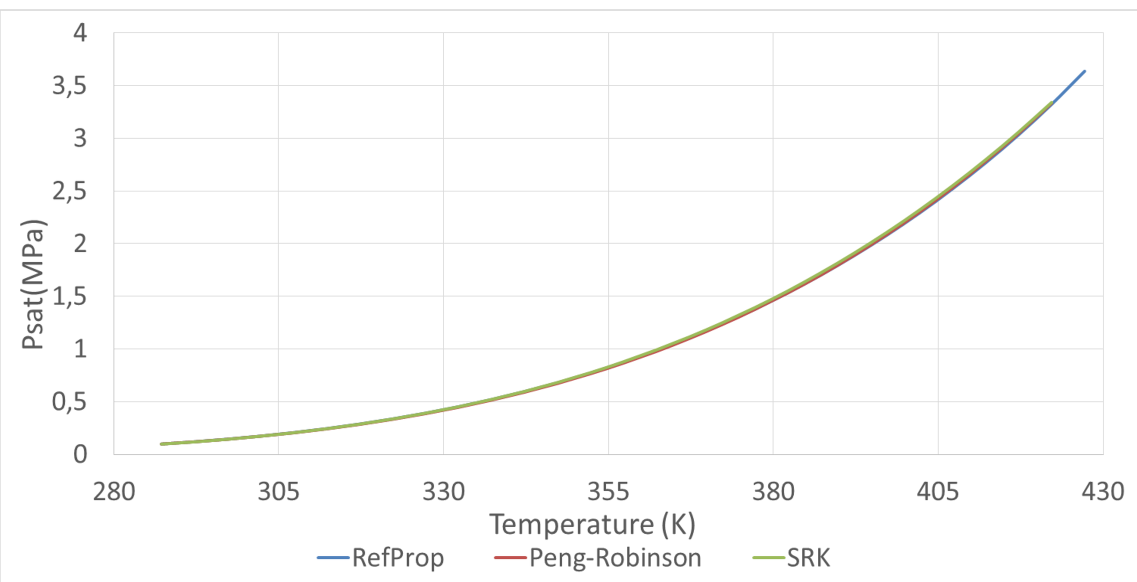
- Condenser

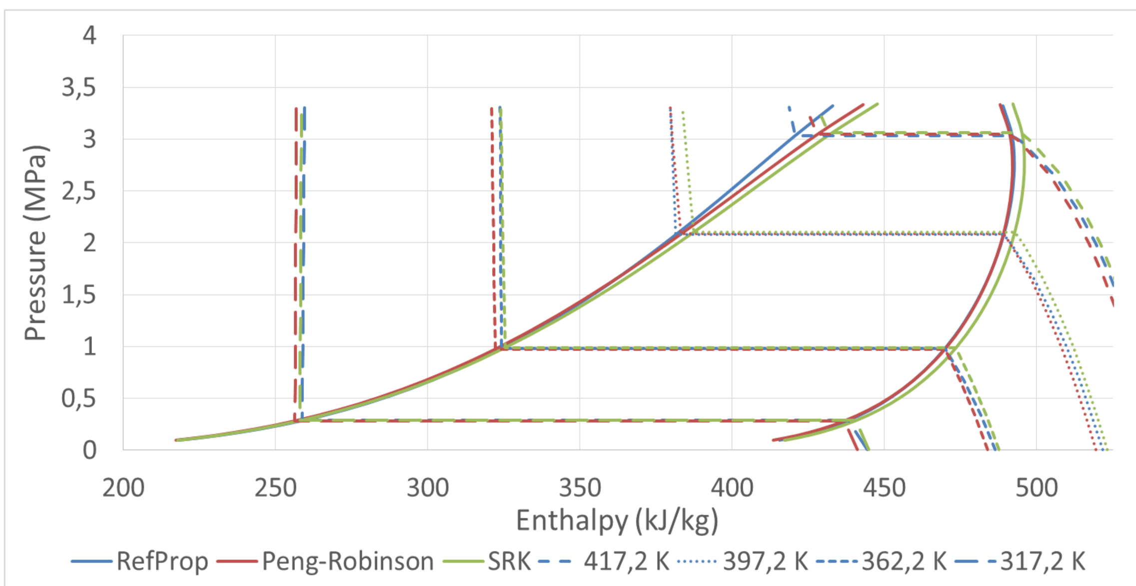
$$Q_{cond} = \dot{m}_{ORC} \cdot (h_{ORC\_5} - h_{ORC\_2}) = \dot{m}_{GW} \cdot (h_{CW\_4} - h_{CW\_1})$$

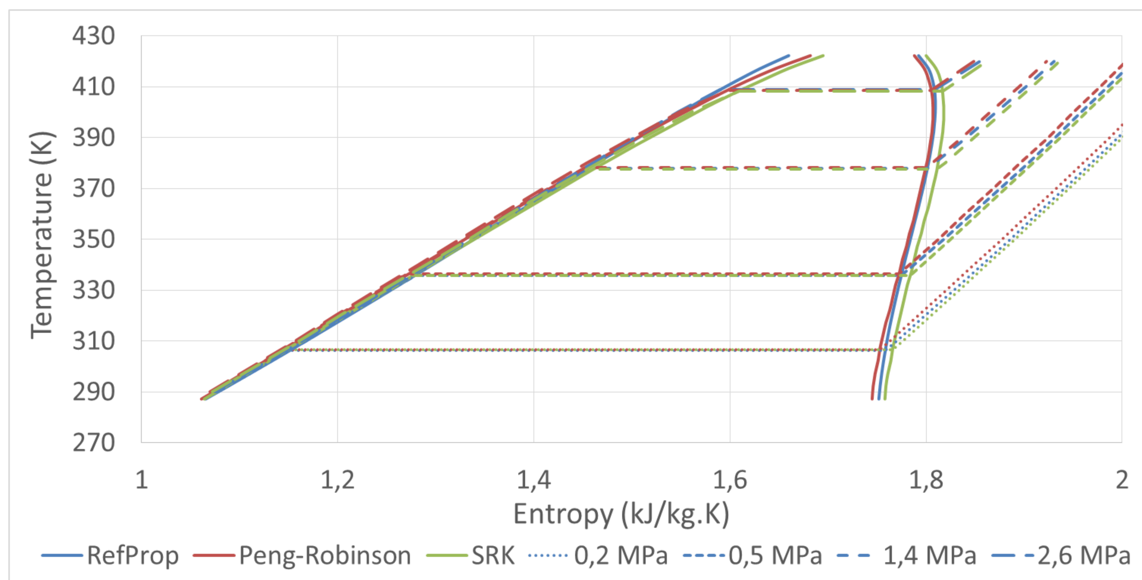
Net electric power :

$$W_{net} = |W_{turb}| \cdot \eta_{gen} - |W_{pump}|$$

Thermodynamic Model Validation

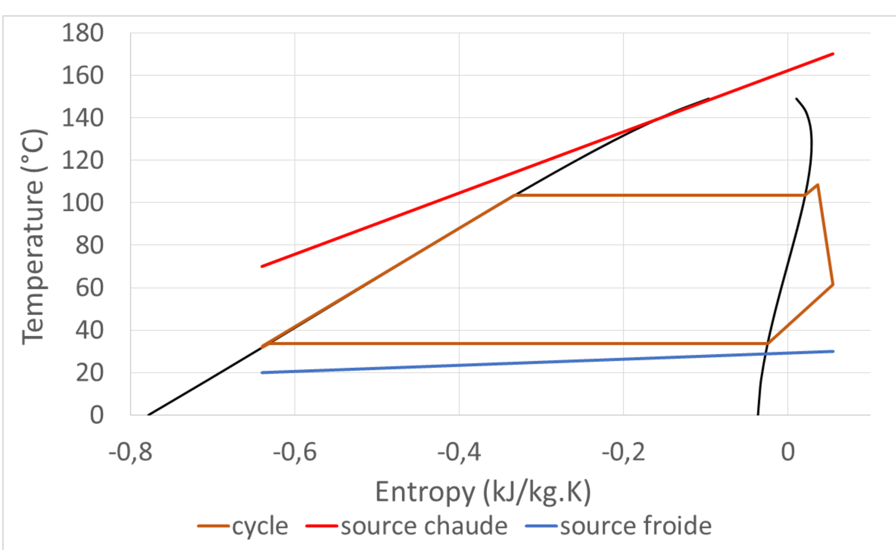


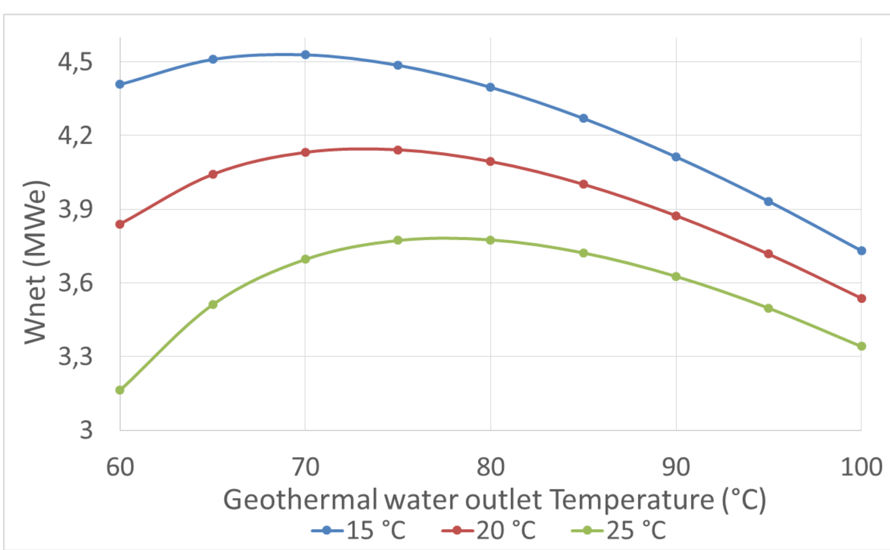




Modelisations Results

- For geothermal water at 170 °C and different temperature level for cooling water





Conclusions

- Peng-Robinson EOS give the best results.
- The modelisation cycle gives coherent results for an ORC, thermodynamics and modelisation are validated.
- By decreasing the geothermal re-injection temperature, the net electric power goes through a maximum.

Outlooks

- Design and cost determination for each module.
- Optimization of ORC.
- Optimization of the global system (ORC + district heating).