ORC2017

Working fluid parametric analysis for regenerative supercritical organic Rankine cycles for medium geothermal reservoir temperatures

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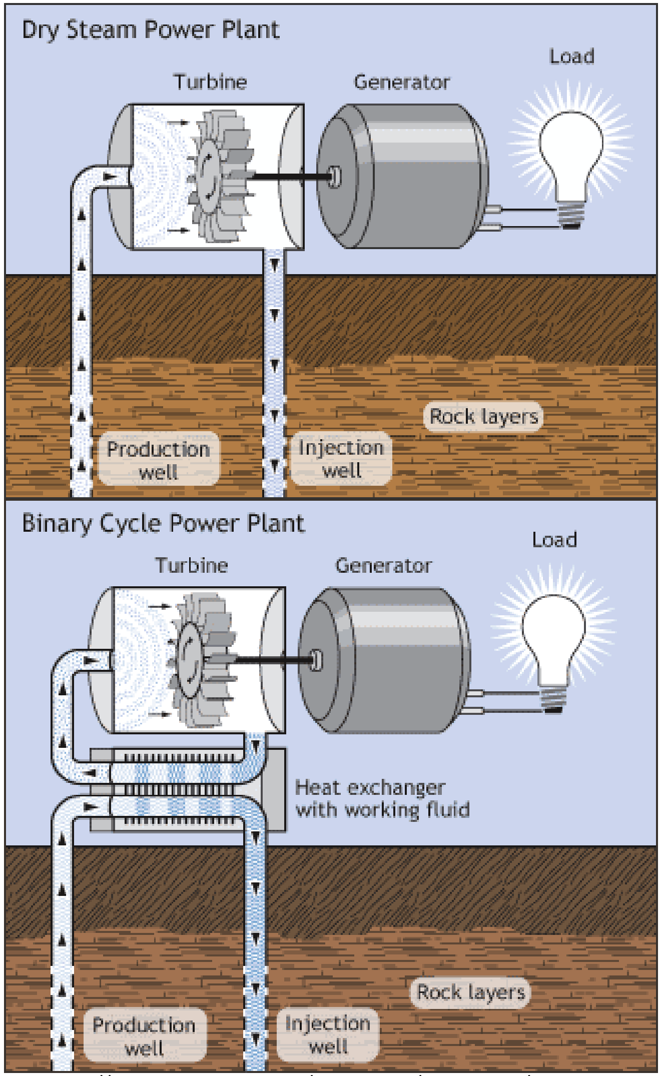
Introduction

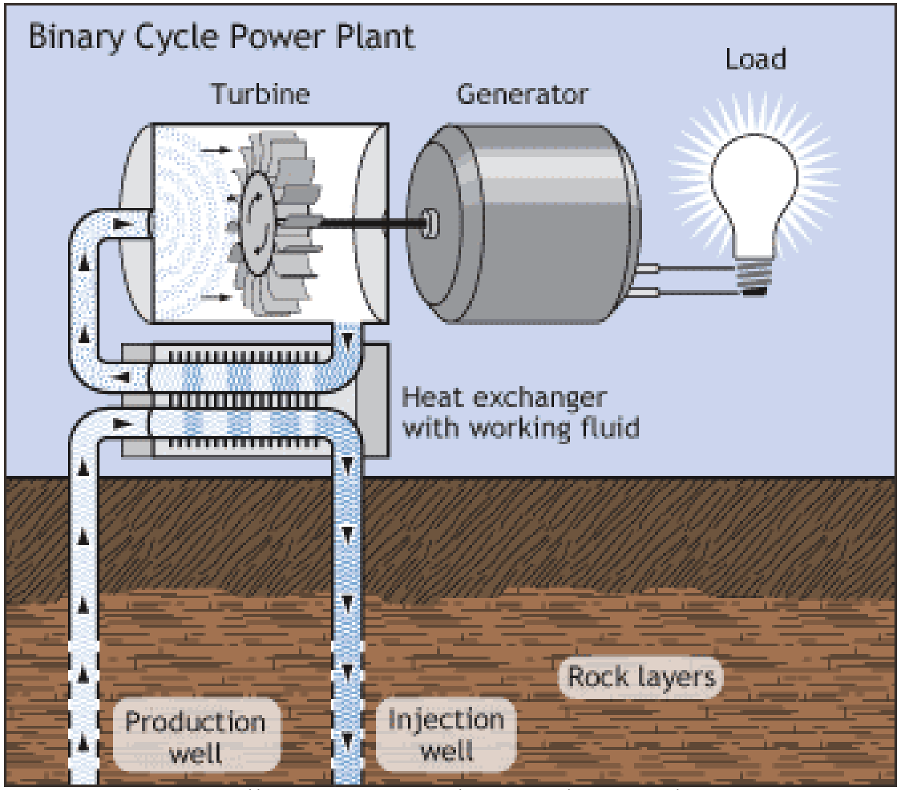
- Problem:
  - Conversion efficiency of geothermal energy
- Conventional approaches:
  - Flash steam
  - Binary systems with organic Rankine cycles (ORC)
- Solution:
  - Supercritical organic Rankine cycle



http://energyalmanac.ca.gov/renewables/geothermal/types.html

Objective

Find optimal fluids and operating conditions for a supercritical ORC suitable for medium geothermal reservoir temperatures



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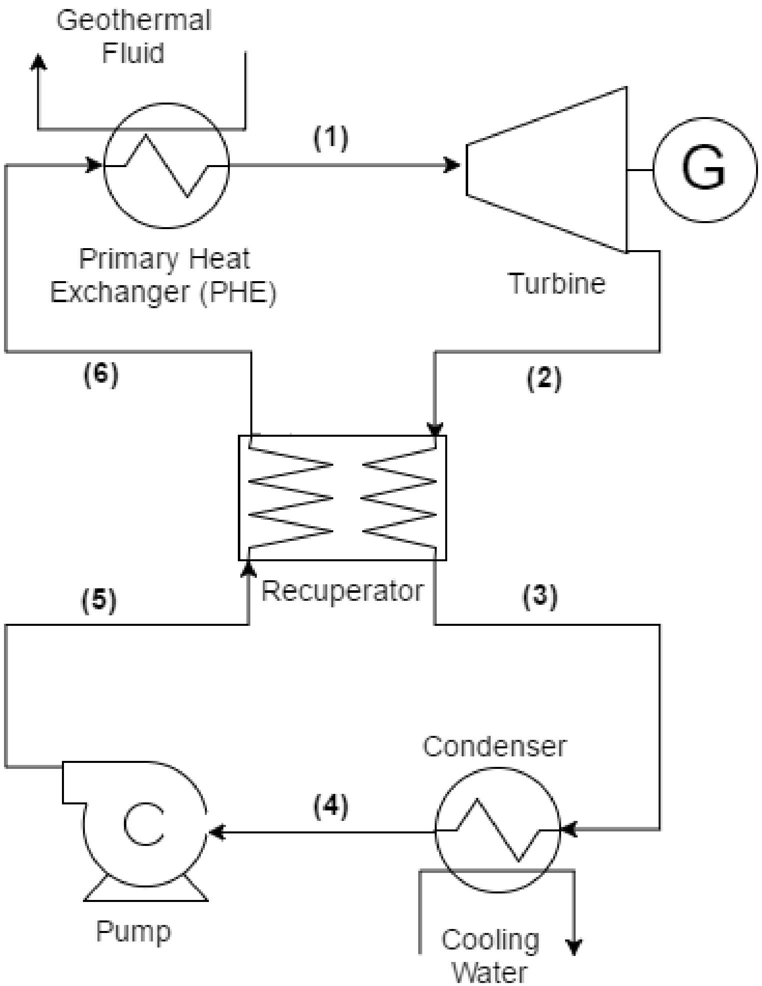
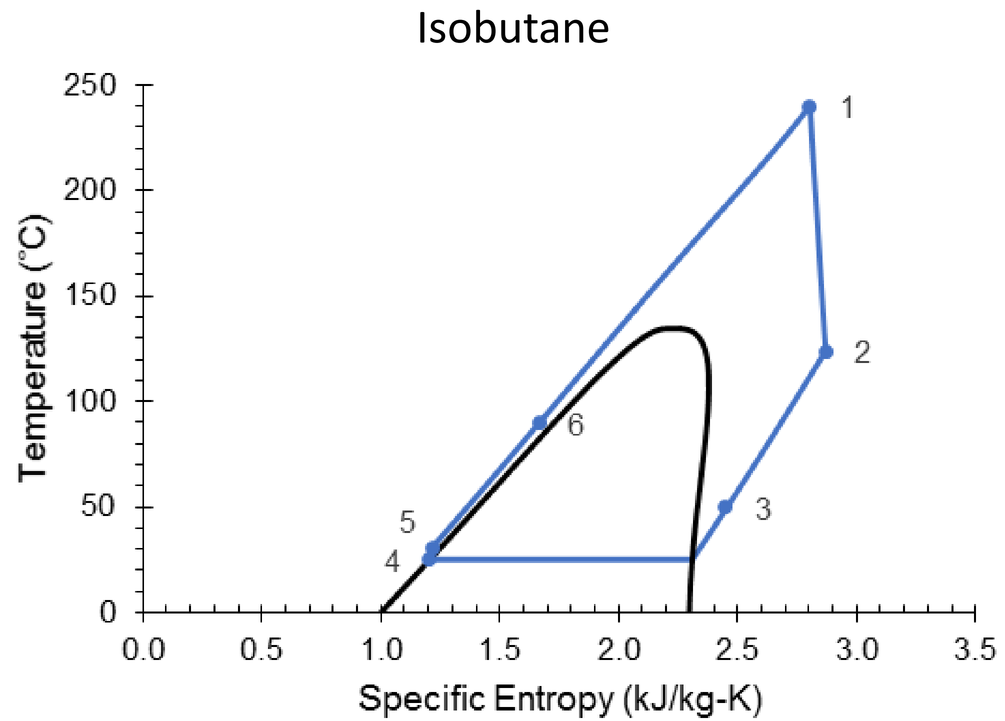
System Schematic

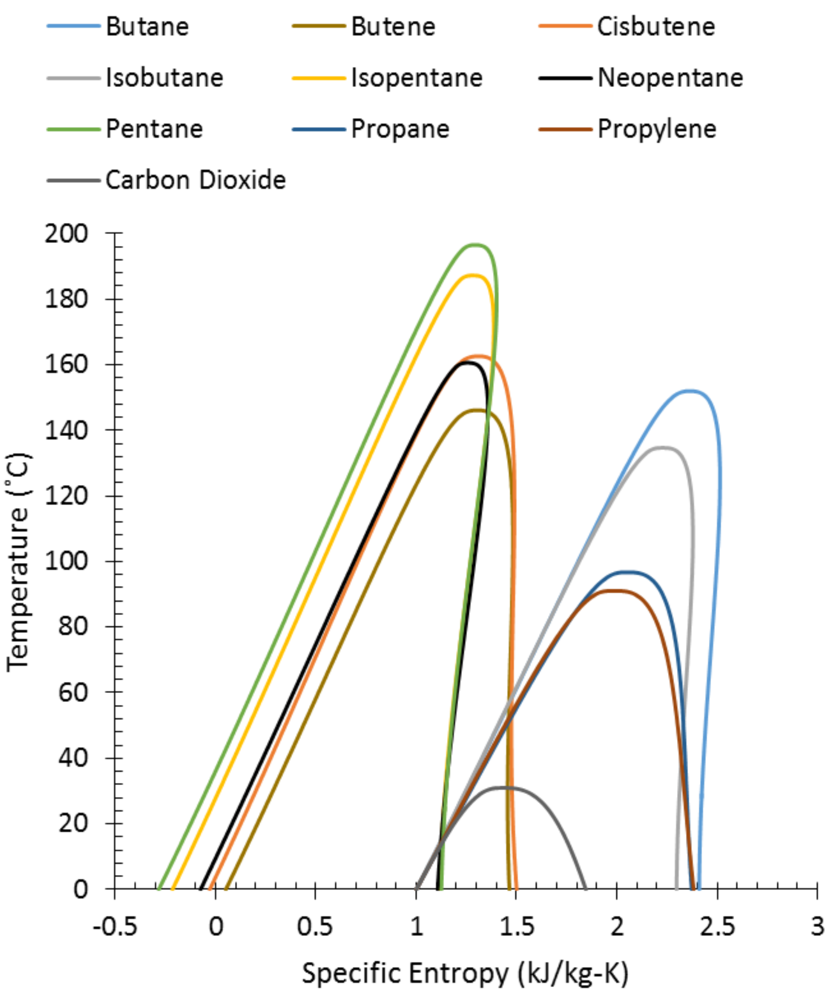




Working Fluids

- Parameters
  - Critical temperature < 200˚C
  - 100-year GWP < 150
  - ODP < 1
  - Ignition and degradation temperature

Fluid	Critical Pressure (MPa)	Critical Temp. (˚C)	Auto-Ignition Point (˚C)	100-year GWP	ODP
Butane (R600)	3.80	152	365	20	0
Butene	4.01	146	385		
Carbon Dioxide (R744)	7.38	31	-	1	-
Cis-butane	4.22	163	324	-	-
Isobutane (R600a)	3.63	135	460	20	0
Isopentane (R601a)	3.38	187	420	4	0
Neopentane	3.20	161	450		
Pentane (R601)	3.37	197	309	11	0
Propane (R290)	4.25	97	450	20	0
Propylene (R1270)	4.56	91	480	20	0



Model

MODEL

- MATLAB
- NIST REFPROP

Key equations

1) $\eta_I = \frac{\dot{W}_{net}}{\dot{Q}_{in}}$
2) $\dot{W}_{net} = \dot{W}_t - \dot{W}_p$
3) $\eta_{plant} = \frac{\dot{W}_{net}}{\dot{Q}_{max}} = \frac{\dot{W}_{net}}{\dot{m}_{hs}(h_{hs,in} - h_{hs,a})}$
4) $\eta_{II} = \frac{\eta_{plant}}{\eta_{rev,max}}$
5) $\eta_{rev,max} = 1 - \frac{T_L}{(T_H - T_L)/\ln\left(\frac{T_H}{T_L}\right)}$

ANALYSIS

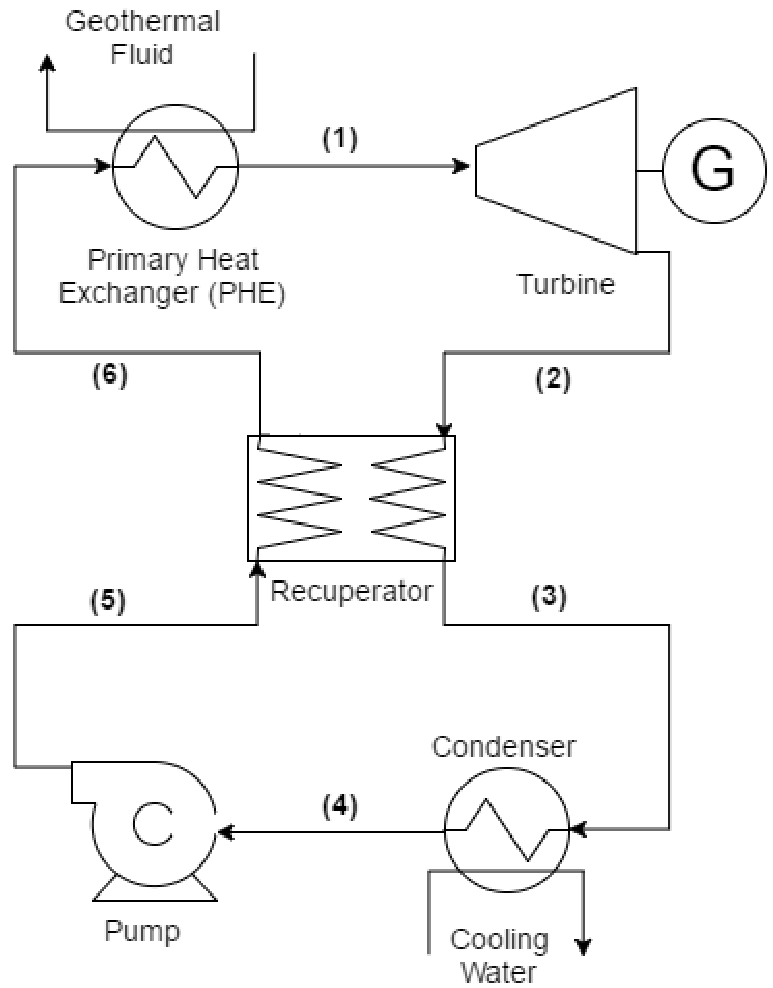
1) Parametric Analysis
   a) Vary turbine inlet temperature
   b) Vary turbine inlet pressure

2) Optimization
   a) First law efficiency
   b) Plant efficiency
   c) Second law efficiency
   d) Effectiveness

Model

ASSUMPTIONS

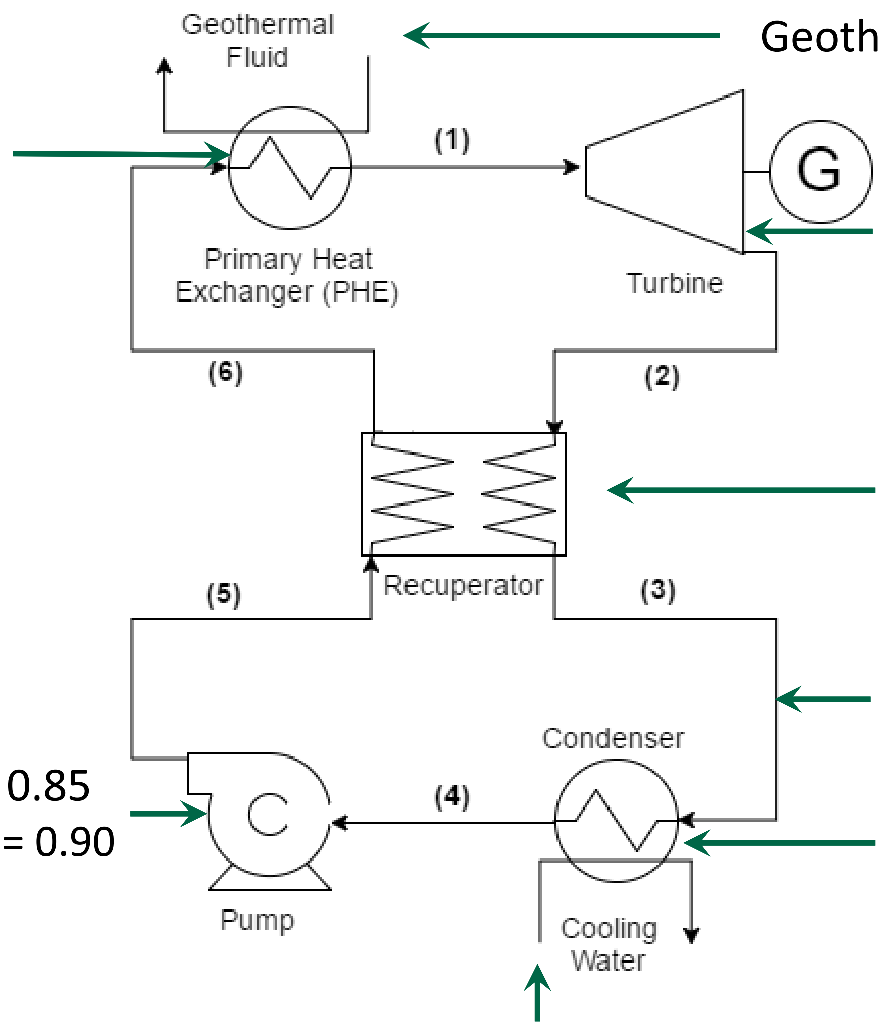
- The geothermal fluid is pure water and saturated liquid
- Pressure is constant in the heat exchangers
- There is no air leakage into the working fluid system
- Power consumption of auxiliary components are negligible



Design Inputs & Constraints

Geothermal inlet (1 kg/s): T1 + 11˚C

PHE pinch = 10˚C
Effectiveness = 0.9



Isentropic Efficiency = 0.85
Mechanical Efficiency = 0.90

Effectiveness = 0.8

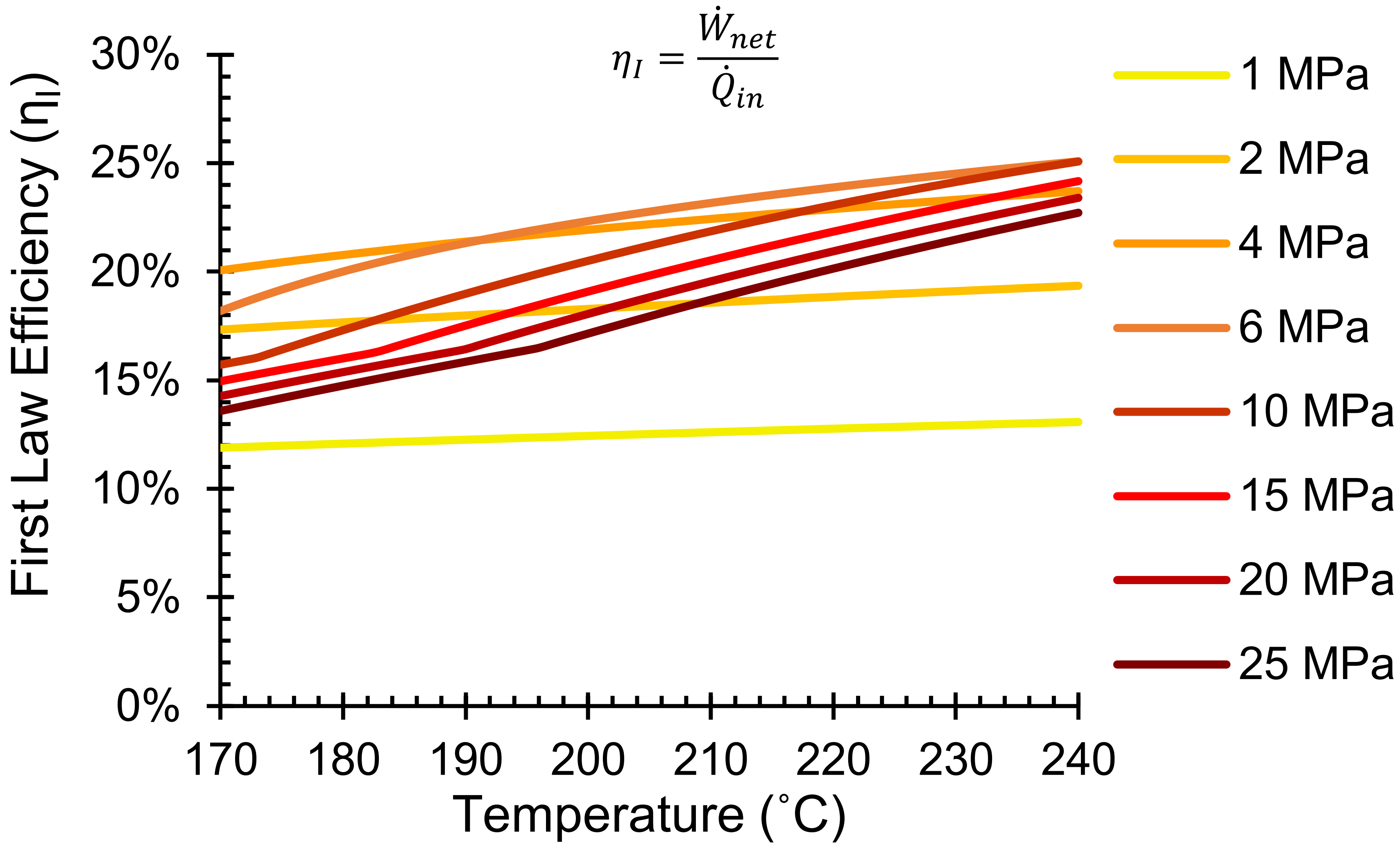
Condensing temp. = 25˚C

Isentropic Efficiency = 0.85
Mechanical Efficiency = 0.90

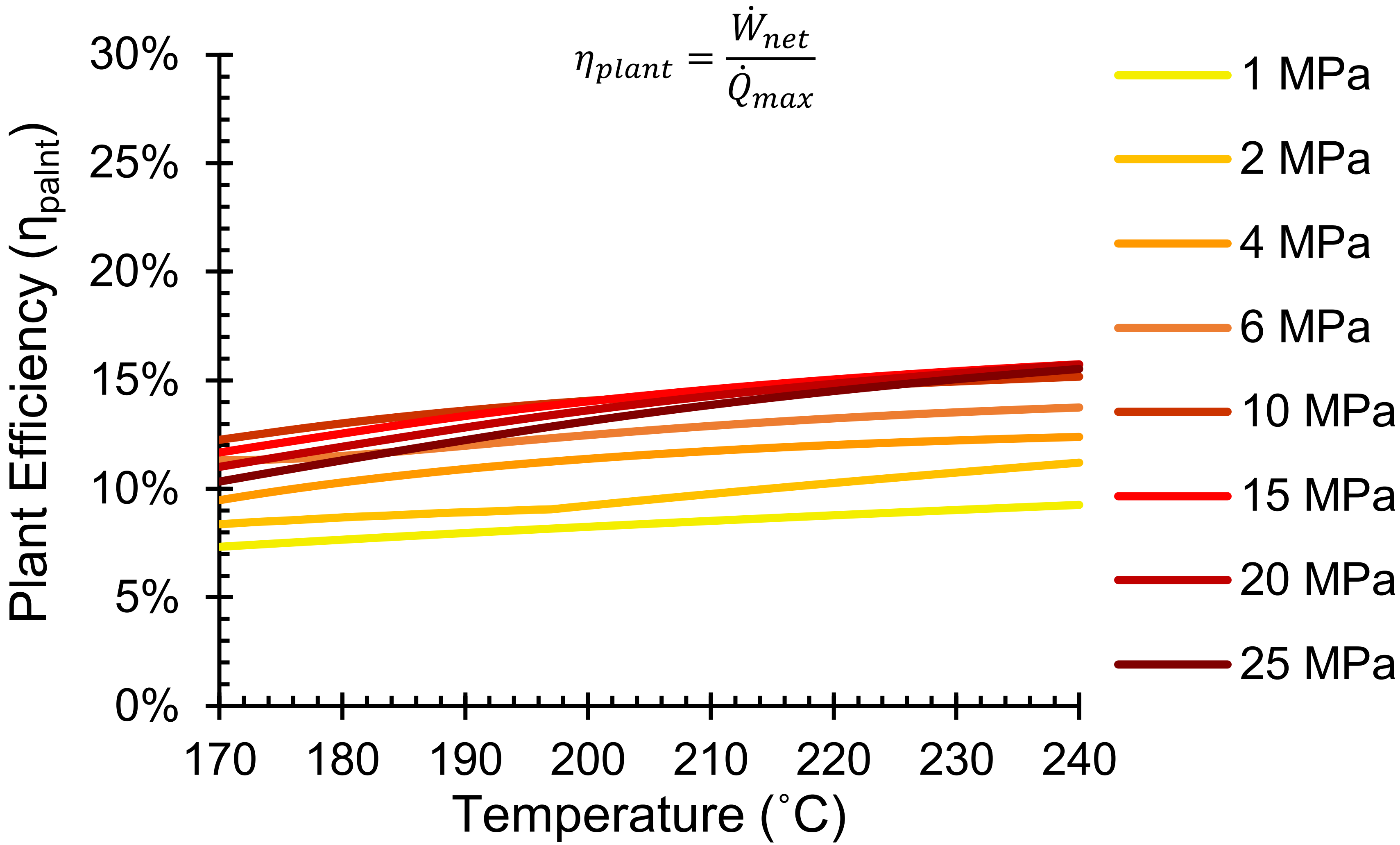
Condenser pinch = 3˚C
Effectiveness = 0.9

Cooling water. = 20˚C, 5 bar

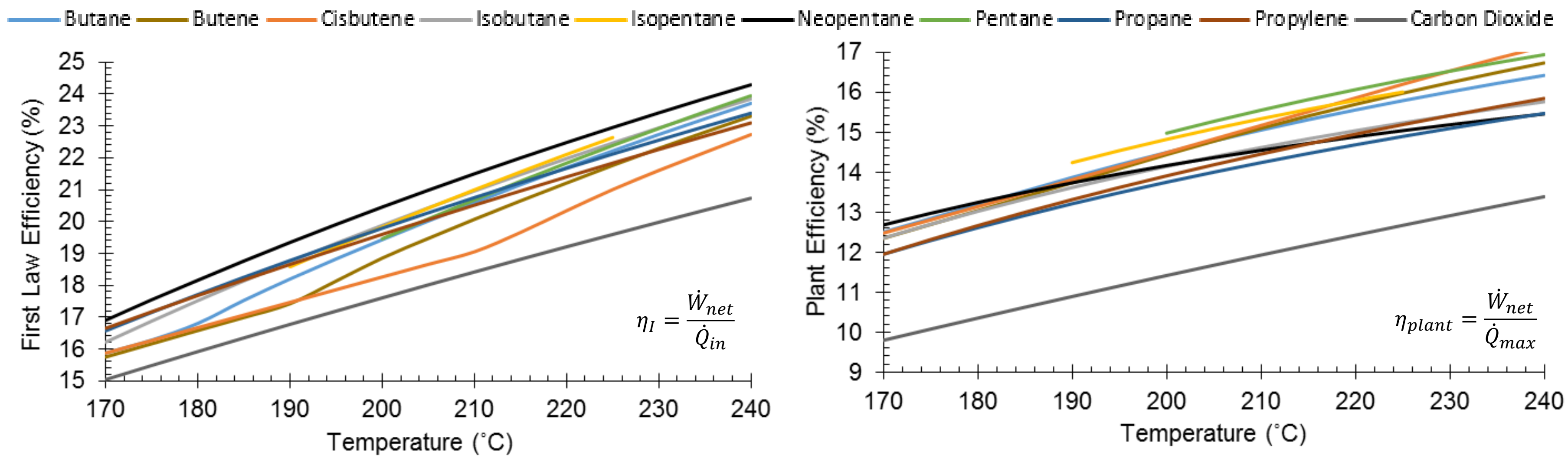
Parametric Analysis - Isobutane

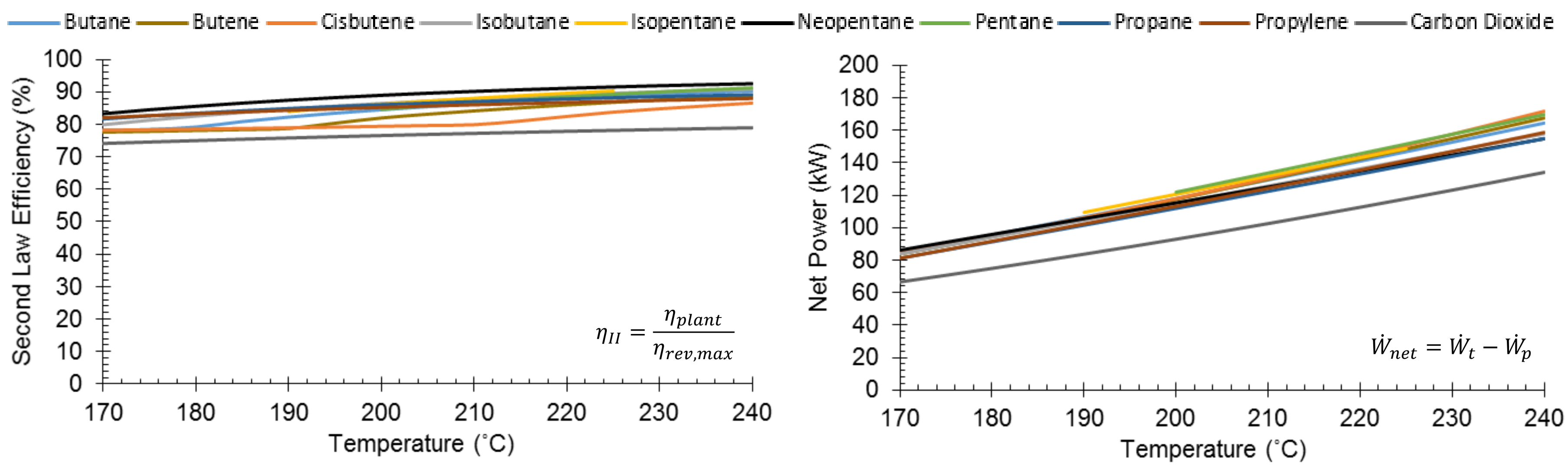


Parametric Analysis - Isobutane

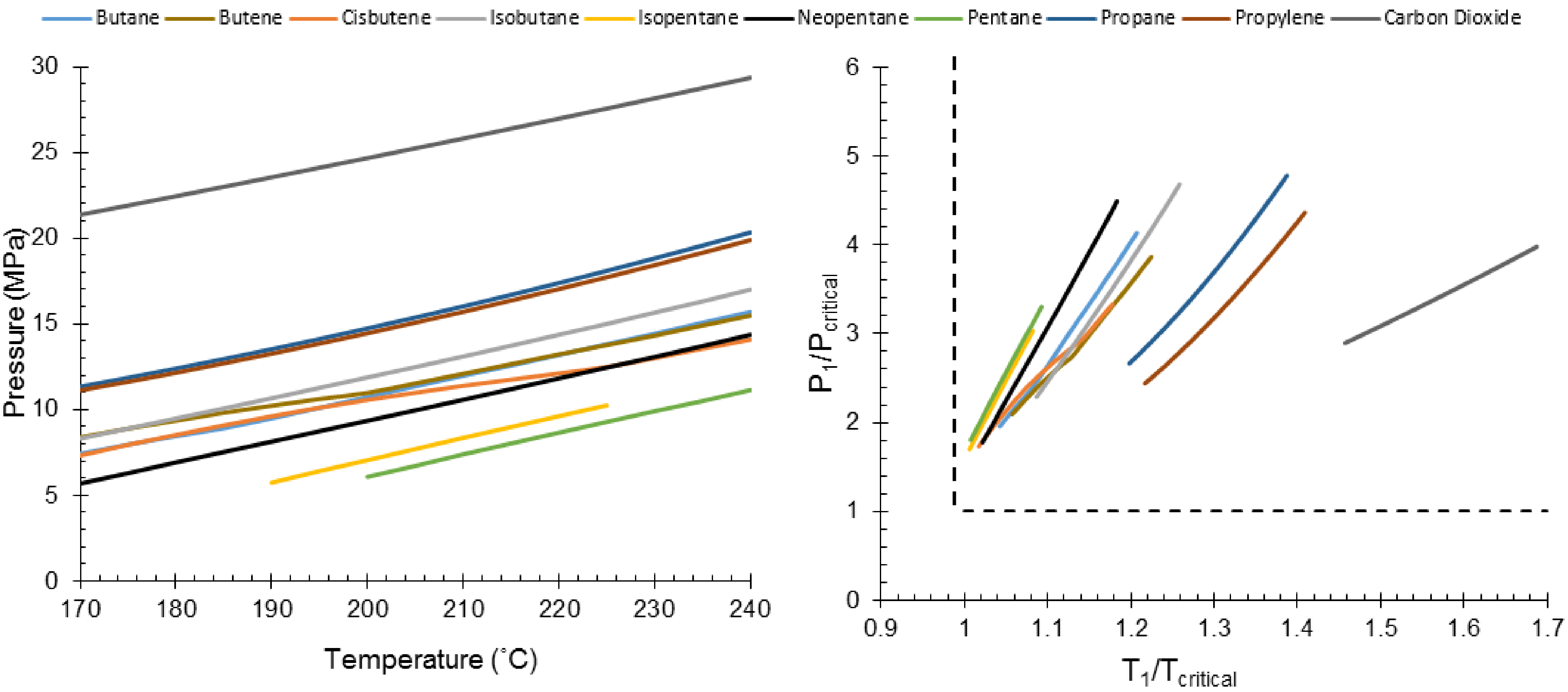


Optimization Results





Optimization Results - Pressure



Conclusion

- Key factors
  - Best performance in plant efficiency: **isopentane, *pentane, butane, butane, and cisbutene*
  - Worst performance: *Carbon dioxide*
  - Non-dimensionalized optimized conditions in respect to the critical point: *No clear trend*
  - For cases with varying inlet temperature: cisbutene, butene, and butane

- Future work
  - Consider auxiliary power
  - Compare different condensers suitable for geothermal power systems
  - Multi-variable optimization: recuperator, condensing temperature, etc

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Thank You

ANY QUESTIONS?