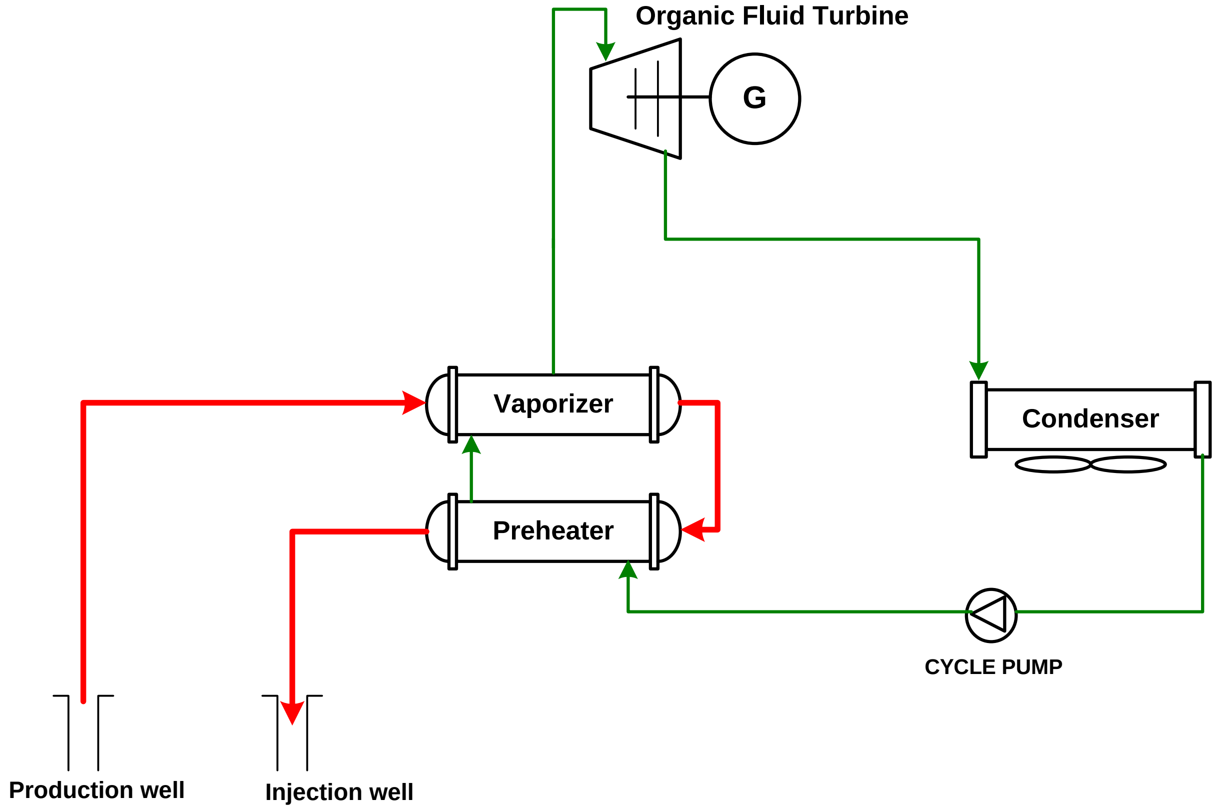
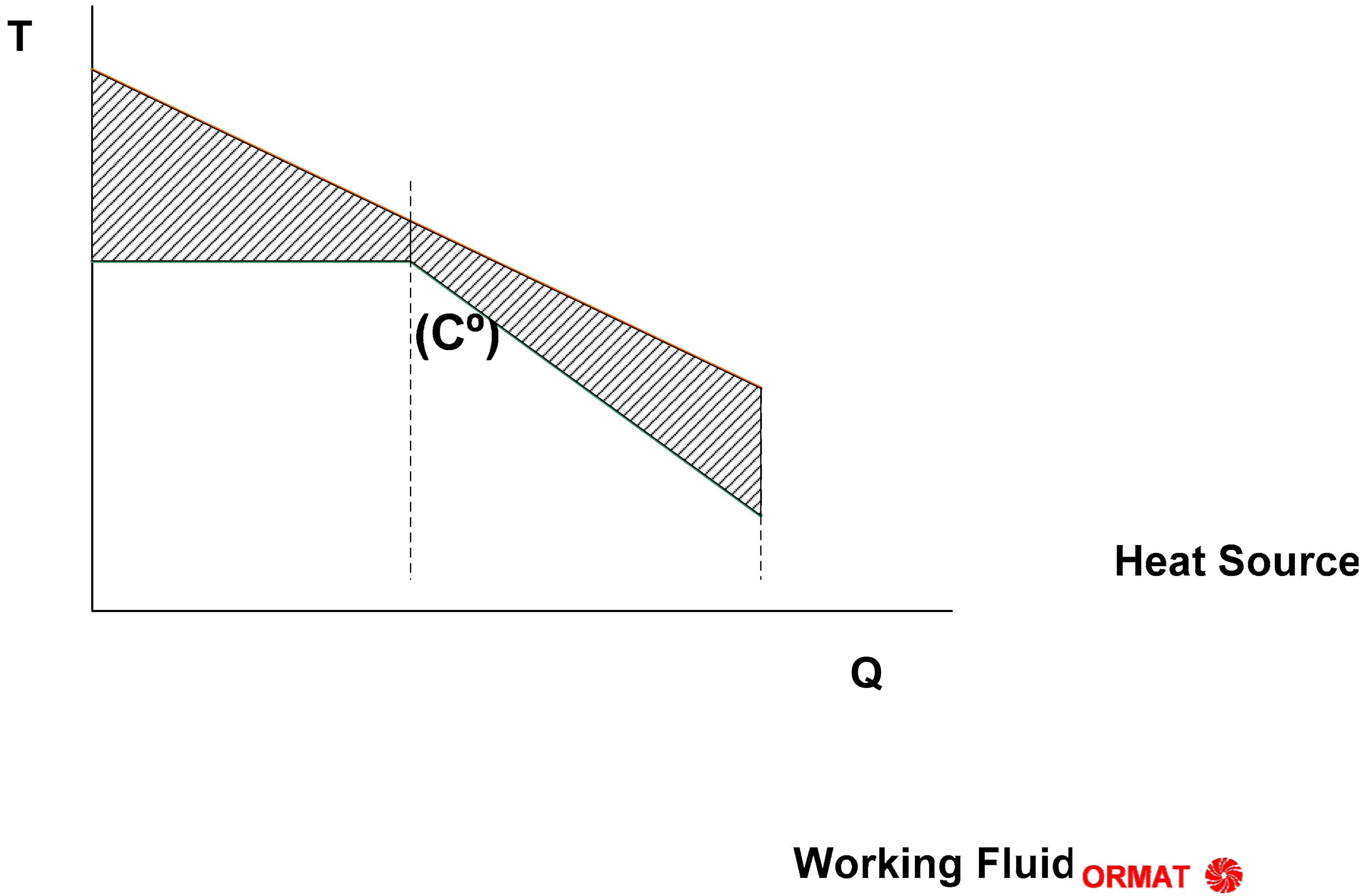
ADVANCED BINARY CYCLES

ORMAT

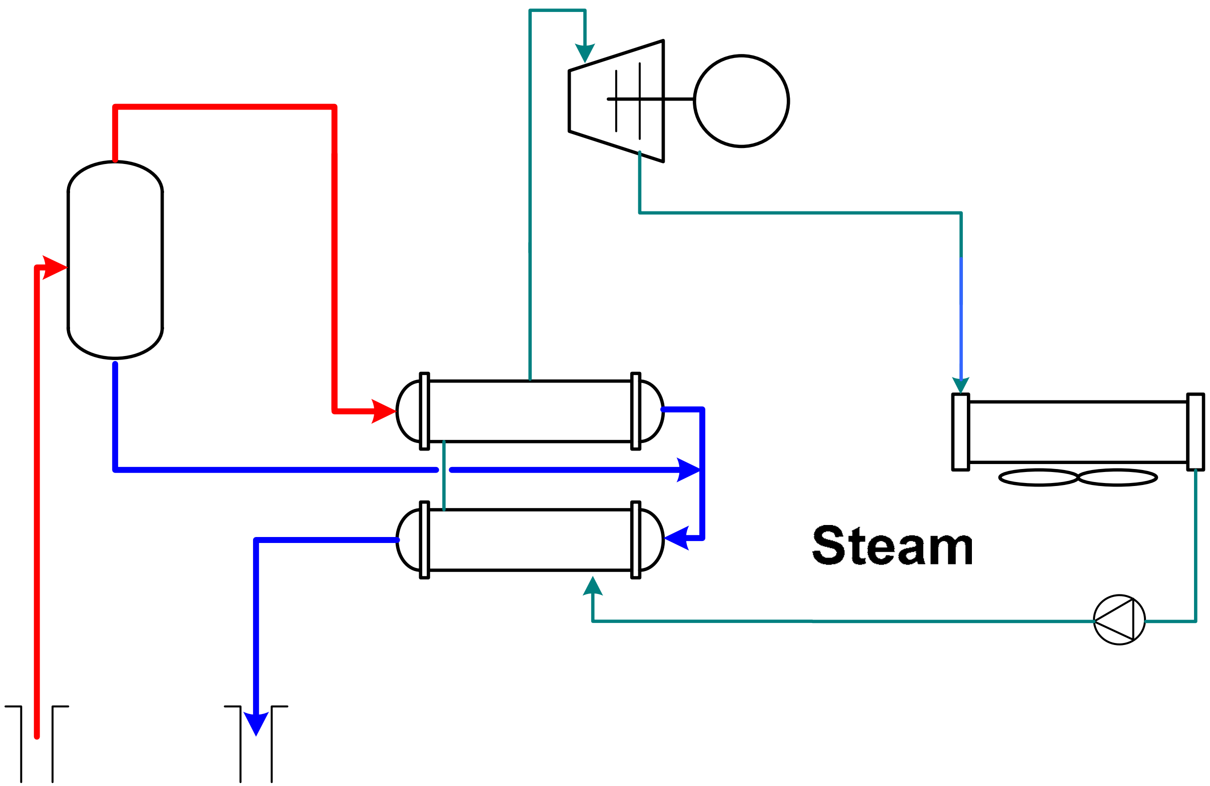
Organic Rankine Cycle





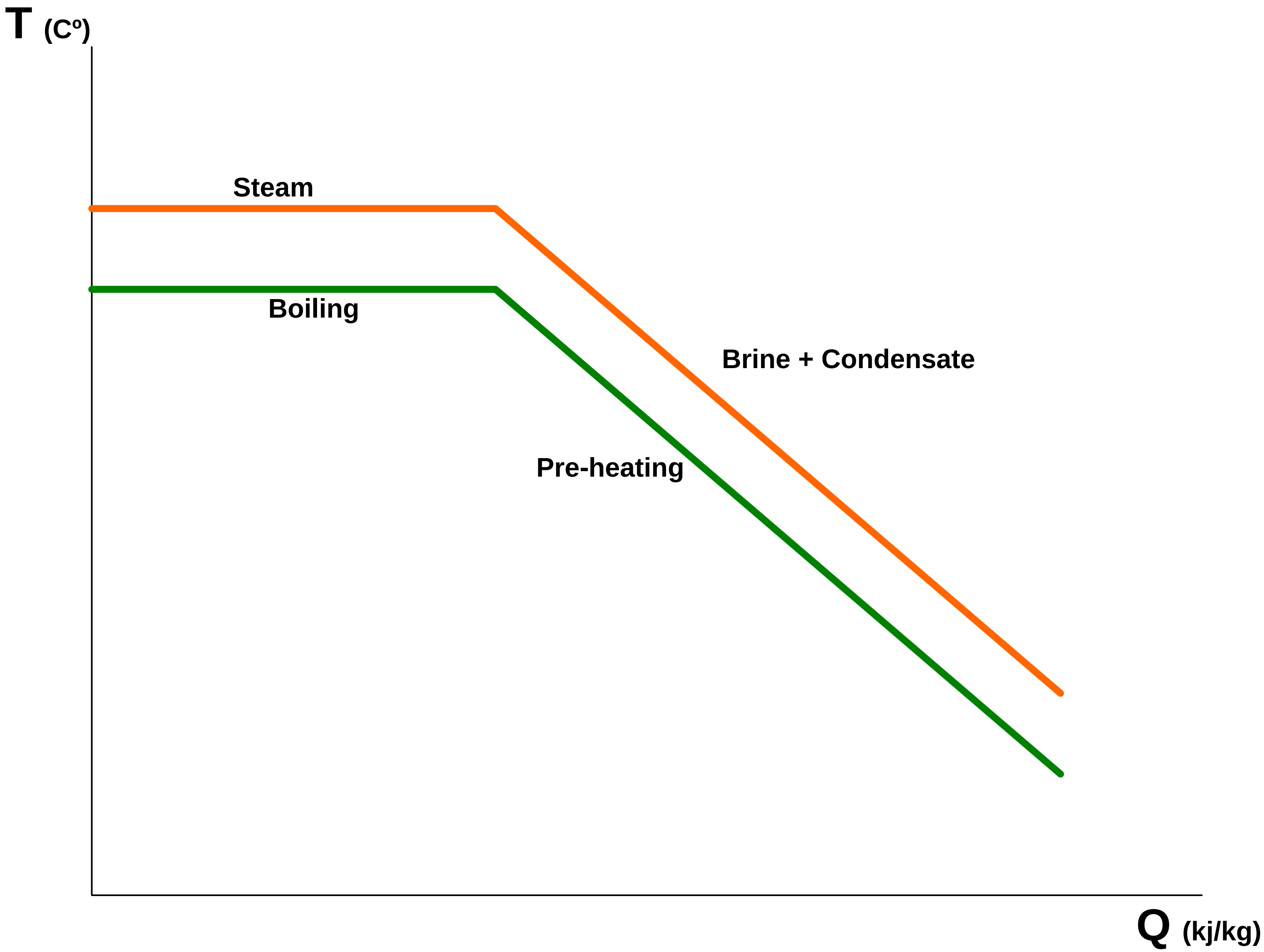
ORMAT

Bi Phase Organic Rankine Cycle

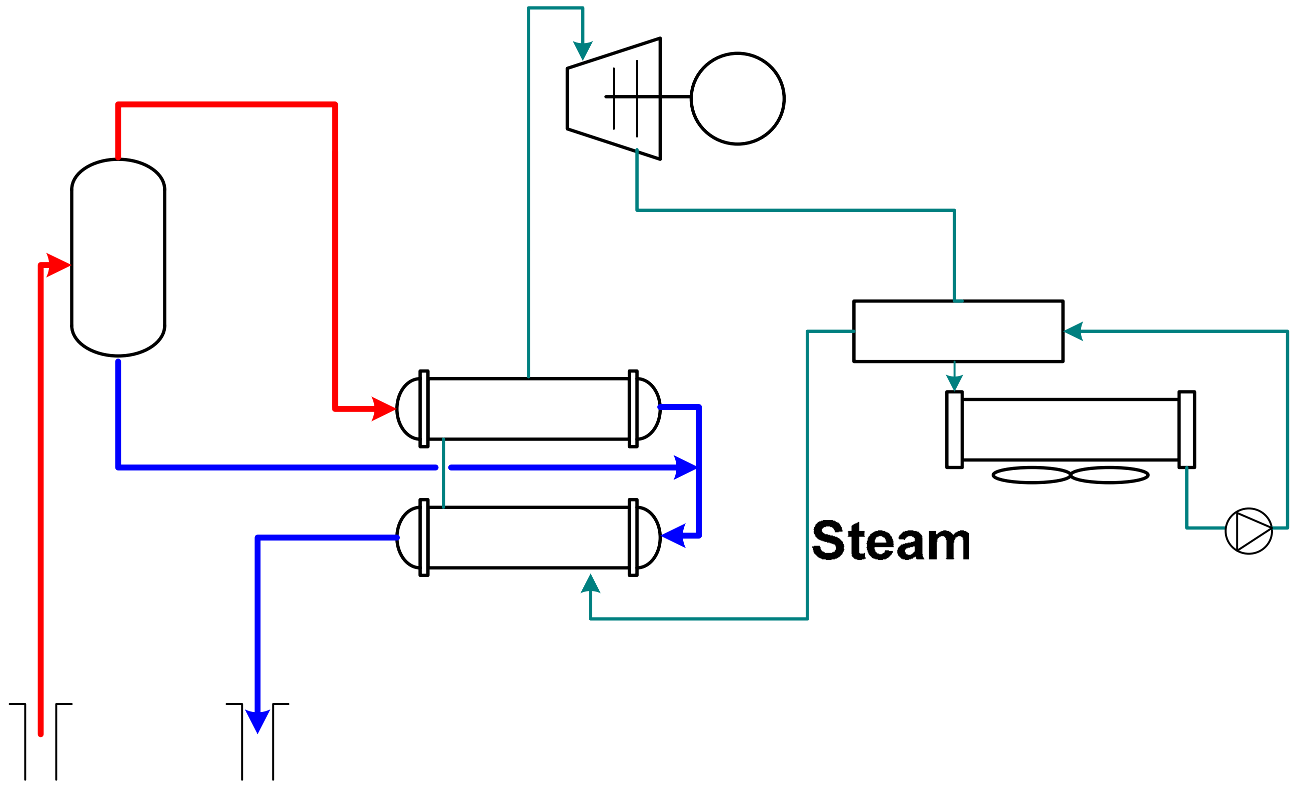


ORMAT

Vaporizer



ORMAT



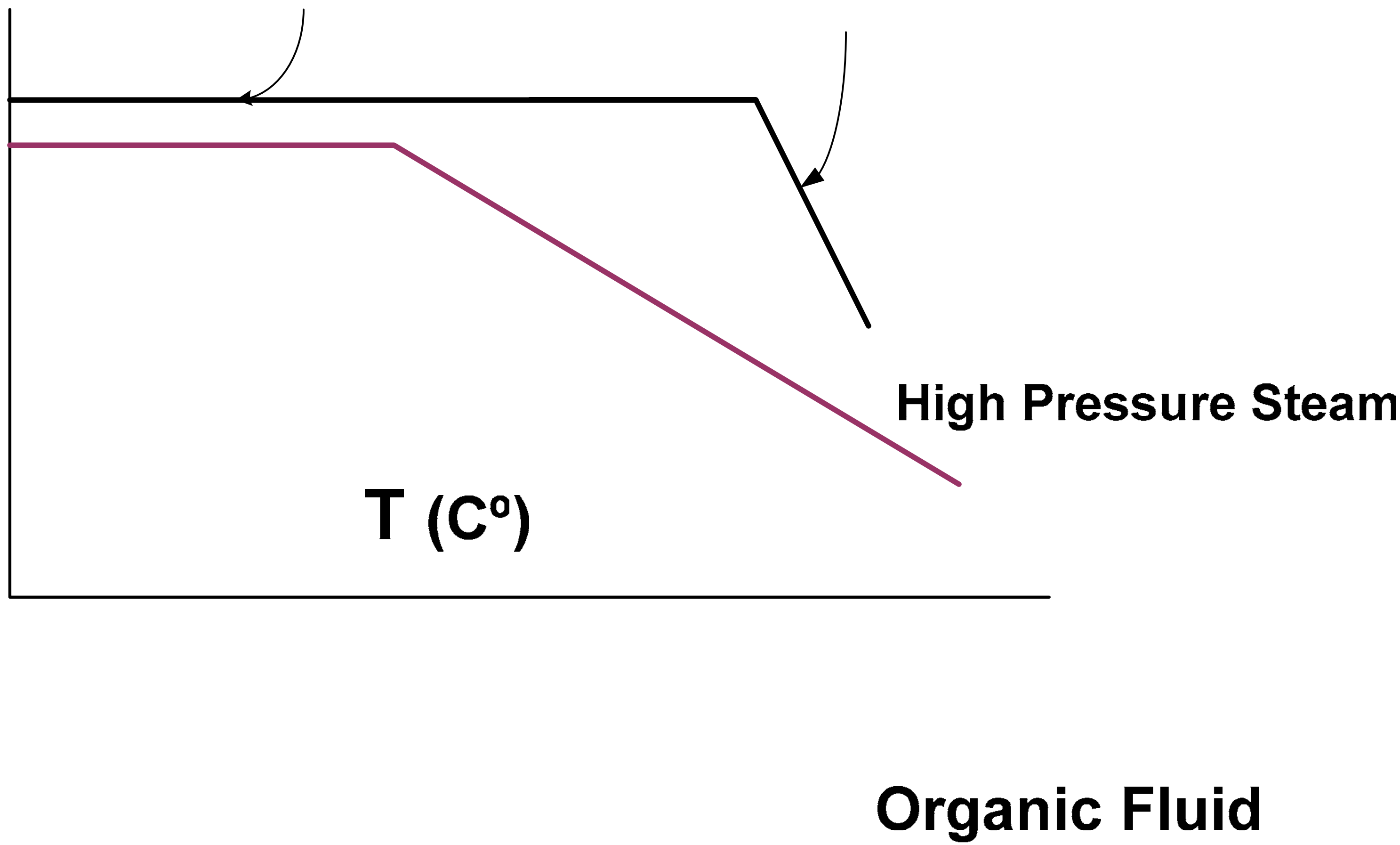
Separator

ORMAT

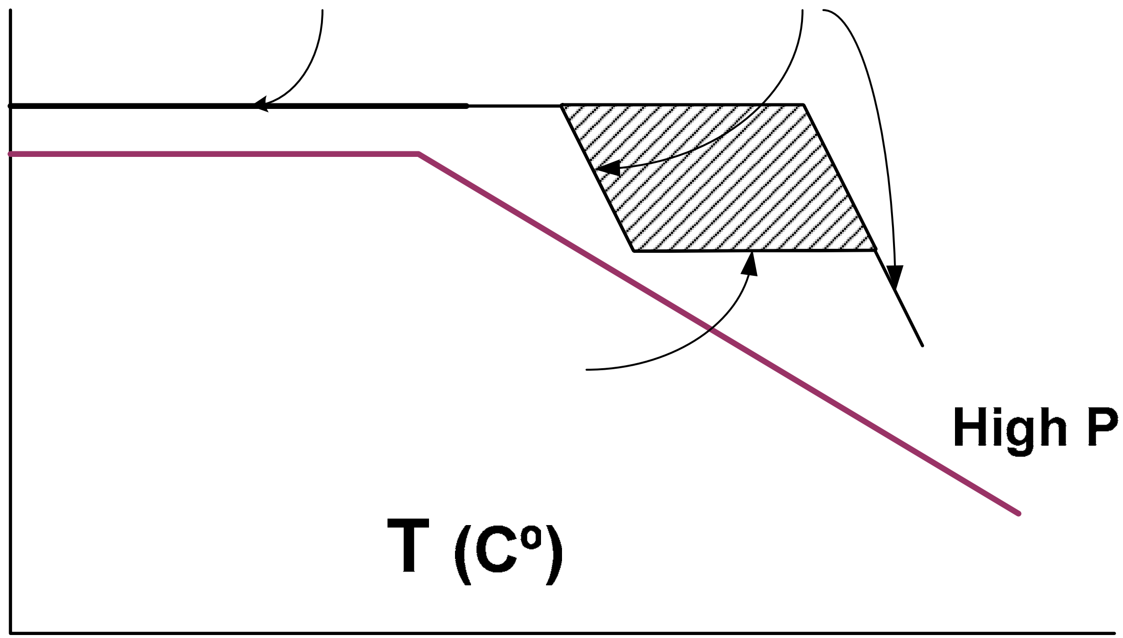
Vaporizer

Bi Phase Binary Cycle
List of Projects

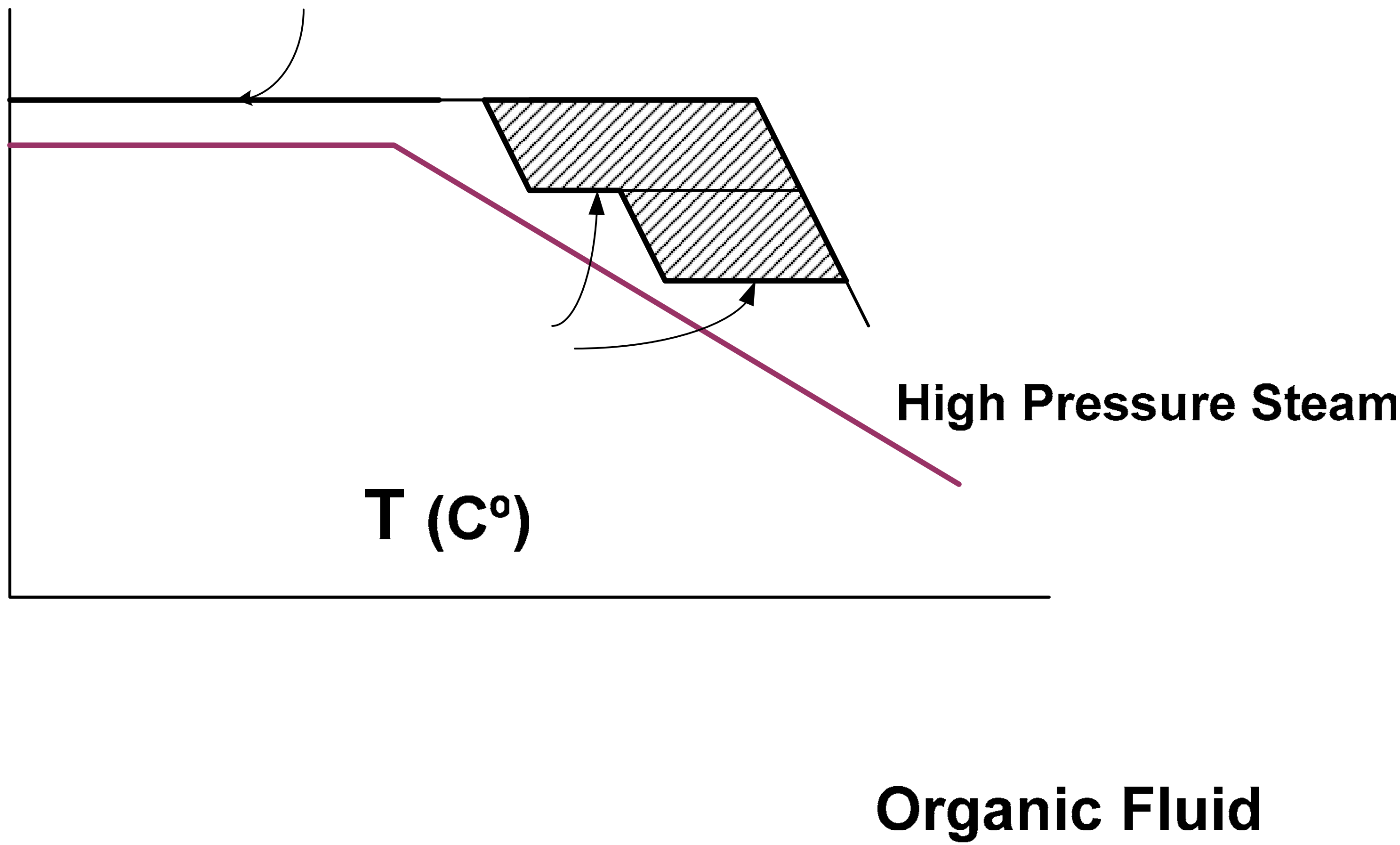
Sao Miguel Phase I – Azores Islands	5.2 MW
Sao Miguel Phase II – Azores Islands	8.5 MW
Ngawha – New Zealand	12 MW
Zunil 1 – Guatemala	24 MW
Hatchobaru – Japan	2.2 MW
Oserian – Kenya	1.8 MW
Rotokawa Extension – New Zealand	6.5 MW



High Pressure Steam
T (C°)
Organic Fluid



High Pressure Steam
T (C°)
Organic Fluid



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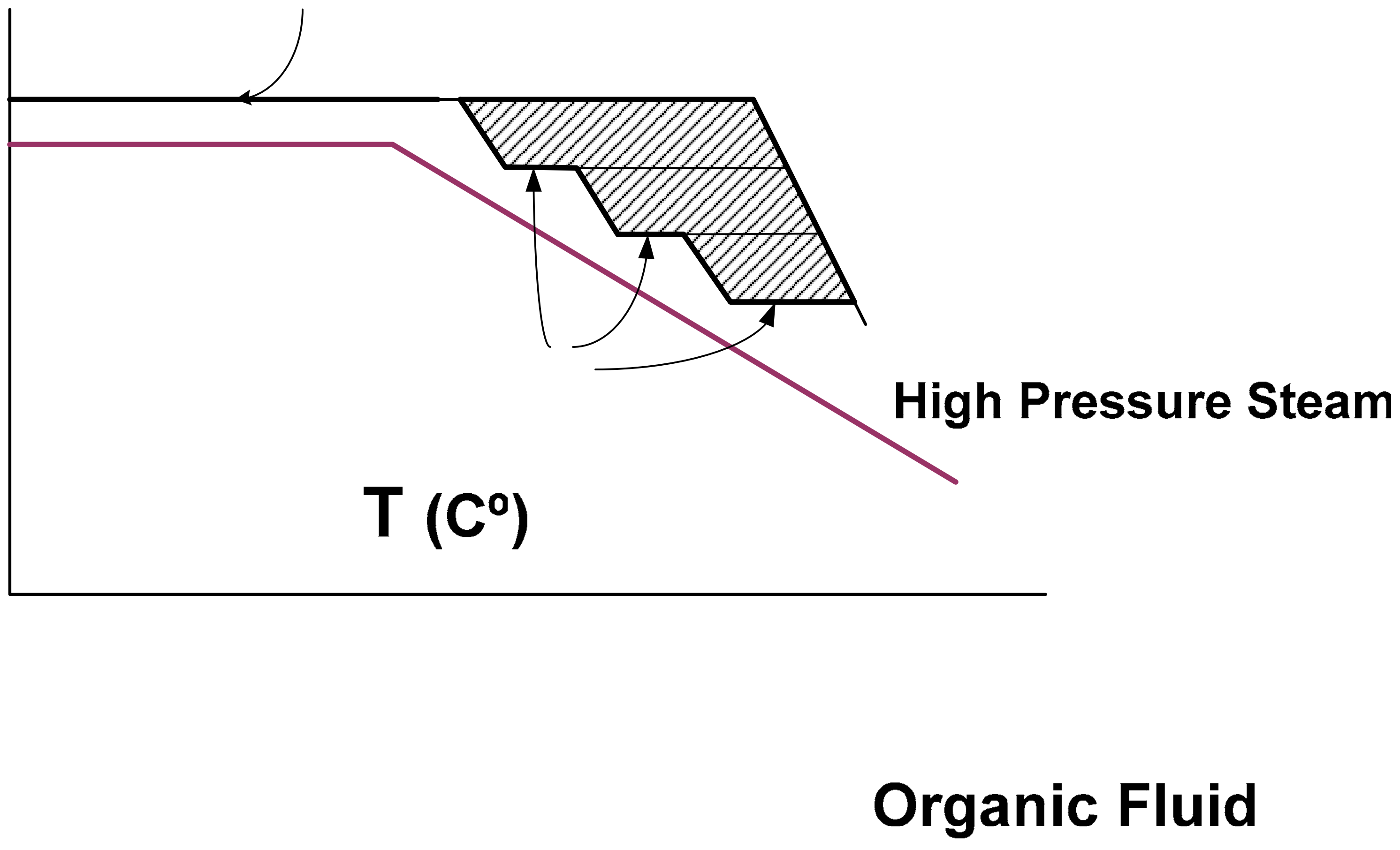
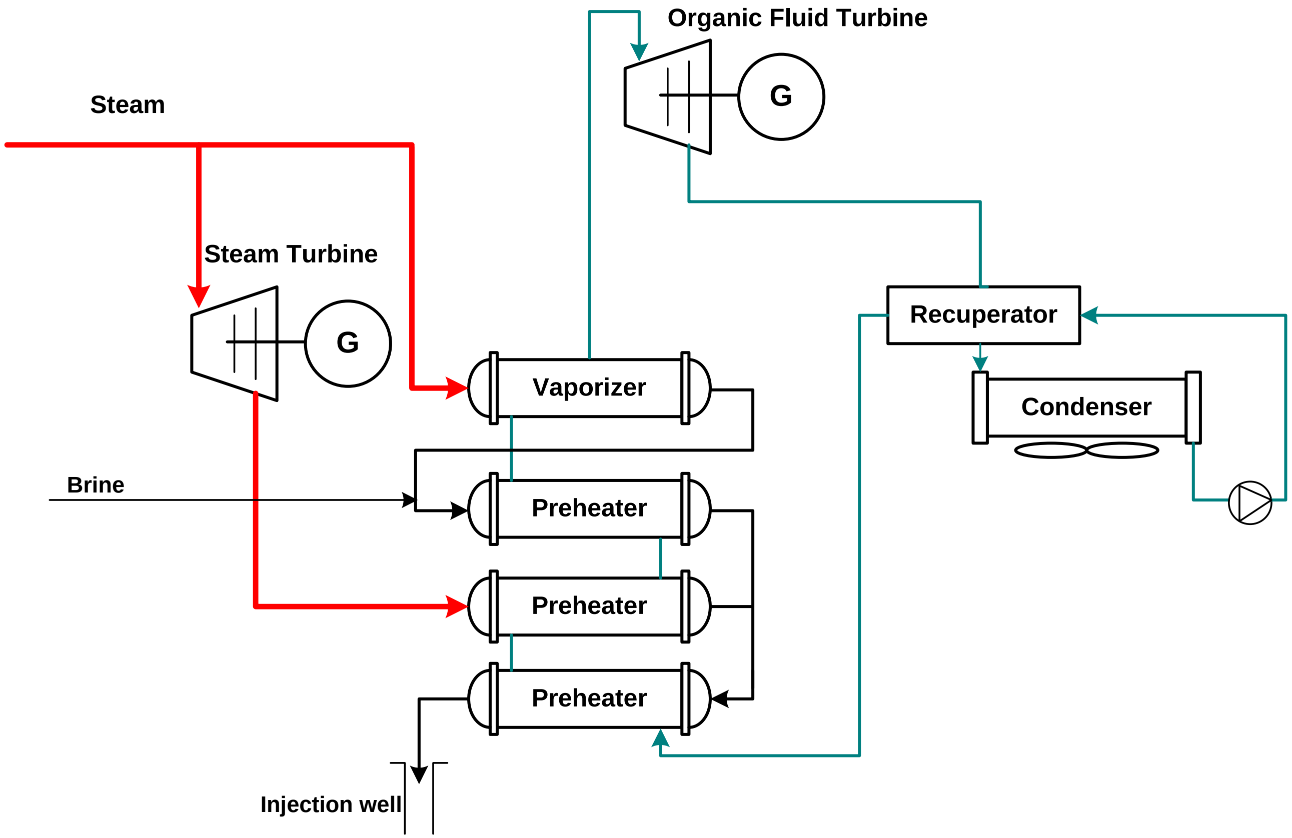
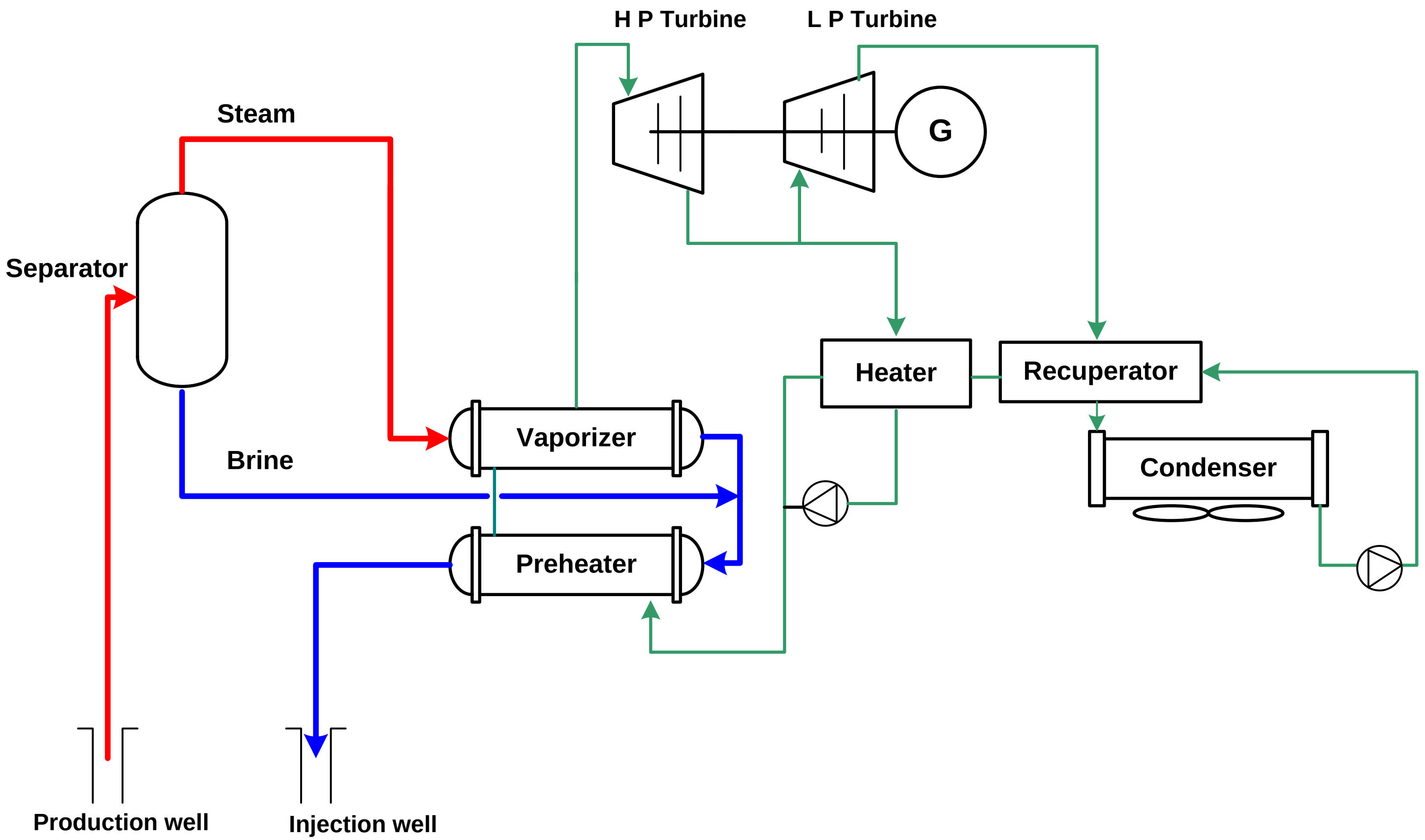
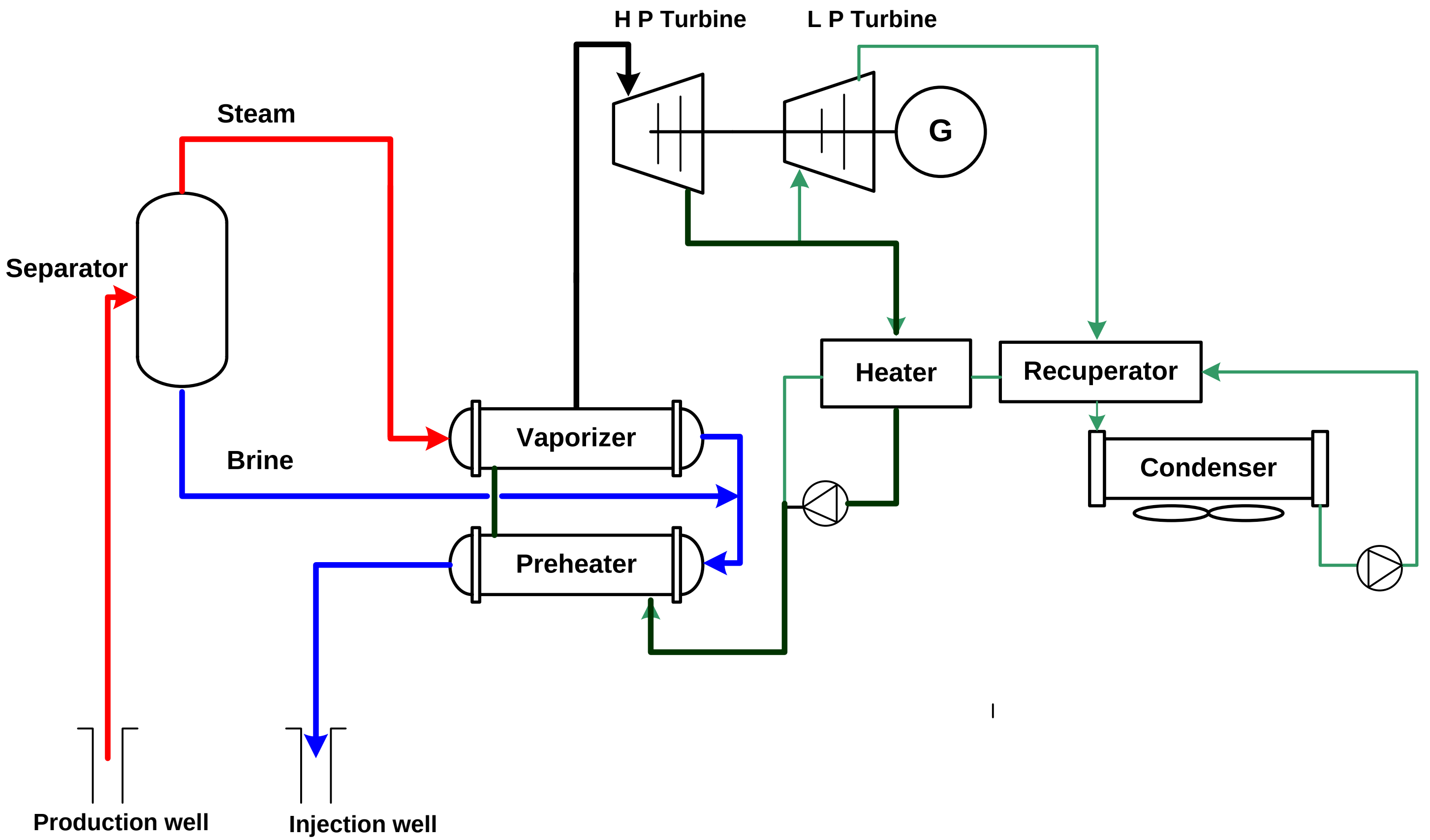
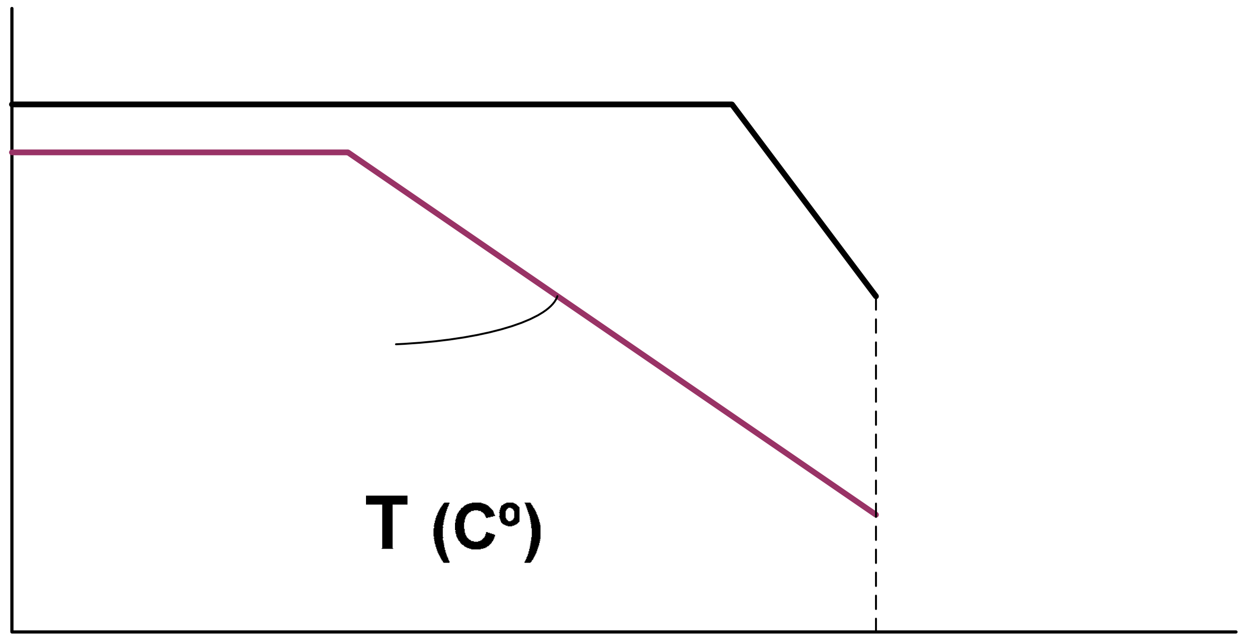

High Pressure Steam
T (C°)
Organic Fluid

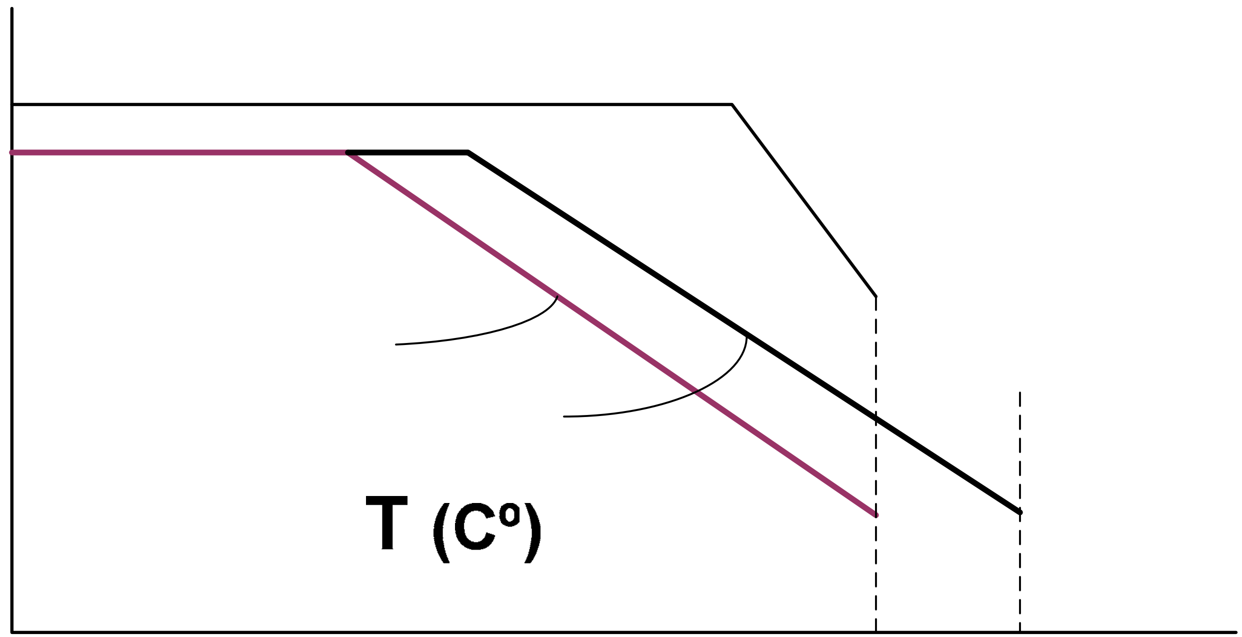

Organic Fluid Turbine
G
Steam
Steam Turbine
G
Recuperator
Vaporizer
Condenser
Brine
Preheater
Preheater
Preheater
Injection well

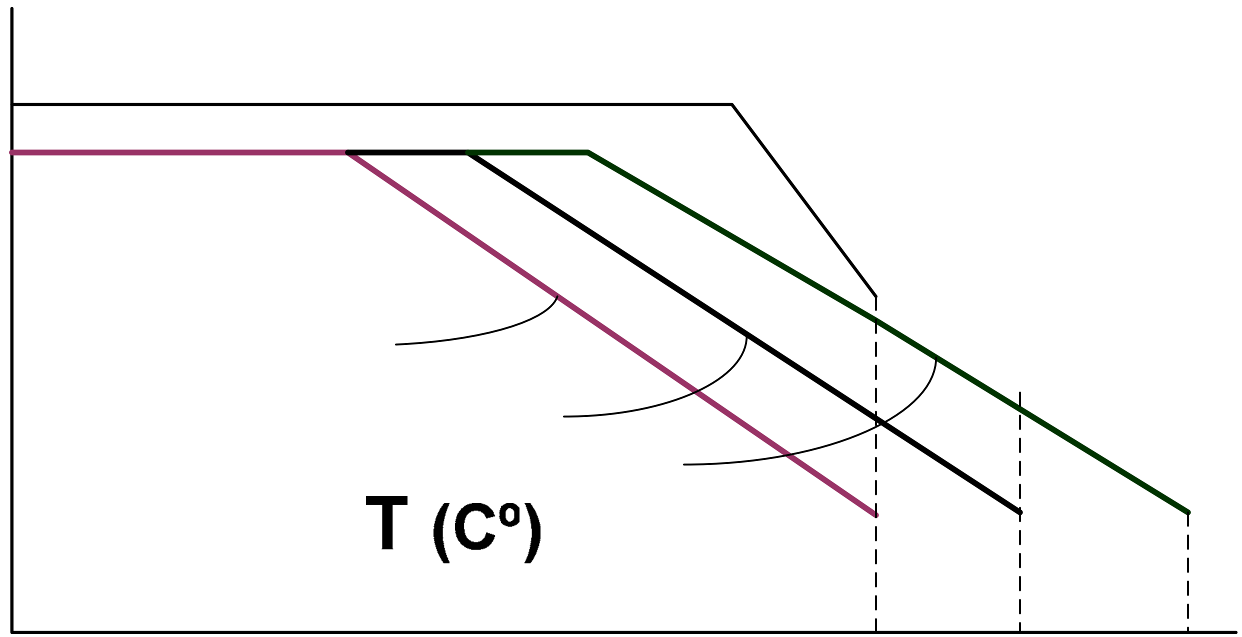

H P Turbine
L P Turbine
G
Steam
Separator
Heater
Recuperator
Vaporizer
Brine
Condenser
Preheater
Production well
Injection well

ORMAT


H P Turbine
L P Turbine
G
Steam
Separator
Heater
Recuperator
Vaporizer
Condenser
Brine
Preheater
Production well
Injection well


T (C°)


T (C°)



A

Exergy Consideration

$$e = h - h_0 - T_0(S - S_0)$$

Where:

e **is the specific exergy**

h **is the enthalpy**

T **is the temperature**

S **is the specific entropy**

Exergetic Efficiency

$$\eta_{ex} = \frac{W_{net}}{m \cdot e}$$

Where :

η_{ex} = overall exergic efficiency

m = heat source fluid mass flow

e = specific exergy

W_{net} = Net power generated by the plant

$$\eta_{ex} = \frac{15{,}000(kW)}{86.53(kg/sec) \times 353.2(kJ/kg)} = 0.49$$

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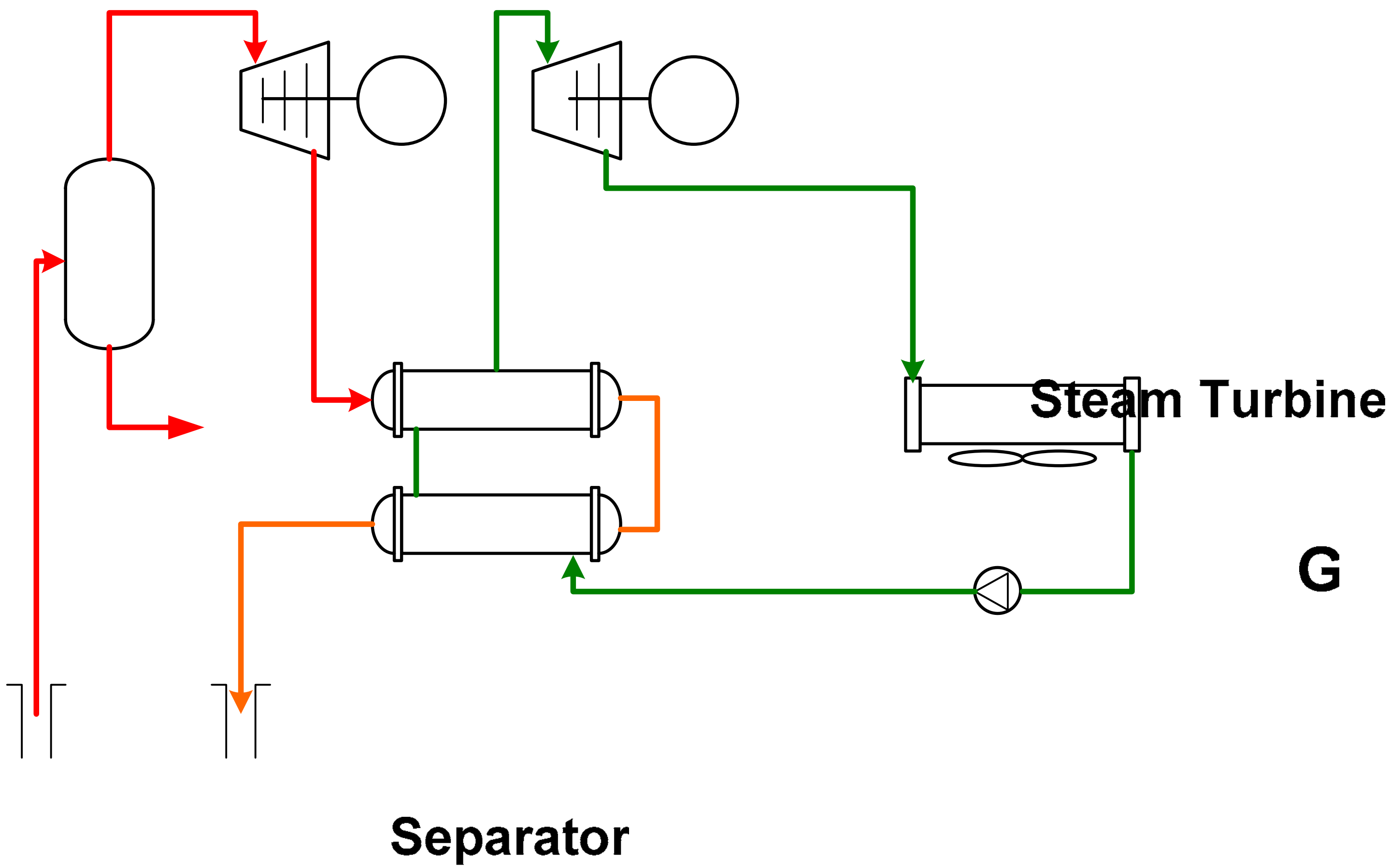
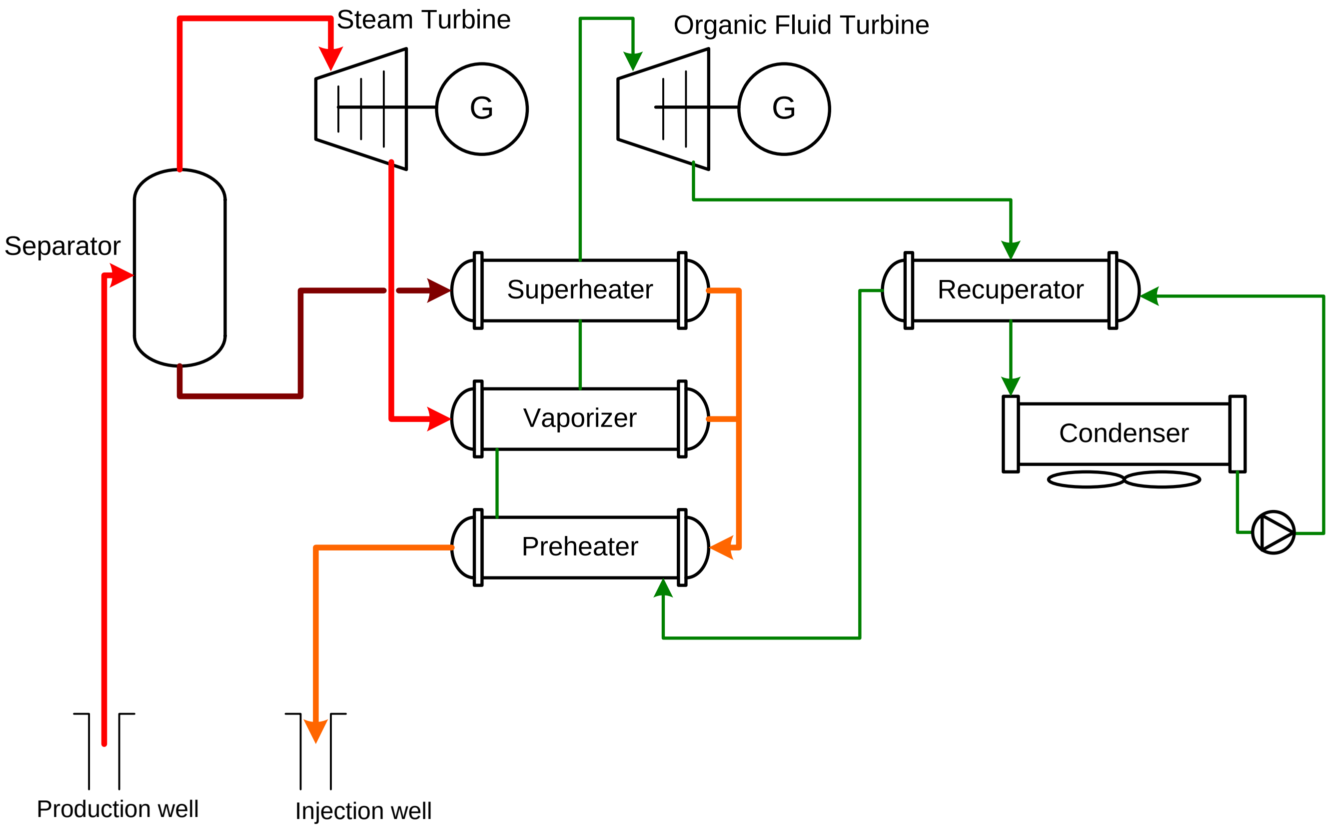
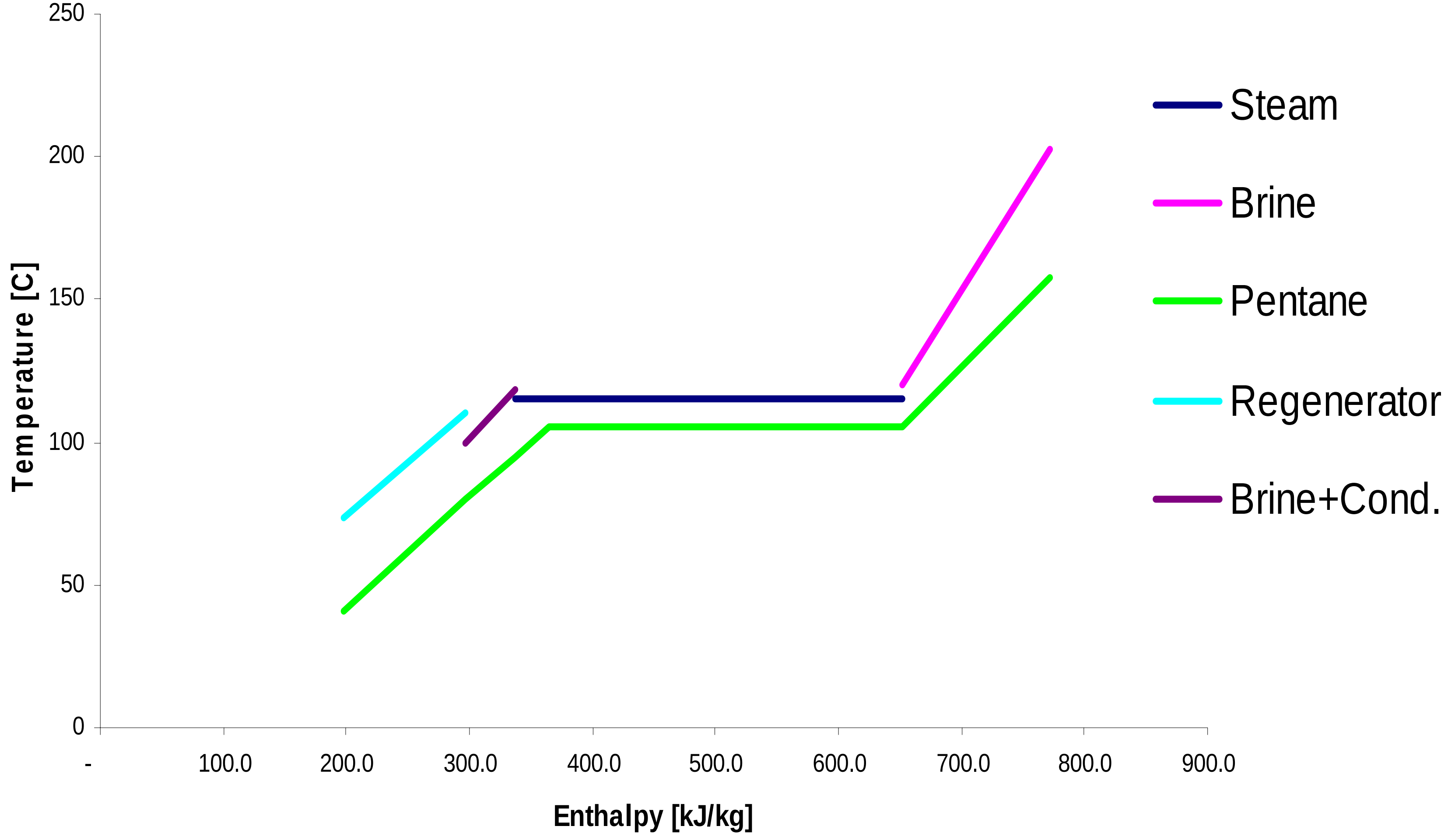
Geothermal Combined Cycle Unit




Steam Turbine
G
Organic Fluid Turbine
G
Separator
Superheater
Recuperator
Vaporizer
Condenser
Preheater
Production well
Injection well

ORMAT



250
200
150
100
50
0
Temperature [C]
-
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
Enthalpy [kJ/kg]
Steam
Brine
Pentane
Regenerator
Brine+Cond.

Heat Exchanger Size Considerations

$$Q = A*U*LMTD$$

Where:

Q = Transferred Heat (kJ)

A= Heat Exchange surface (m^2)

U= Total heat transfer coefficient ($kJ/m^2/C^o$)

LMTD= Log Mean Temperature Difference (C^o)

Or

$$A = \frac{Q}{U*LMTD}$$

Conclusions:

- The efficiency of the plant can be improved by selecting a thermodynamic cycle which fits the heat source parameters
- The use of advanced binary cycles for two phase geothermal fluid results in high exergetic efficiency
- The high cycle efficiency combined with the high reliability, low maintenance and reservoir sustainability results in record high long term plant economy