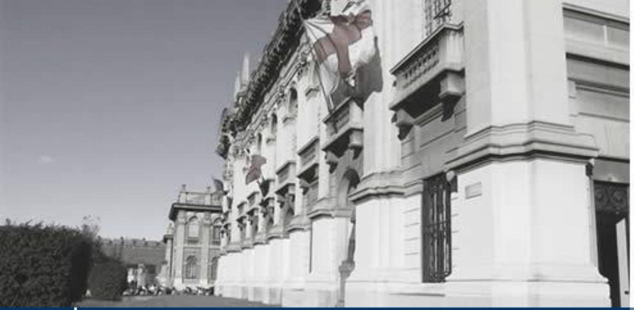

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4th International Seminar on Organic Rankine Cycle Power Systems
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Potential performance of environmental friendly application of ORC and Flash technology in geothermal power plants

Group of Energy COnversion Systems
www.gecos.polimi.it

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INTRODUCTION

Context

- **Geothermal power plants** temperature range of 150-200°C

Objective

- **Definition and simulation of environmental friendly geothermal plants** evaluating the performances
- **Effect of concentration of the CO_2** on the performances of the two scheme of plants

Methodology

- **Bibliographic review** for experimental data for validation of the thermodynamic model for the geothermal fluid
- **Aspen Plus** simulations of the geothermal plants

Overview on geothermal fluids

The chemical composition of the geothermal fluid is strongly site dependent (water, salts, gases).

Main gas: CO_2

Other gases: H_2S, hydrocarbons, N_2, H_2…

Case of Italy: sites with non-condensable gas content from 4 to 10% by weight

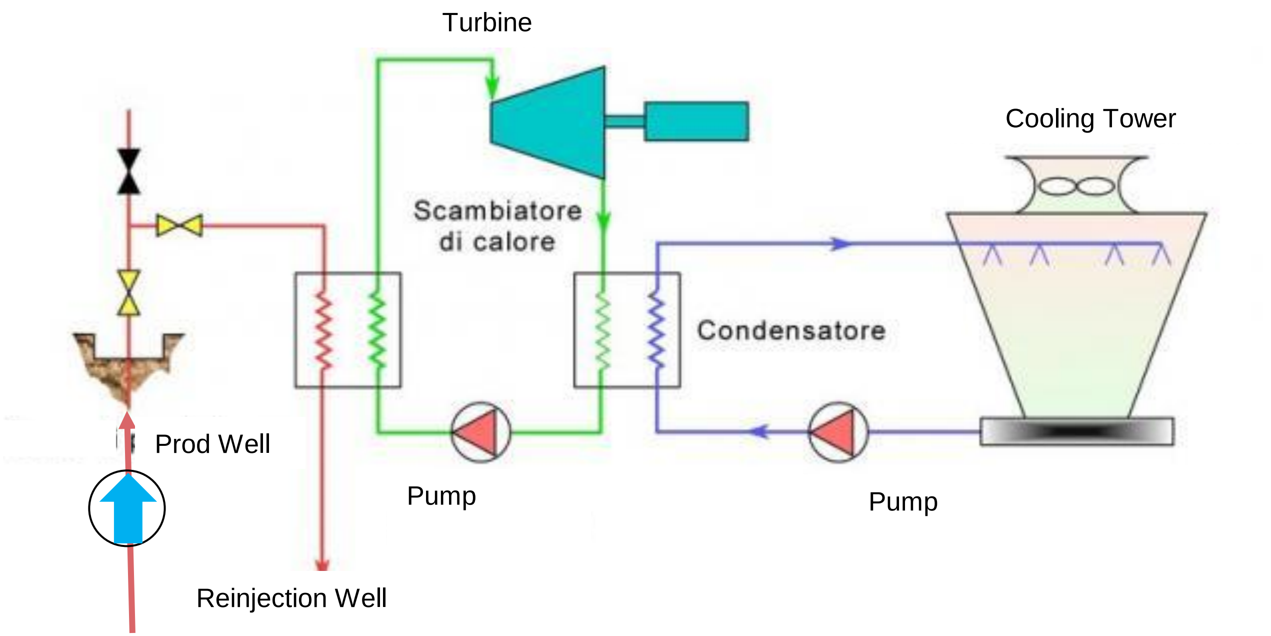
The concern for "climate change" encourages the investigation of possible power plant schemes which do not release CO_2 in the atmosphere.

Main technologies – binary systems

Geothermal fluid 100 °C- 160 °C (and higher)

advantage, geothermal fluid in a closed loop

Common configuration of binary cycle technology is equipped with submersible pump that can guarantee a stable well production, but that is subjected to scaling, cavitation that determine a short lifespan.

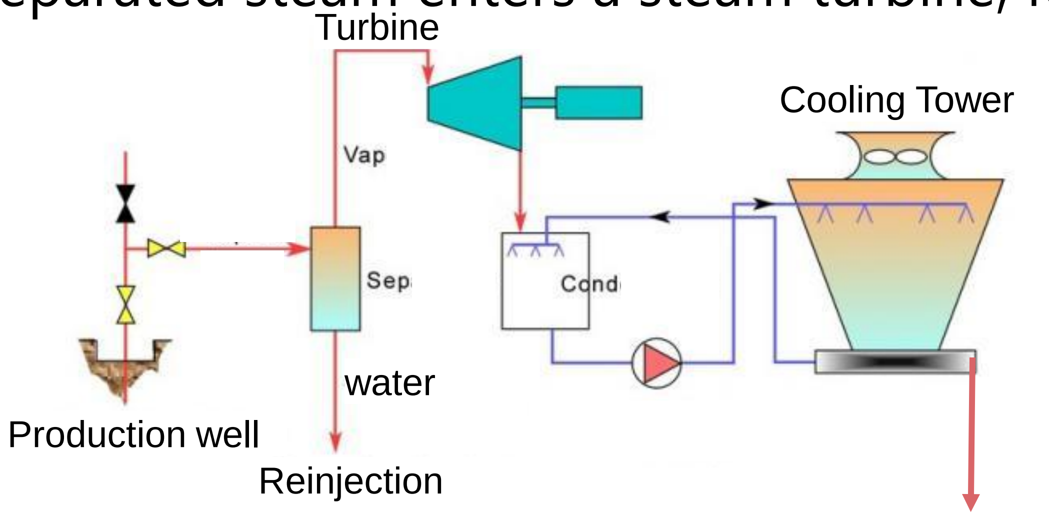


Main technologies – flash systems

Geothermal fluid > 160 °C

In the traditional flash plant layout non-condensable gases are extracted from the condenser,

The main feature of this technology is the adoption of a direct cycle, whereby the geothermal fluid coming from wellhead is flashed, and separated steam enters a steam turbine, followed by a condenser.



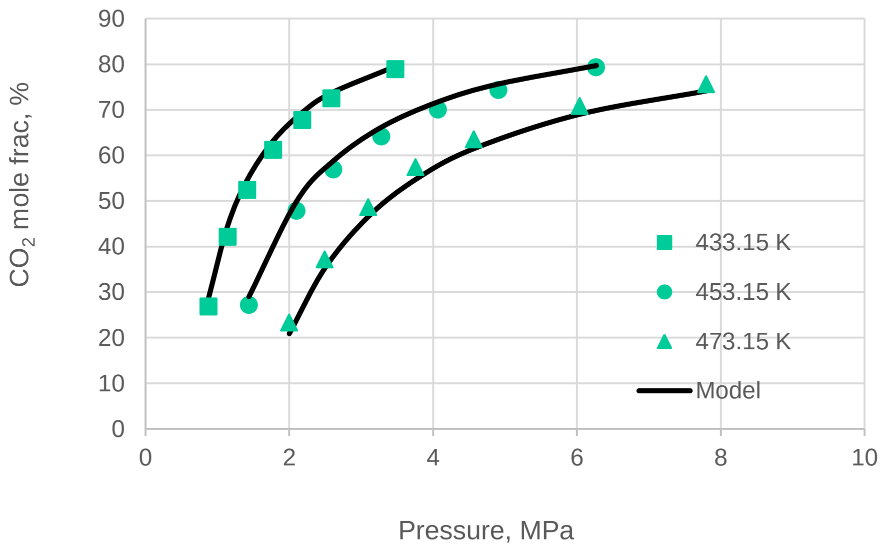
The gas collected at the condeser are at low pressure: they are recompressed at higher pressure

Thermodynamic properties of the geothermal fluid

This work focusses on the CO_2 issue, and therefore only the carbon dioxide is considered as non-condensable gas present in the geothermal fluid.

The **thermodynamic model** adopted to study the performances of the plants is validated with experimental results available in literature.

The thermodynamic model that better performs is the Electrolyte-NRTL, it considers the carbonic chemical equilibrium.



Simulation of the Reservoir

The well-reservoir flow is simulated considering a horizontal mass flow in a porous medium, followed by a vertical flow in a pipe, under steady conditions.

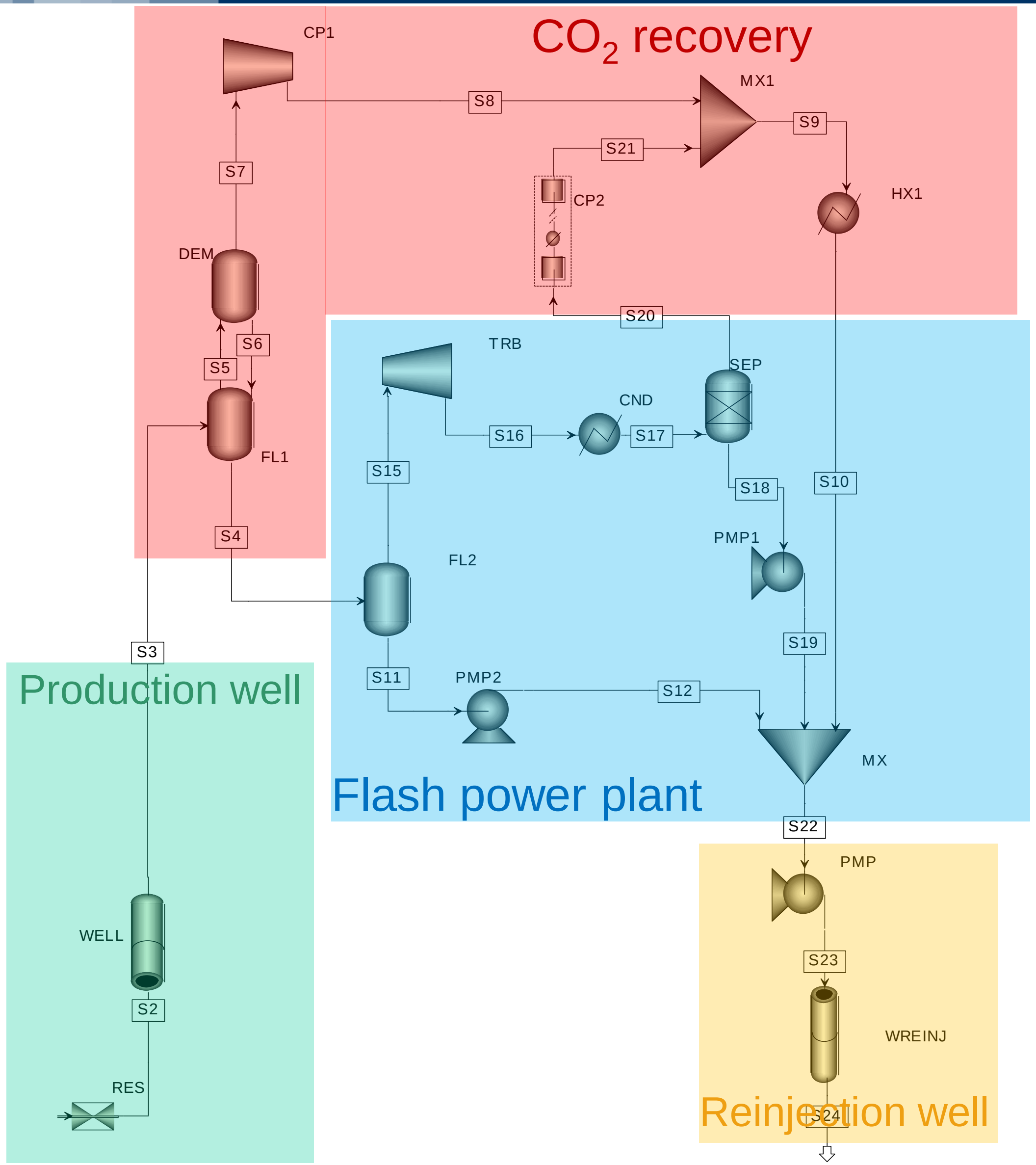
Pressure difference between an undisturbed point in the reservoir and the well feed is expressed by

$$C_D = \frac{\Delta p}{\dot{m}}$$

Parameter		
Drawdown coefficient	C_D	**0.4 bar/kg·s**
Reservoir pressure	p_{res}	**100 bar**
Well depth	L	**1000 m**
Well diameter	**D**	**0,339 m**

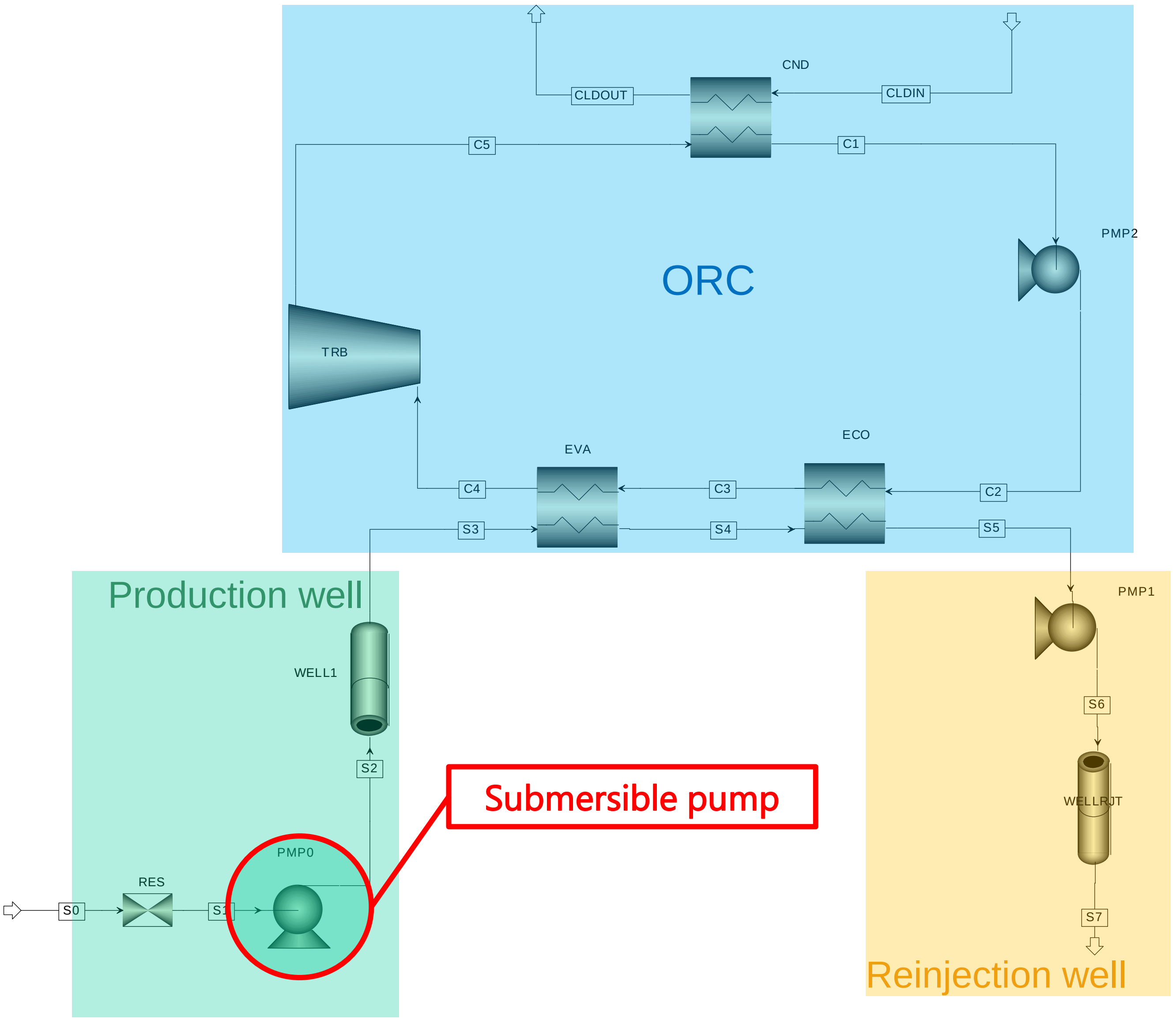
The correlations of Beggs-Brill good results, it is quite largely adopted in geothermal applications.

Simulation of zero emix Flash Plant



Description of the component	
CMP	compressor
CND	condenser
DEM	demister
FL	flash
HX	heat exchanger
MX	mixer
PMP	pump
RES	reservoir
SEP	separator
TRB	turbine
WELL	well

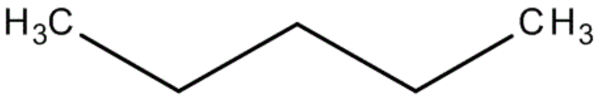
Binary plant (ORC)



Description of the component

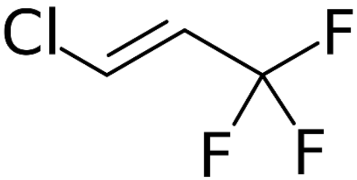
CND	condenser
ECO	economizer
EVA	evaporator
PMP	pump
RES	reservoir
SEP	separator
TRB	turbine
WELL	well

Organic Fluids



n-Pentane (flammable fluid).

T_{Cr}: 196.5 °C; P_{Cr}: 33.7 bar MW: 72.2 g/mol



HCFO-1233zd(E) trans-1-chloro-3,3,3-trifluoropropene

T_{Cr}: 165.6 °C; P_{Cr}: 35.7 bar MW: 130.5 g/mol

It is environmentally friendly: GWP = 5; non-flammable.

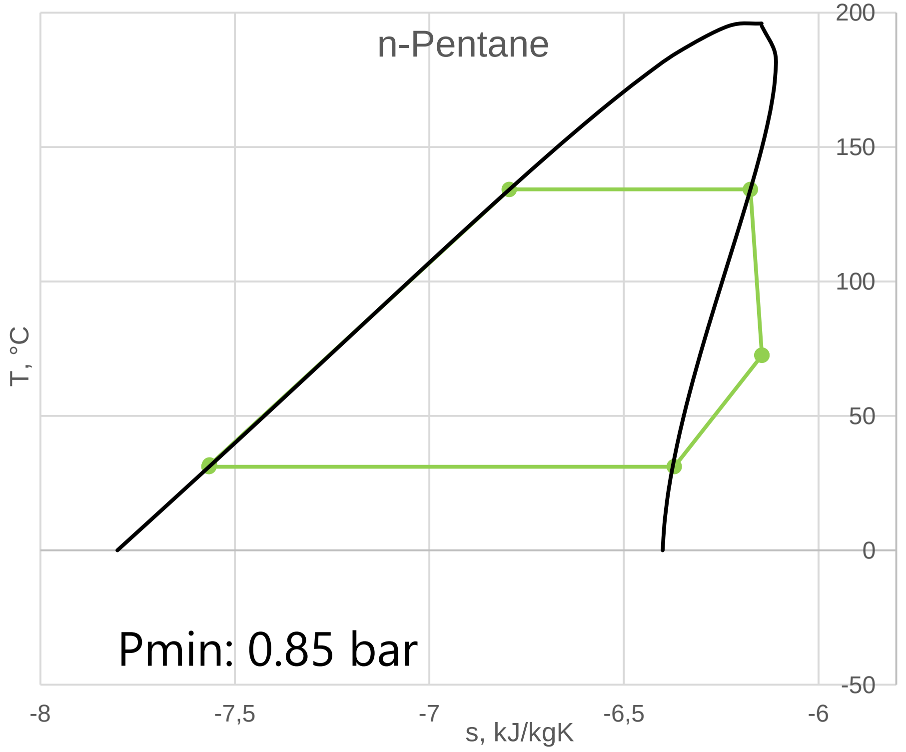
According to preliminary investigation, it seems thermally stable at least up to nearly 200 °C.

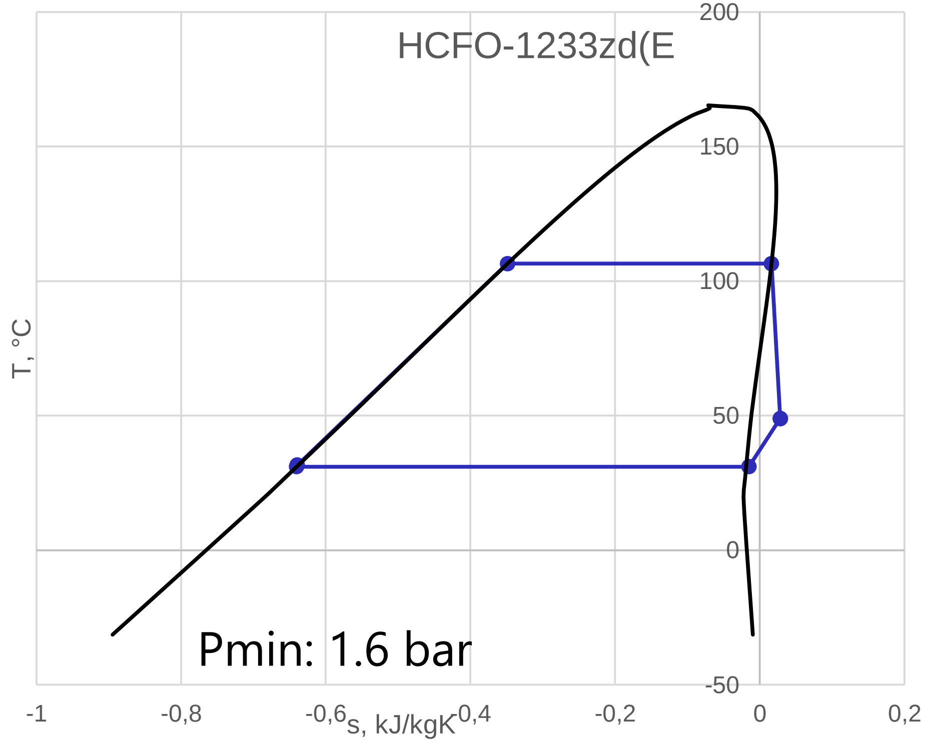
Thermodynamic cycles

Expample of saturated cycles

max pressure of 12 bar

min temperature of 32 °C





Basic assumptions for the parametric analysis

Parameter	
Ambient temperature	15 °C
Condenser cooling medium	Water
Turbine isentropic efficiency	0.9
Pump hydraulic efficiency	0.8
Organic-electric efficiency	0.95
CO_2 mixing pressure	80 bar
Condensing temperature	32°C
Heat rejection electric consumption	0.01 $MW_e \cdot MW_{th}^{-1}$

<u>Performance evaluation</u>

- Reservoir temperature (150°C, 175°C and 200°C)
- CO_2 content (0%, 1% and 5%)

Results Flash plant with CO_2 recovery

Mass flow rate (productivity of the well)
Pressure drop at "pre-flash": 1%

<u>A parametric analysis</u>
Pressure at the flash chamber before the turbine

200 °C			
CO_2 conc.	0%	1%	5%
p_{Wh}, bar	2.3	9.2	15.9
$\dot{m}_W$, kg/s	93	80	105
P_{aux}, MWe	0.74	5.4	2.6
Q_{cond}, MW_{th}	33.5	16.4	23.3
NetP, MWe	**4.9**	**2.0**	**2.6**

Results Binary plants

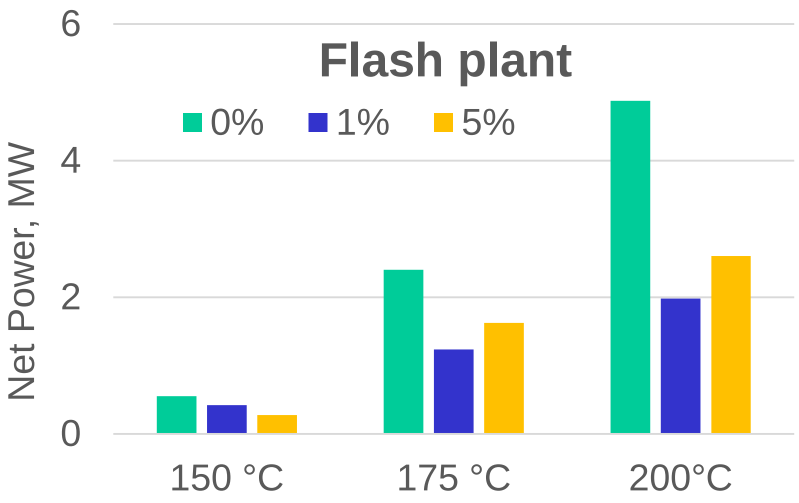
Mass flow rate (max of pump: 200 l/s)
ΔT_{min} at heat exchangers: 10 °C

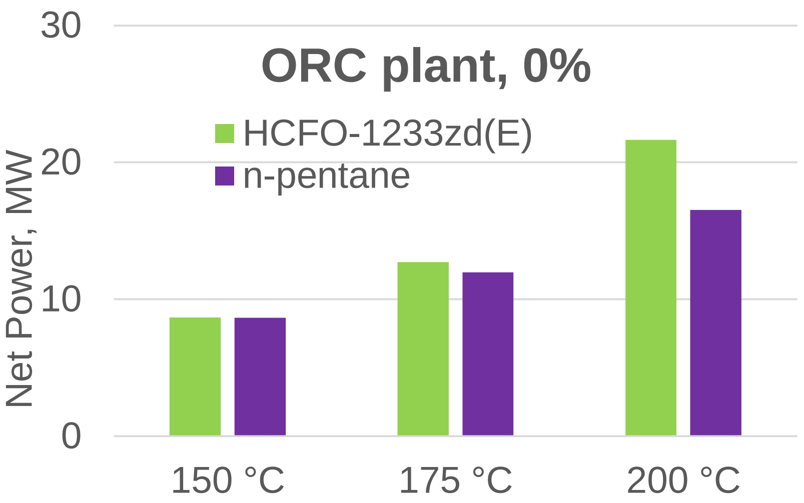
<u>A parametric analysis</u>
Pressure of the cycle maximization of power production
CO_2 concentration: not possible exceed 1% because of cavitation

200 °C				
	HCFO1233zd(E)		n-Pentane	
CO_2 conc.	0%	1%	0%	1%
$\dot{m}_{ORC}$, kg/s	547	488	220	210
$T_{max\ ORC}$, °C	153	153	130	130
$P_{max\ ORC}$, bar	29	29	11	11
Q_{cond}, MW_{th}	112	104	95.4	91.1
NetP, MWe	21.6	19.3	16.5	15.7

Comparisons of results

Organic Rankine Cycle reach higher values, but the CO_2 content is a limitation in case of use of a pump in the well





Conclusions and future works

Conclusions

The performance of investigated layout are highly affected by the concentration of the carbon dioxide present in the reservoir. In general:

- Submersible pump has good effect on power production
- Presence of CO_2 decrease the power production
- Flash plants can handle wide range of CO_2 concentration
- HCFO-1233zd(E) is a possible option for geothermal application

Future works

- Presence of salts in geothermal fluid
- Flash: recovery of heat duty of the CO_2 compression; separated reinjection of CO_2; 2 pressures level.
- ORC: other scheme of plants (2 pressure levels)
- Techno-economic analysis