40th Anniversary

Feasibility study for implementation of a Binary power plant in Lake Abhe geothermal area with a particular hot arid climate, Djibouti

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Presentation Overview

- Introduction
- Djibouti in the regional geology
- Lake Abhe Geothermal Field
- Objective
- Results
- Conclusion

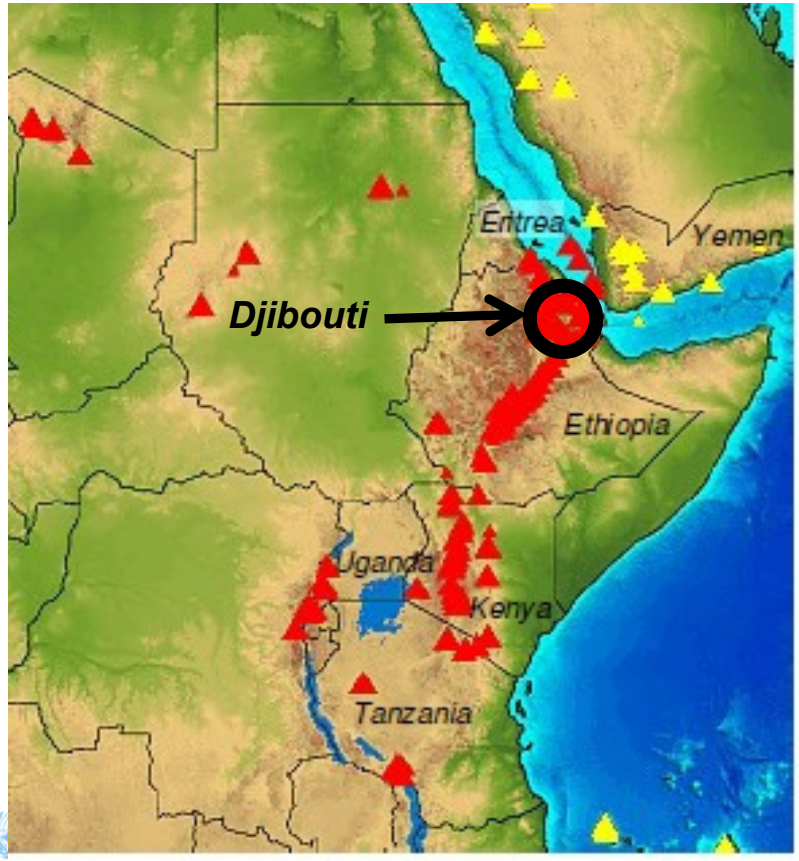
Introduction: Djibouti

Djibouti is located on the East Coast of Africa between Ethiopia and Somalia, the entrance of the Red Sea in the extreme West of the Aden Gulf.

- **Independence day:** June 27th 1977

- **Total area :** 23.200 km²
- **Population :** 900.000
- **National Languages :** Somali & Afar & Arabic
- **Official languages :** French and Arabic
- **End altitudes**: -155m (Lac Assal) +2021 m (Moussa Ali)
- **Nombers of regions :** 6
- **Currency :** Djibouti Franc (FDJ), pegged at a fixed rate to the dollar. 1 $ US = 177,721 FDJ

Introduction: Geology of Djibouti unique in terms of geodynamics activity

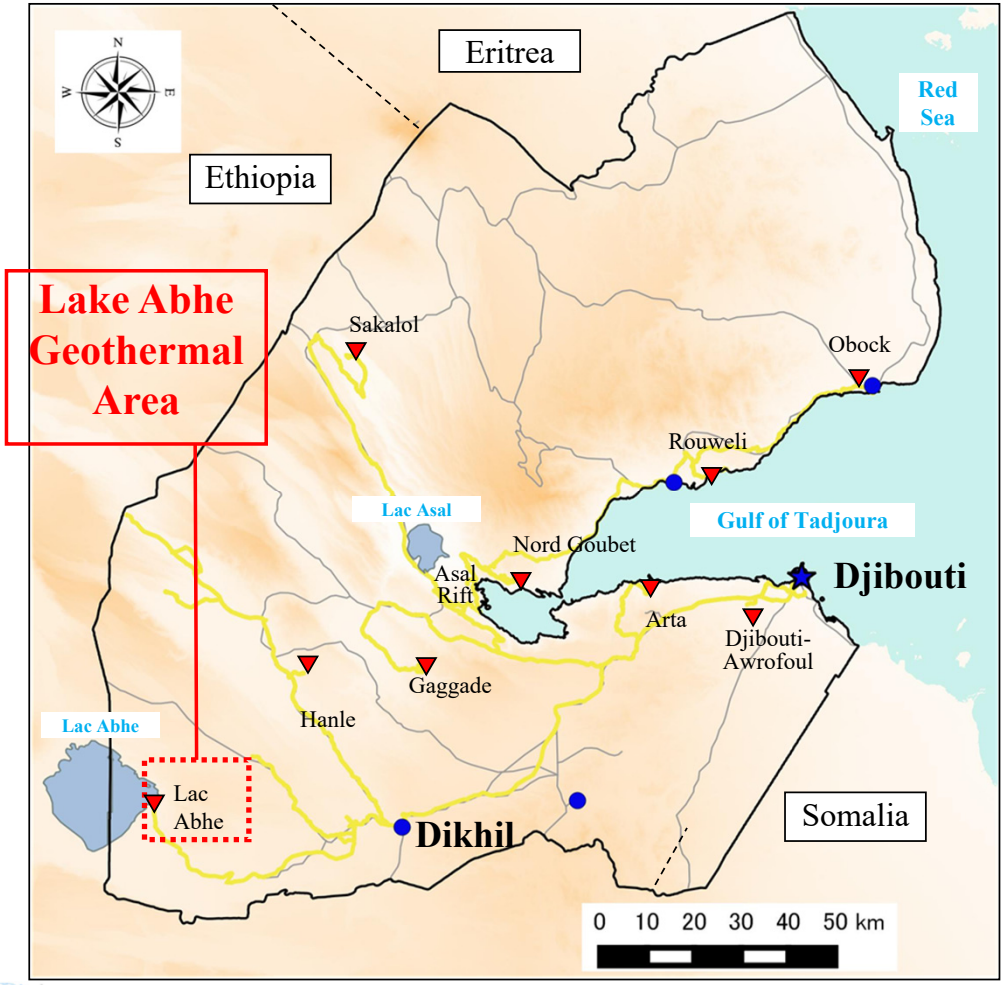


▲ Volcanoes with known or inferred Holocene eruptions
Source: http://www.volcano.si.edu/gvp/

- The geologic characteristics of the territory of the Republic of Djibouti are exceptionally favourable for the development of Geothermal Energy.

- Djibouti includes the Afar depression, which is part of the East African Rift, located at the intersection of three important tectonic structures.

Lake Abhe Geothermal Field (LAGF)



Source : JICA (2014).

Lake Abhe is located in the south-western region of the Republic of Djibouti, on the border with Ethiopia.

LAGF is marked by hydrothermal activities which are manifested by:

- hot springs (>90°C);
- Fumaroles
- Travertines
- Alteration

- The total dissolved solids range from 1700 to 3400 mg/l.
- The result of geothermometer of all studies indicated a reservoir range from 110 to 176°C
- The estimated total water flow from the manifestations is around 20-25 L/s.

Source : https://upload.wikimedia.org/wikipedia/commons/f/f3/Lac_Abbe-01.JPG

LAGF: 2D model

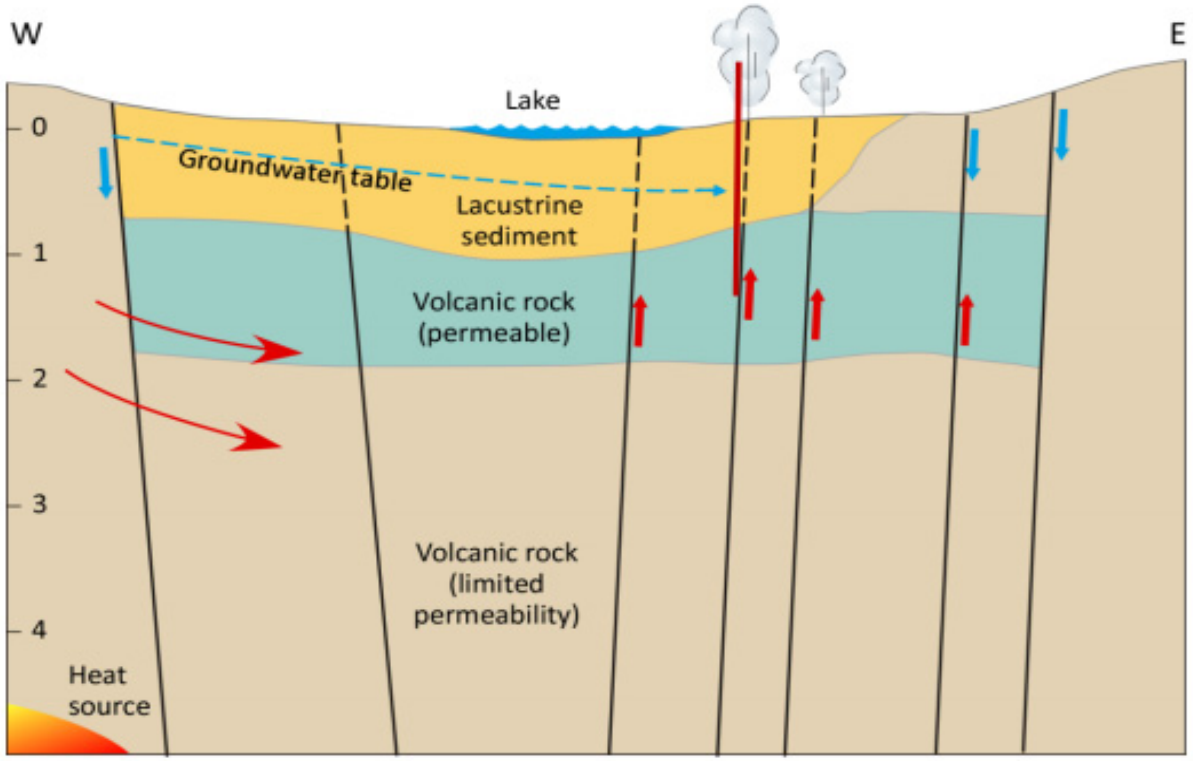


Figure 5: Cross section. A well drilled to more than 1000 m depth, intersecting one of the main permeable fault in the system is shown as a red vertical line on the cross section (ODDEG-ISOR, 2016).

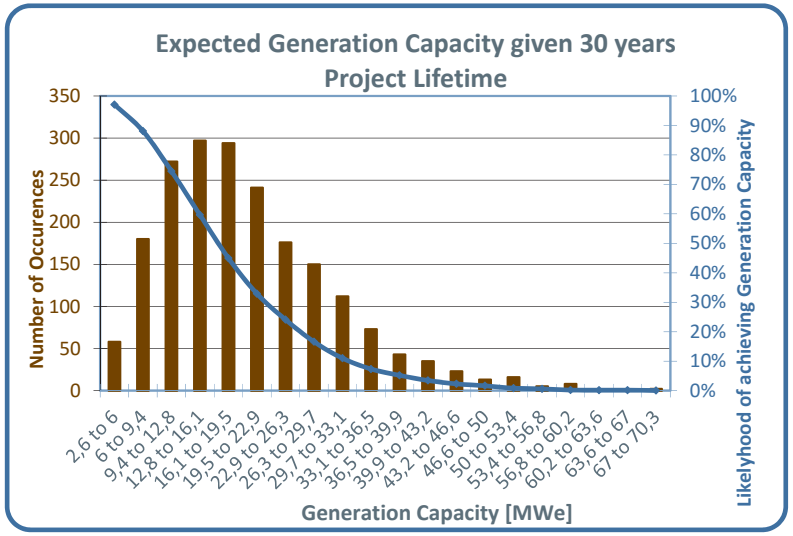
The conductive zones go from 900 m up to 1500 m before showing higher resistivity

Estimation of Geothermal Resources

Geothermal resource is calculated by the Monte Carlo Volumetric Method

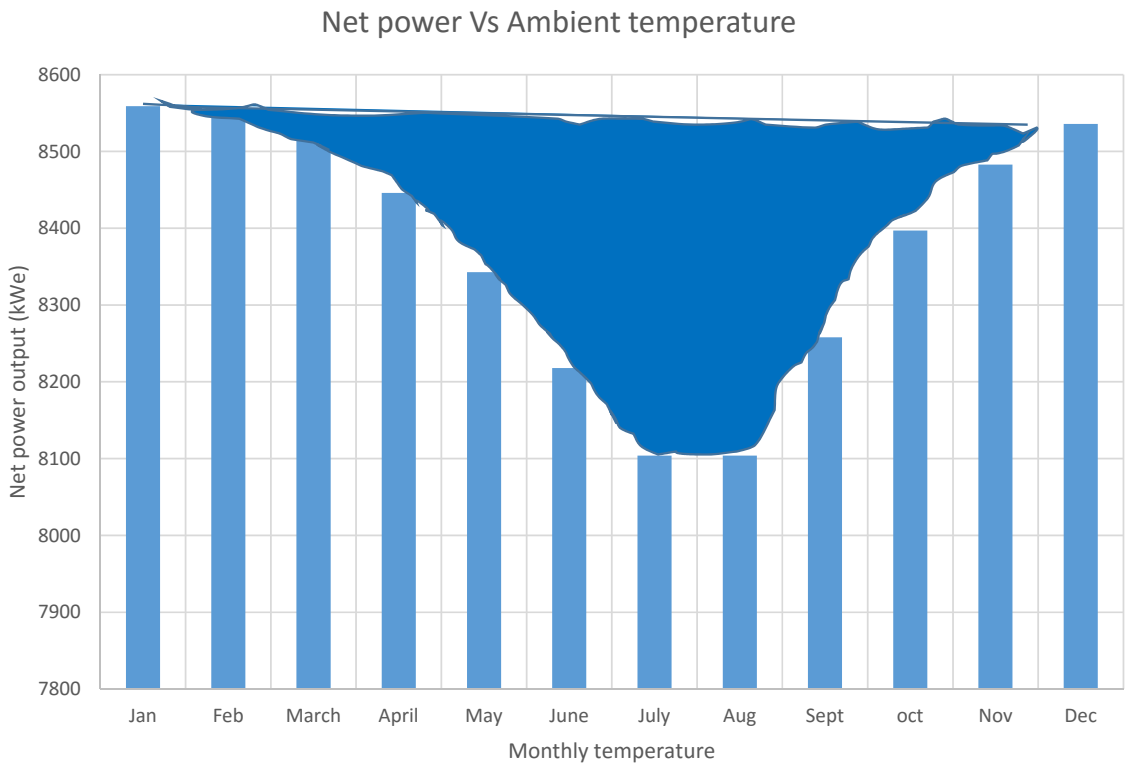
Parameter	Unit	Minimum	Most likely	Maximum	Distribution
Reservoir Area (A)	km^2	70.0	75.0	88.0	Beta
Reservoir Thickness (H)	m	800	1000	1200	Beta
Reservoir Temperature (T)	°C	110	150	176	Beta
Recovery Factor (R)	%	5%	10%	20%	Beta
Utilization Factor (u)	%	35%	40%	45%	Beta
Porosity (fi)	%	5%		20%	Even
Specific Heat of Rock (CR)	kJ/m^3 /°C		950		Fixed
Average Reservoir Depth (D)	m		1500		Fixed
Rejection Temperature (Ta)	°C		90		Fixed
Plant Capacity Factor (F)	%		95%		Fixed
Project Lifetime	years		30		Fixed

Capacity (MW)		
90%	Most Probable	10%
8,8	14,45	33,9



- The results of the simulation show that the Lake Abhe reservoir has potential between 12,8 and 16,1 MWe for 30 years.
- The cumulative frequency distribution indicates that the most likely value for the reserve is 14,45 MWe.

Objective



- The figure depict the variation of the ambient temperature and how the latter affects the power output of the plant.
- The backbone of the thesis will be how to deal with the hot arid climate in order to improve the efficiency of the binary Power plant.

Methodology

- Resource assessment
- Plant technology options
  - Binary with air cooling condenser
  - Binary with water cooling condenser
  - Binary with cooled condenser using cooling tower
  - And finally Solar-geothermal hybrid plant
- Programming in EES
- Results and preferred technology
- Commercial aspects
  - Financial model
- Conclusion

Results

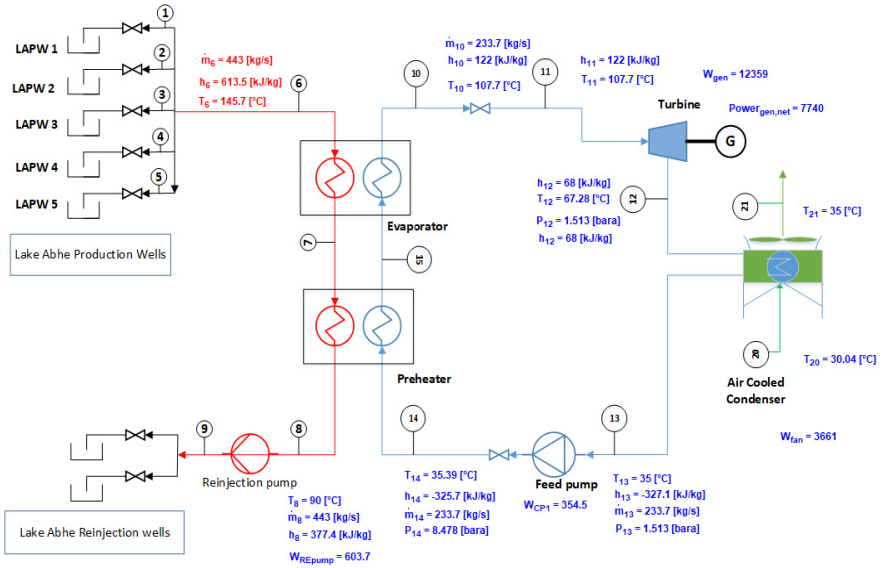


Figure 8: Schematic of the power plant with ACC

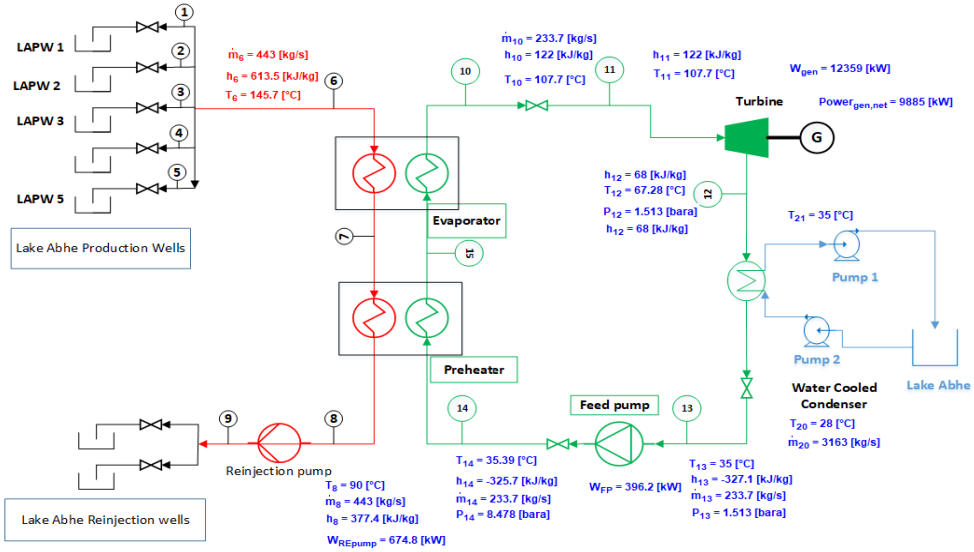


Figure 9: Schematic of the power plant with WCC

- The net power output of air cooled condenser calculated with the annual average ambient temperature (30°C) is 7740 kWe.
- The net power output of the water cooling temperature calculated with the annual average temperature of Lake Abhe water (28°C) is 9885 kWe.
- Comparing the two methods the net power output increase 27.7% for the benefit of water cooling condenser. However, the required amount of water for this case is calculated to be about 99.7 million tons per yr. (Quantities of LA water = 3 billion m^3)

Results cont'd

Table 3: Results of the scenarios

Parameters	Value for basic model ACC	Hybrid solar-geothermal	Units
Gross power output	11706	14778	kWe
Net power output	8805	11382	kWe
Auxiliary power	2902	3396	kWe
% of Auxiliary to Gross power	24.8	23	%
Power fan	1698	2193	kWe
% fan in Auxiliary	58.5	64.6	%
Efficiency	0.12	0.11	[-]
Specific Power Output (SPO)	19.87	25.69	kW/(kg/s)
Geothermal fluid flowrate	443	443	Kg/s
ORC WF mass flow (R245fa)	466.3	466.3	Kg/s
Solar WF mass flow (Benzene)	[-]	445.9	Kg/s

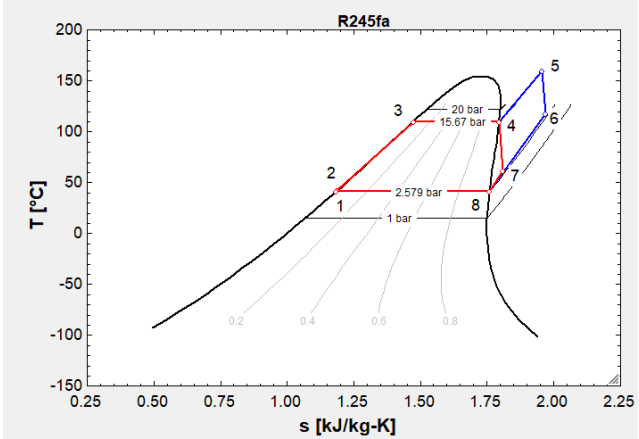


Figure 10: temperature–entropy diagram of the hybrid plant using the working fluid superheating operating mode.

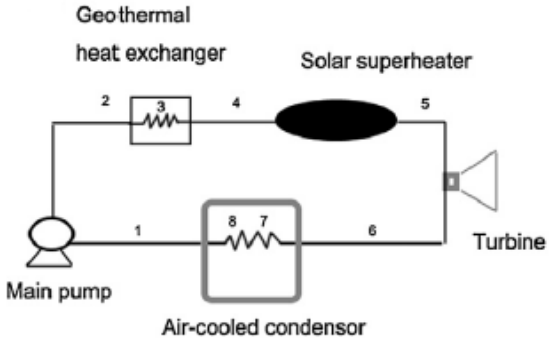


Figure 11:Simplified process flow diagram of the hybrid solar–geothermal power plant.

The both curves have the same trend with a gap between the both which is reducing when the ambient temperature increases.
The temperature at the condenser is kept fix at 46°C

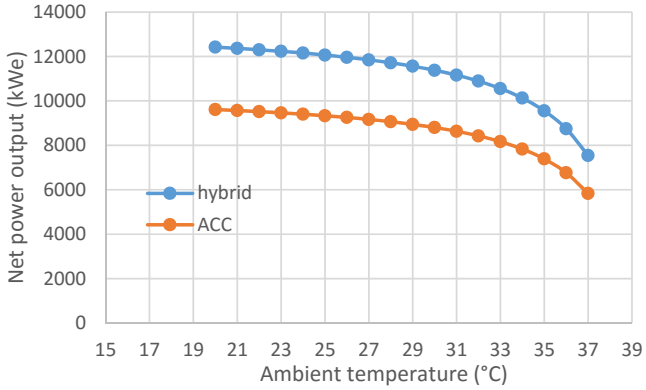


Figure 12: Comparison of the net power of the hybrid and ACC models.

Thank you for your attention