Fact sheet for geothermal development to promote Public Private Partnerships in East Africa

Djibouti

Overview of electricity sector status

The electricity sector is highly developed over the last 5 years with an installed capacity of 173 MWe including imported power from Ethiopia (Table 1). Thermal energy represented the most important part of the power generation. A solar plant and an interconnection line from Ethiopian power company (EEP) were added to the energy offer in 2011. The Ethiopia-Djibouti interconnector provides an additional electricity source, based on renewable (hydro), ranging from 180 to 300 GWh per year. The line terminates at a 220/63/20 kV substation, 12 km west of Djibouti-Ville, where the voltage is stepped down to 63 kV for interconnection with the existing transmission system. The transmission system is currently limited to a 63 kV inter-connector between the main stations, and two 20 kV transmission circuits from Djibouti-Ville to Arta, some 40 km away. There is also a 20 kV circuit between Dikhil and Ali Sabieh in the south of the country. The distribution system comprises 20 kV radial circuits emanating from the main substations. Most customers are supplied at low voltage (LV) via distribution substations. More projects using renewable energy, including geothermal energy, are planned in the near future.

Table 1: Installed capacity and production for electricity generation.

	Thermal power (HFO and Diesel)	Solar power plant	Hydro-electricity (Imported)	Total
Installed capacity (MW)	126 MW	0.30 MW	42 MW[2]	168.3 MW
Annual Production (MWh)	66,637 MWh[1]	522 MWh[3]	354,901 MWh[1]	422,060 MWh

Source: (United Nations Environment Programme, 2019); (USAID Power Africa, 2014)

Figure 1 shows grid-connected installed electricity capacity trends in Djibouti by source start from 2010 to 2020 (IRENA, 2022). As of 2021, the installed capacity connected to the grid is about 123 MW, of which none is geothermal. Since 2010, installed capacity has not been significantly changed, and all of it is fossil fuel thermal power.

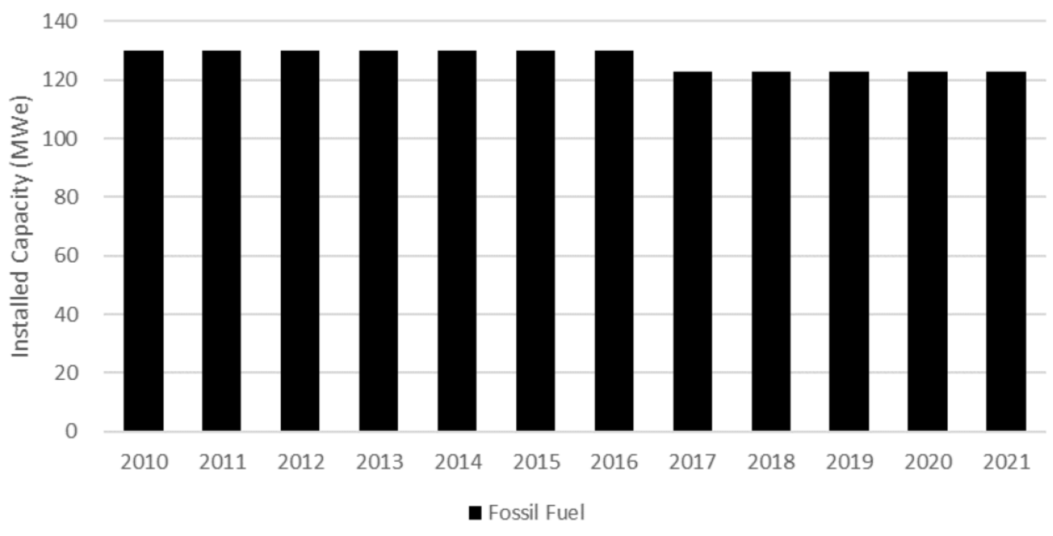

Figure 1: Grid-connected installed electricity capacity trends in Djibouti by source (Data Source: (IRENA, 2022)

As shown in Figure 2, Djibouti's electricity generation has been stable since 2013. Approximately 70% of the domestic electricity consumption comes from hydroelectric generation imported from Ethiopia through an interconnected grid. The remaining 30% comes from diesel-powered generation facilities installed in the country. Electricity production and supply in Djibouti are costly, and the country's network infrastructure suffers frequent power outages due to maintenance and investment delays. In addition, the growing demand for electricity is mainly concentrated in the urban areas, making access to the power grid relatively difficult in rural areas.

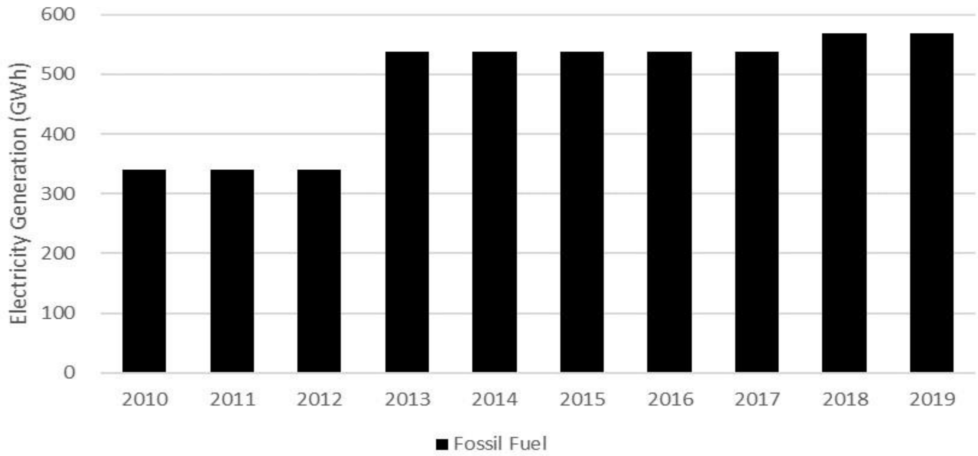

Figure 2: Grid-connected electricity generation trends in Djibouti by source

(Data Source: (IRENA, 2022)

Electricity generation from diesel and heavy fuels represent important cost for operation and maintenance of power plants. The cost of electricity was decided to assure an optimum service and to prevent electricity shortages. Government legislate the price of the electricity (Table 2).

Table 2: Consumer tariffs of the electricity

Customer	Price per kWh
Social tariff (1kVa)	15 US$ cents
Residential customer	55 US$ cents to 40 US$ cents
Industrial customer	34 US$ cents to 42 US$ cents

(United Nations Environment Programme, 2019)

Overview of geothermal development status

Geological setting

The geology of the country is affected by the volcano tectonics at the junction of the Gulf of Aden, the Red Sea Oceanic ridge, and the East African Rift Valley (EARV) system which constitute the triple junction system (Figure3). Djibouti lies within what is referred to as the Afar Depression also known as the Afar Triple Junction (Boschetti, Awaleh, & Barbieri, 2018). The Afar depression is the region where crustal extension occurred caused by the separation of the Arabian, Nubian and Somalian plates and thus, establishes the connection between the current oceanic ridge in the Red Sea and the Gulf of Aden system, and the EARS intra-continental rifts.

The Gulf of Aden and the Red Sea ridge are the most active geological system in East Africa, with high extension result that has resulted in the presence of shallow magma chambers. Almost all of the Afar depression is covered by basalt strata bound, eventually partially hidden by sediments infilling in the grabens, and were created by the early stages of proto-oceanic rifting (Barberi & Varet, 1977). Almost all the rock composition in the country is basaltic like Dalha basalts (8-4 Myr), Somali basalts (5 to 3 Myr), Stratoid basalts (3.5 to 1 Myr) etc, as shown in Figure3. Three rift tectonic trends are well developed in Djibouti and these are controlled by the NE trending Gulf of Aden, NW Red Sea trend and the SW trending EARS. One of the youngest volcanic activity in Djibouti occurred at Ardoukoba volcano in 1978 (Figure4).

Djibouti is one of the countries in Eastern Africa with high potential for high enthalpy geothermal resources that are suitable for power generation and alternative uses. This is due to the location of the country within an active spreading centre at the intersection of the three rifting trends (triple junction). However, most of the geothermal manifestations are associated with the NW Red Sea trend (Figure5). The identified geothermal prospects are Lake Asal, Gale La Koma, North Ghoubbet, Lake Abhe, Obock, Sakalol-Alol, Gaggade, Hanlé and Arta.

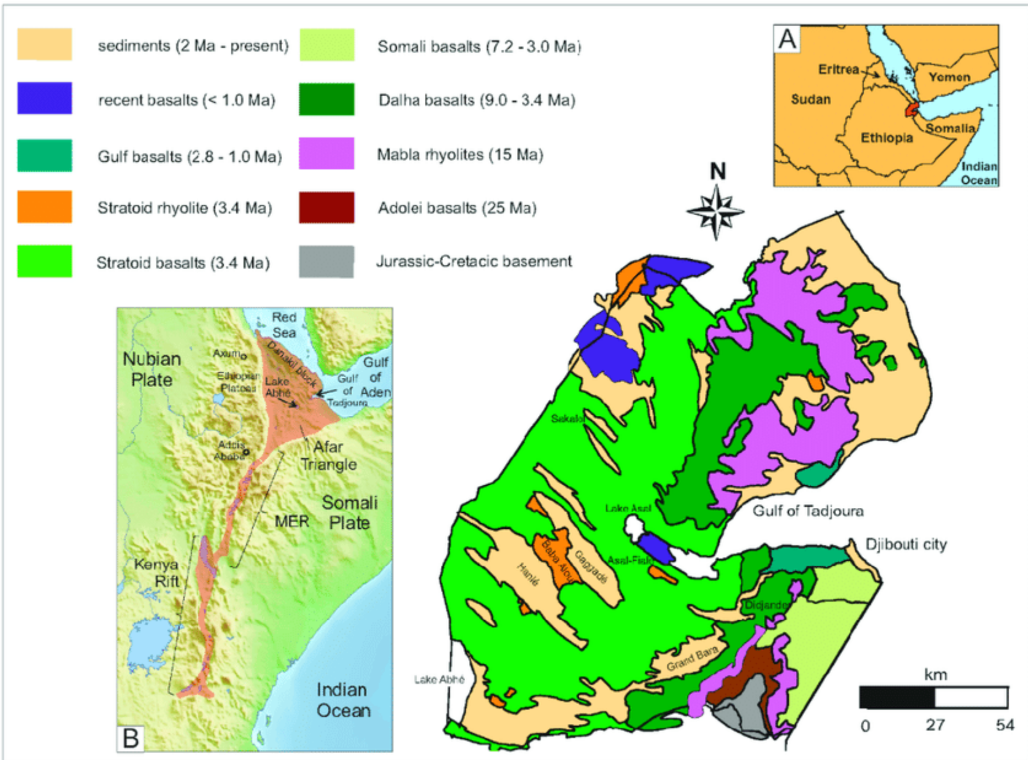

Figure 3: Geological map of Djibouti

From (Boschetti, Awaleh, & Barbieri, 2018)

Figure 4: Photo showing the geology of part of the Lake Asal rift zone from the top of Ardoukoba volcano that erupted in 1978. Lake Asal is visible in the centre left.

Since the years 1970's, several surface studies were done in the country which identified at least 13 potential areas of geothermal interest. The most promising prospects lie along the main NW-SE active axis of spreading extending from the Gulf of Tadjoura to Manda Inakir. Preliminary studies identified Asal-Ghoubhet zone as the most promising for exploration and development. Exploratory drilling undertaken in 1975 confirmed the existence of a high temperature geothermal system. Additional drilling was undertaken 1987 in the Hanle graben and in the other sectors of the Asal prospect.

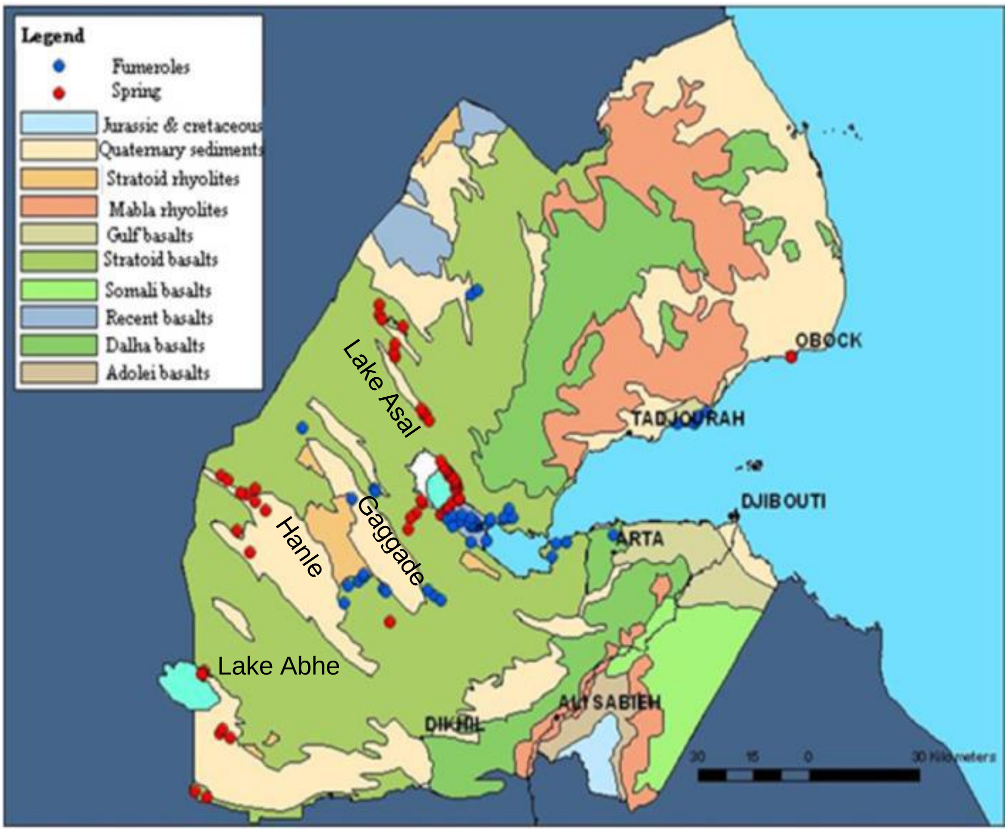

Figure 5: Geological map of Djibouti showing locations of geothermal manifestations

(Abdillahi, Mohamed, Moussa, & Khaireh, 2016)

Geothermal fields[1] and prospects[2]

- **Asal Geothermal field**

The Asal geothermal field is located in the Asal-Ghoubhet rift which extends north of Lake Asal. This area is the most explored geothermal field in the country. The first geothermal investigation was undertaken in 1970, by the French geological survey (BRGM). The investigations lead to the discovery of the high enthalpy geothermal reservoir. With the financial support of the World Bank, additional 3 wells were drilled totalling 6 deep boreholes (Figure 6). The wells had downhole temperatures of 261-345oC but all had problems of high salinity and low permeability. These wells have very high salinity of the reservoir fluids. Subsequently, with a view to exploring better quality reservoir fluids, the Lake Asal field was divided into three sectors, namely, Asal NW, Gale La Koma, and Asal-Fiale. Appraisal drilling following new conceptual model were undertaken in Fiale caldera and Gale La Koma (Abdillahi, Mohamed, Moussa, & Khaireh, 2016) with mixed results.

- **Asal-Fiale geothermal field**

The Fiale caldera geothermal prospect was evaluated in 2008 using integrated geoscientific studies which indicated the potential presence of a geothermal resource (ISOR, 2008). Seismic studies revealed strong seismic activity at 3.5 - 5km which could be the upper part of the magma chamber

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[1] A geothermal prospect where at least one drilled well has proved a viable geothermal system that can be developed for commercial applications like power generation, direct use, etc

[2] An area with occurrences of thermal manifestations that seem to have economic potential

(Varet, 2014). Prefeasibility studies predicted a maximum reservoir capacity of about 300 MWe. Therefore in 2011, the Government of Djibouti raised funds from the World Bank and other financiers for exploration drilling of four exploration wells. The wells had low output with cold water incursion being of major concern. The thermal history of Fiale 3 demonstrates a cooling of the geothermal system due to the large intrusion of cold seawater throughout the faults of the Asal-Ghoubbet rift (Figure 63).

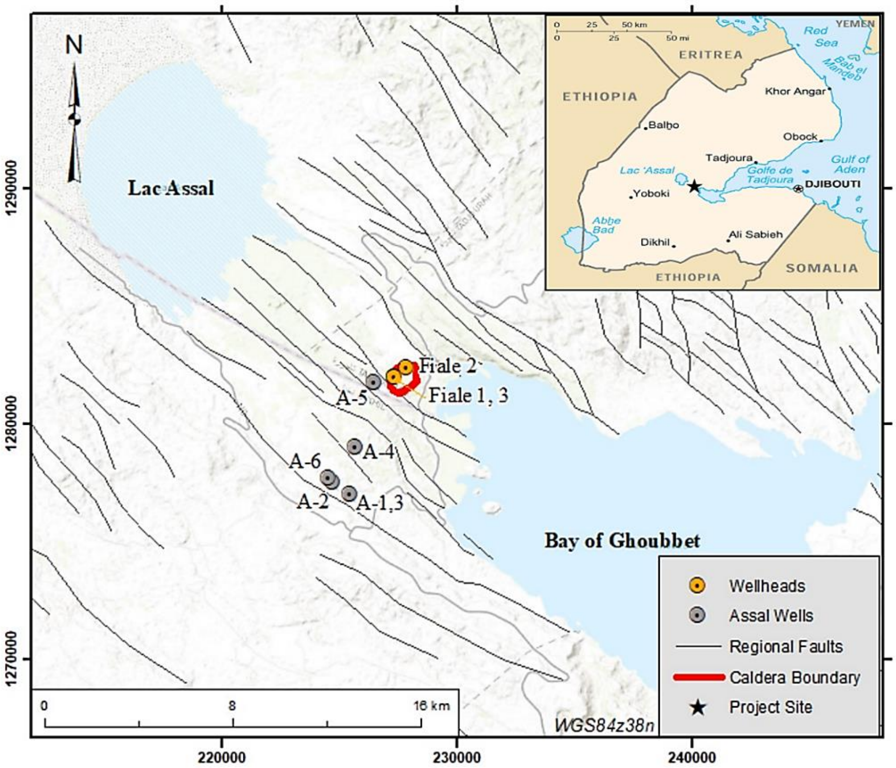

Figure 63: Structural map showing the Fiale and Gale La Koma sectors of Lake Asal field

- **Asal -Gale Le Koma geothermal field**

Djiboutian Office for Geothermal Energy Development (ODDEG) undertook intensive field activities in the Asal rift in the area called “Gale Le Koma” to the south west where the first successful drilling was undertaken in 1975 (Figure 63). The objective of this program was to quantify the shallow reservoir discovered during the geothermal exploration drilling in Asal in 1975, and confirmed by further wells drilled between 1987 and 1988. ODDEG and partners designed an appraisal drilling programme of four wells to evaluate the shallow reservoir. The project is funded by Kuwait Funds Arab Economic Development. So far, one well has been drilled to about 1300 m depth and encountered high temperatures of more than 260oC, however, permeability seems to be low. Drilling of subsequent wells were temporarily suspended to allow for procurement of some critical drilling equipment. Drilling of the remaining three wells will commence soon.

- **North-Ghoubhet Geothermal prospect**

The North–Ghoubhet geothermal prospect is located close to the Asal Geothermal field in the north-eastern part. The area is limited to the north by the Goda mountain and the by the Ghoubbet sea (westernmost extension of the Aden ridge) in the southern part (Allaleh, et al., 2015). The geological structure is composed mostly of deeply faulted, tilted and eroded basaltic rocks. The tectonic activities of the zone are controlled by complex fracture networks from NW to SE following the Asal rift with other directions resulting from the transform fault system linking the Ghoubbet rift segment to the Tadjoura rift segment (Figure7). Geothermal surface manifestations are mostly fumaroles and hot grounds. Resistivity surveys undertaken in the prospect shows a conductive electrical anomaly. Geochemistry measurements were also done including fumarole and hot springs sampling along the east sea shore. The geothermometry gave a temperature range of 170°C to 220°C. The chemistry of the springs suggest lower reservoir fluid salinity compared to the Asal system. Conceptual model suggests a magmatic heat source located at the sub marine side of North Ghoubbet.

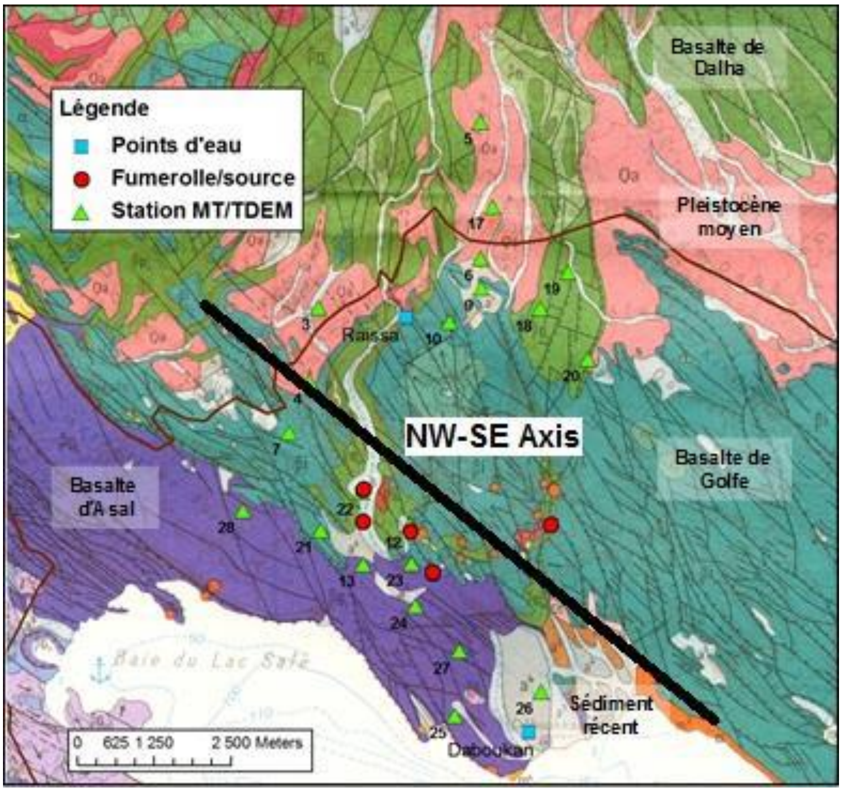

Figure 7: Geological map of the North Ghoubhet geothermal area

(Allaleh, et al., 2015).

- **Lake Abhe Geothermal Prospect**

The Lake Abhe geothermal area has the second highest estimated geothermal potential in Djibouti. The prospect is located at the border between Djibouti and Ethiopia adjacent to Lake Abhe (Figure). The Abhe geothermal prospect is characterized by the presence of the Dama Ale volcano which is suggested to define a magmatic heat source under the volcano. The tectonic setting is defined by three regional tectonic structures: the NNE-SSW-trending Ethiopian rift, the ENE-WSW-trending Gulf of Aden and the NNW-SSE-trending Afar rift (Red Sea) (JICA, 2014).

The combined effect of the drifting of the three associated tectonic plates confers on the region a very severe tensional tectonism and a high extension rate, as also evidenced by the tholeiitic affinity of the magmas ejected from the Dama Ale volcano. Surface hydrothermal manifestations abundant around the lake include fumaroles and hot springs at temperatures of more than 90°C.

- **Hanle-Garrabayis Geothermal prospect**

A geothermal study was conducted in the Hanle graben (southwest of the Republic of Djibouti), in the years 1981 to 1987, with the assistance of the Italian government and the World Bank. Subsequent studies revealed the possible occurrence of a geothermal system within the Hanle graben. Results from gas geothermometry indicates the possible existence of a geothermal system with reservoir temperatures of more than 230oC. However, some geothermometric estimates produce lower reservoir temperatures. Exploration drilling is planned after completion of the Gale La Koma project as is funded by financing from JICA of USD24 million.

- **Sakalol Geothermal prospect**

Sakalol is located in the northwest region of the Republic of Djibouti within the NW extension of the Asal rift system (Figure 5). This is an elongated graben produced by normal faulting affecting the Stratoid series (3.5 to 1 Myr old). Although it is deprived of any recent volcanic activity, Sakalol has been considered as part of the important geothermal sites in the Republic of Djibouti as it has some fumaroles and hot springs.

- **Other Geothermal Prospects**

The other geothermal prospects in Djibouti include Arta and Obock. Arta geothermal prospect is located 40km from near Djibouti town (Figure5). Geothermal manifestations occur aligned in the NW trends along faults. There are no active volcanoes in the area and therefore the geothermal system is most likely due to deep circulation along the fault planes. Obock geothermal prospect is located in the northern part of the country across the Gulf of Tadjourah at the shores of the gulf. Hot springs at Obock are aligned along normal faults that are parallel to the axis of the nearby mid-oceanic ridge. The hot springs are not related to any volcanic centres and there can be presumed to have their genesis from deep circulation of surface waters.

Status of the development of the geothermal power projects

Djibouti received funds from several development partners for the development of Fiale caldera, Gale La Koma and Hanle-Garrabayis geothermal prospects (Table3,

Table4). The funding plan for the Asal-Fiale geothermal field development is shown in

Table4. If successfully completed, the implementation of this project will contribute to the development of Djibouti's first geothermal power plant since the prospect is expected to have lower salinity which is suitable for power generation (African Development Fund, 2018).

ODDEG obtained a further US$ 27M grant from Kuwait Development Fund to develop the Gale Le Koma geothermal project for drilling of 10 wells (eight production wells and two reinjection wells). In the first phase, feasibility study for the construction of a pilot geothermal power station with a capacity of 15 MW will be conducted and later the capacity will be expanded to 50 MW in its final phase.

Table3: Status of Geothermal Projects in Djibouti

No.	Site	ODDEG (Government)	World Bank, AfDB, OPIC, AFD, GEF, and ESMAP	Wells drilled and planned	Estimated capacity (MW)
1	Asal-Fiale		Kuwait Development Fund	Drilled 3	50
2	Gale La Koma		Kuwait Development Fund	Drilled: 1 Planned: 10	50
3	Hanle-Garrabayis		JICA	Planned: 2	36

Table 4: Funds from international institutions (Data Source: World Bank, 2022)

Institution	Project	Plan (million US$)	Actual (at the end of 2019) (million US$)
World Bank	Asal-Fiale	6	6
GEF	Asal-Fiale	6.04	6.04
ESMAP	Asal-Fiale	1	1
OFID	Asal-Fiale	7	7
AFD	Asal-Fiale	3.25	3.25
AfDB	Asal-Fiale	7.34	25.35
Ministry of Economy and Finance (Djibouti)	Asal-Fiale	0.5	9.08
Kuwait Development Fund	Gale La Koma	27	
JICA	Hanle-Garrabayis	24	

Direct use applications

There is no recorded large-scale direct use of geothermal resources in Djibouti, except for trapping of steam for water production from steam condensation. However, preliminary studies indicate that there could be potential for direct use in drying fish, aquaculture heating, desalination, cooling of greenhouses and space cooling at several sites close to large population centres. Djibouti is currently dependent on imports for most of its food, as climatic conditions and the country's poor soil limit crop production, and domestic food production meets only about 15% of demand. Only 0.1% of the country's land area, or 2,000 hectares, is available for farming. Under these circumstances, aquaculture and hydroponics are ideal economic activities that directly utilize geothermal heat, but access to water is a challenge (FAO, 2022). The CTCN report singled out vegetables and/or fruit drying and balneotherapy or cooling as applications suitable for the areas (CTCN, 2020). LEAPRE project funded by the EU commission is undertaking a project at Lake Abhe to evaluate the potential of the shallow reservoir to support community-based electricity generation and direct use facilities under the “Geothermal Village” concept.

Policy, regulatory and institutional framework for development of geothermal resources

Institutional framework

The institutional framework for the energy sector in Djibouti is led by the Ministry of Energy which is in charge of the energy sector and is also the sector regulator. The Électricité de Djibouti (EDD) is the sole generator, transmitter and distributor of electric energy. On a regional level, the country is a member of the East African Power Pool. An Electricity Law is under preparation. The Djibouti National Energy Master Plan and the National Strategy and Action Plan for the electricity sector guide developments in the sector. In the geothermal sector, the Ministry of Energy oversees the policy development and licensing of geothermal projects while ODDEG under the Presidency of Djibouti undertakes project implementation on behalf of the Government. Prior to the establishment of ODDEG, geothermal projects were undertaken through Le Centre d'Etudes et de Recherche de Djibouti (CERD) which is a government entity responsible for research and technology development under the Ministry of Higher Education. These are described below.

- **Ministry of Energy**

The Ministry of Energy is in charge of policy development and regulation of the energy sector and also oversee the management of national resources.

- **Electricity of Djibouti (EDD)**

The electricity of Djibouti is a government corporation in charge of the development of the electricity sector. Until 2014 EDD was also in charge of geothermal development. The energy sector was liberalized, the monopoly of EDD for electric production was opened up to IPPs as well.

- **Djiboutian Office for the Development of Geothermal Energy (ODDEG)**

ODDEG is under the supervision of the Presidency. The core mandate of ODDEG is the identification of geothermal resources of the country, conducting reconnaissance and surface development studies, undertaking prefeasibility and feasibility studies aimed at commercial development of the resources, fostering partnership with IPPs and other stakeholders for cost-effective development of geothermal energy in the country. ODDEG is empowered to undertake all activities related to the geothermal resource development in order to make available geothermal resource for investment by IPPs.

- **Djibouti Study and Research Center (CERD)**

CERD is public owned scientific institution. Before the establishment of ODDEG this body was responsible for geothermal research activities including geothermal. Before the establishment of ODDEG, CERD was the institution responsible for geothermal exploration in Djibouti.

Policy and regulatory framework

Djibouti Government has clear policy target for geothermal development, but has not developed adequate policies for private investor entry into the sector. In terms of regulation, Djibouti doesn't have clear law to regulate geothermal exploration and development, but has decree for the creation and management of geothermal development projects. Vision Djibouti 2035 establish the foundations for controlled development. The vision sets a goal for Djibouti to be a "100% green" by 2035, using renewable energy for supply, sustainably managing water, and adapting to climate change and related risks such as desertification. It states that the country will promote the development of renewable energies such as geothermal, wind, and solar through public private partnerships. In this vision, the country planned to cover 50 MW of electricity generation capacity with geothermal power in 2019, but no geothermal power plant is in operation as of 2023.

The Government further enacted a decree on the creation and management of Geothermal Development Projects (Decree no. 2012-257/PRE). The decree defines and discusses the roles of the geothermal development project supervision and management bodies. This decree establishes a Steering Committee (SC) consisting of the Secretary General of the Ministry of Economy and Finance, a representative of the Ministry of Energy, the Director General of Electricity of Djibouti, the Director of the Centre for Studies and Research, and a Project Management Unit for geothermal development under the Ministry of Energy.

Regulation for Geothermal Power Plant Licensing and Authority was enacted under Law no. 88/AN/15/7e L and Decree no. 2019-013/PR/MERN. The law regulates the production, purchase, and sale activities of electric energy by independent operators from renewable energy sources and/or traditional energy sources (fossil). It also defines the role of the Energy Directorate of the Ministry of Energy responsible for Natural Resources (MERN), which is the regulatory and supervisory body for the electric power sector, including the production and sale/purchase of electric energy. The government of Djibouti further enacted Regulations for Environmental Impact Assessment Procedure vide Decree no.2011-029/PR/MHUEA. Regulations for PPP have also been enacted under Law no. 186/AN/17/7e L. The Republic of Djibouti is keen to develop favourable policy for investments in the energy sector. The energy sector suffers high electricity costs in the region which enables the development of renewable energy projects a potentially profitable business. The Government supports and assists the private developers (IPP) through the national investment agency (ANPI) at different step of the process.