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AU-NEPAD African Networks of Centers of Excellence on Water Science

Status of Geothermal Industry in East African Countries

ACEWATER2

Joint Research Centre
Water Resources Unit
European Commission

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Ispra, Italy
???. ??, 2020

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Outline

Introduction

Geothermal Energy in the EARS

International Stakeholders

Countries Status

Introduction

The assessment of the status of geothermal industry in East African countries has been performed within the project "**The African Networks of Centres of Excellence on Water Sciences PHASE II** (ACE WATER 2)".

The general objective of the study was to present the state-of-the-art on the geothermal resource development for **power generation** in East African Countries (**Eritrea**, **Djibouti**, **Ethiopia**, **Kenya**, **Tanzania, Uganda**, **Rwanda**, **Burundi**, and **Comoros**) and in two Southern African countries (**Malawi** and **Zambia**) crossed by the **East African rift Systems (EARS)**.

The report is the result of a desk-based work, consisted in a literature review of selected papers approximately from year 2005, institutional web sites, and news searched on web resources.

Introduction

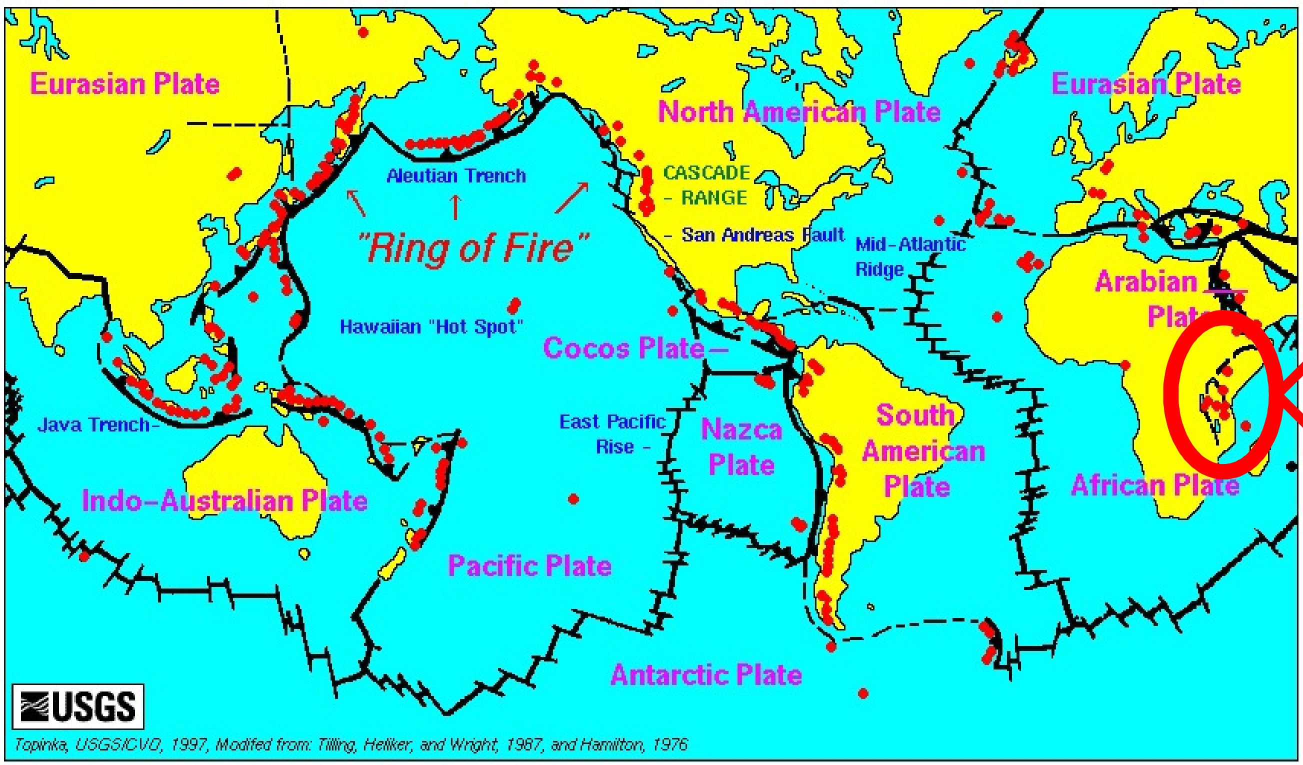
The results of the study have been documented in the JRC report by *Battistelli, Crestaz, Carmona-Moreno* (2020). "**Status of Geothermal Industry in East African Countries**". JRC Technical Report, JRCxxxxx.

Main characteristics of geothermal energy have been reviewed and the main features of the geothermal systems found within the EARS reminded. The business models implemented are discussed, together with Constraints delaying a more widespread use of geothermal energy for electric power generation in East Africa

The **International Stakeholders** and their role in supporting the development of geothermal energy in East Africa have been presented.

Finally, the status of geothermal development in each of the 11 considered countries has been presented with data and news collected until May 2020.

Geodynamic contest



(USGS, 1997)

The **East African Rift System** (**EARS**) is a succession of intracontinental rift valleys that extends from Northern Mozambique in the South to the Afar Depression in the North.

Total length is over 4,000 km.

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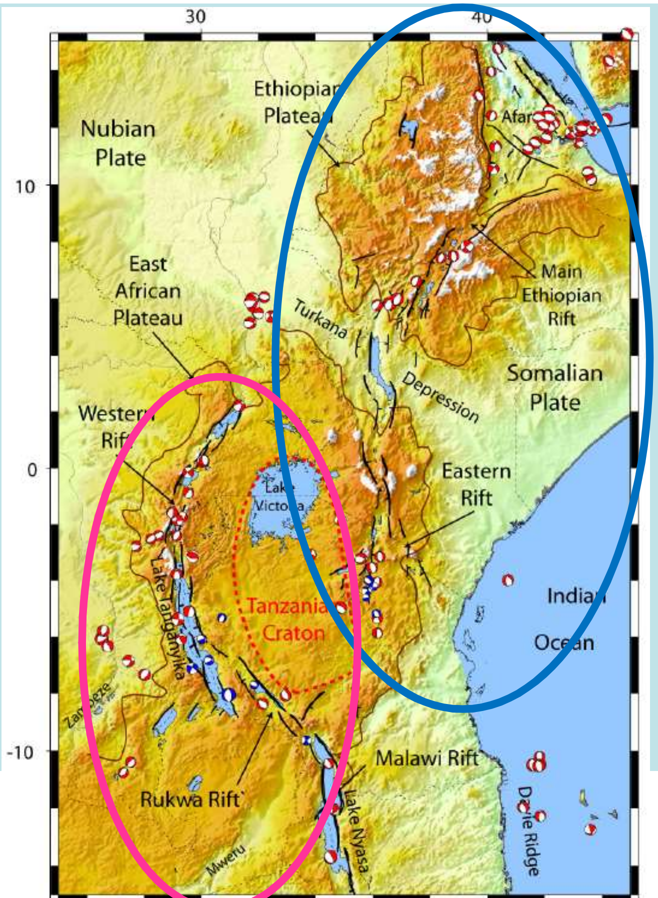
Geodynamic contest



The EARS is composed by the **Eastern Branch** (Eritrea, Djibouti, Ethiopia, Kenya and Tanzania) and the **Western Branch** (Uganda, Rwanda, Burundi, Tanzania, Zambia and Malawi).

The Comoros, the archipelago located in the Indian ocean, has also been included in the review.

Congo (RDC) and Mozambique have not been included.

(*Omenda, 2018*)

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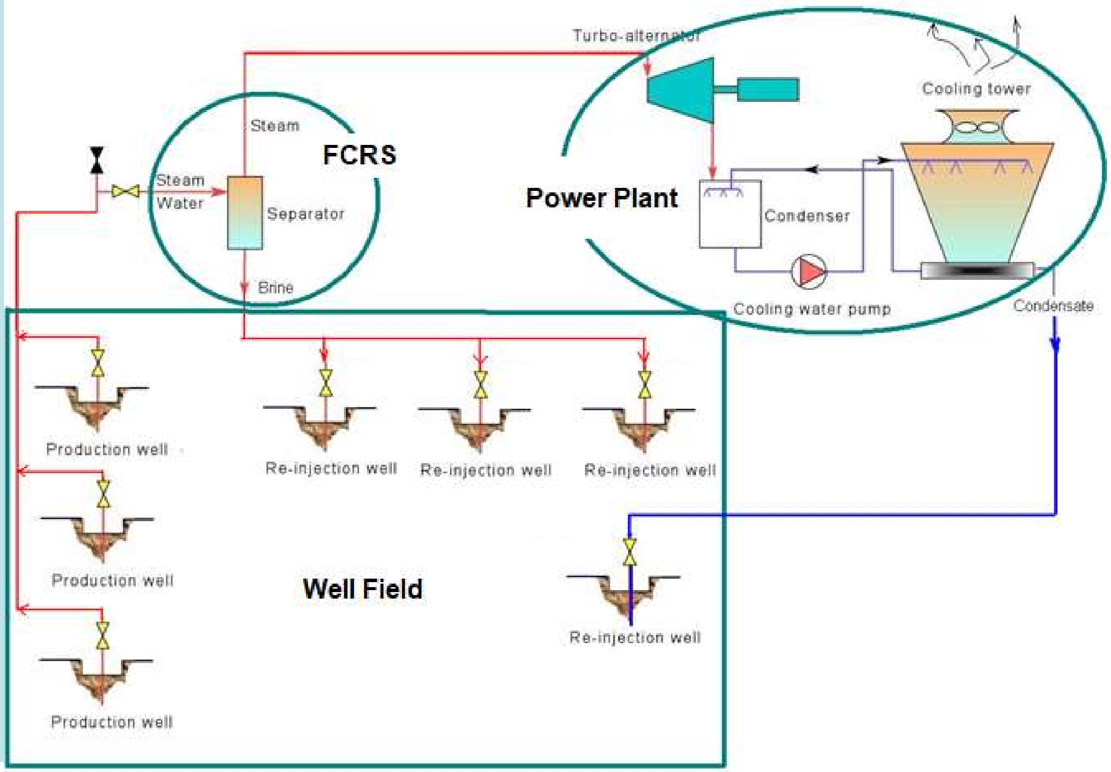
Basic components of a geothermal field



The basic components of an exploited geothermal field are:

- the **Well Field** (production and reinjection wells);
- the **Fluid Collection and Reinjection System** (FCRS; pipelines, separator stations, pumping stations);
- the **Power Plant** (turbine, alternator, condenser, cooling tower).

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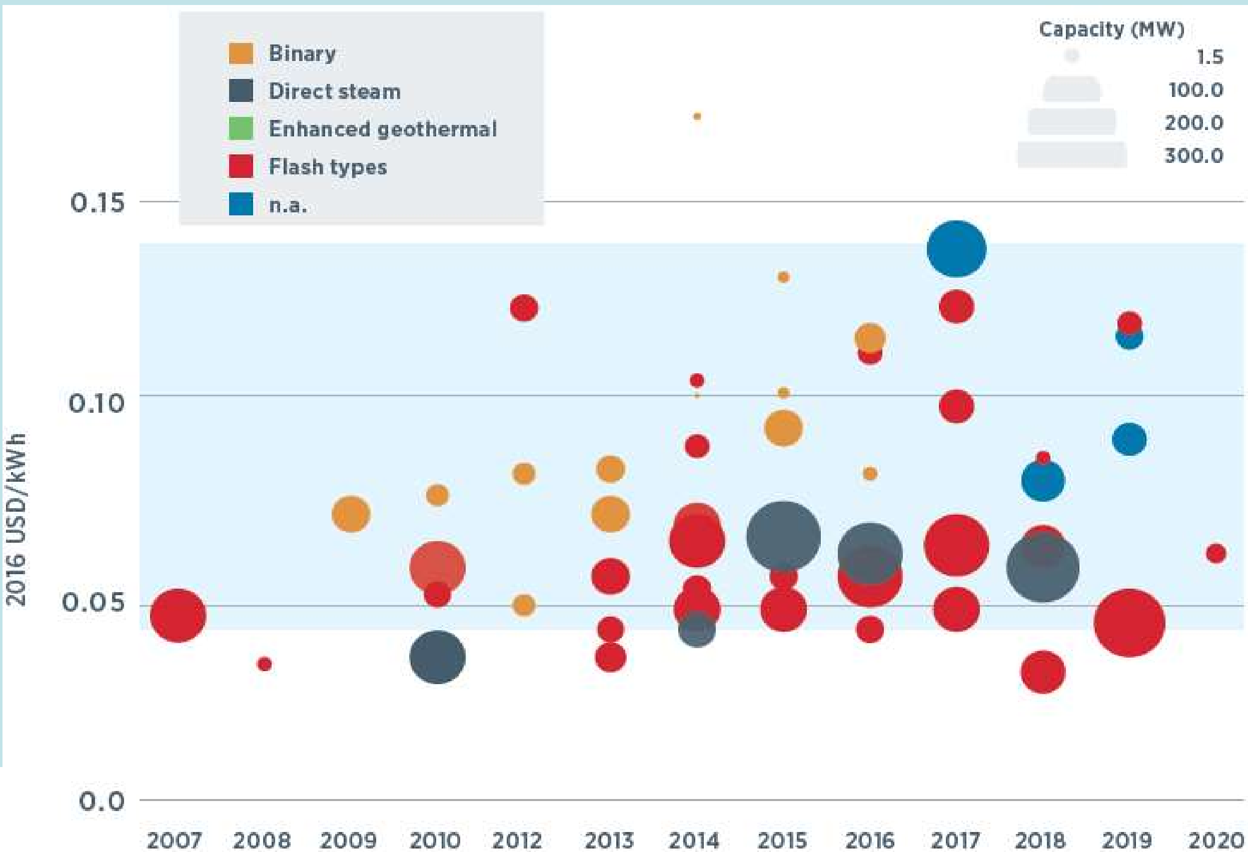
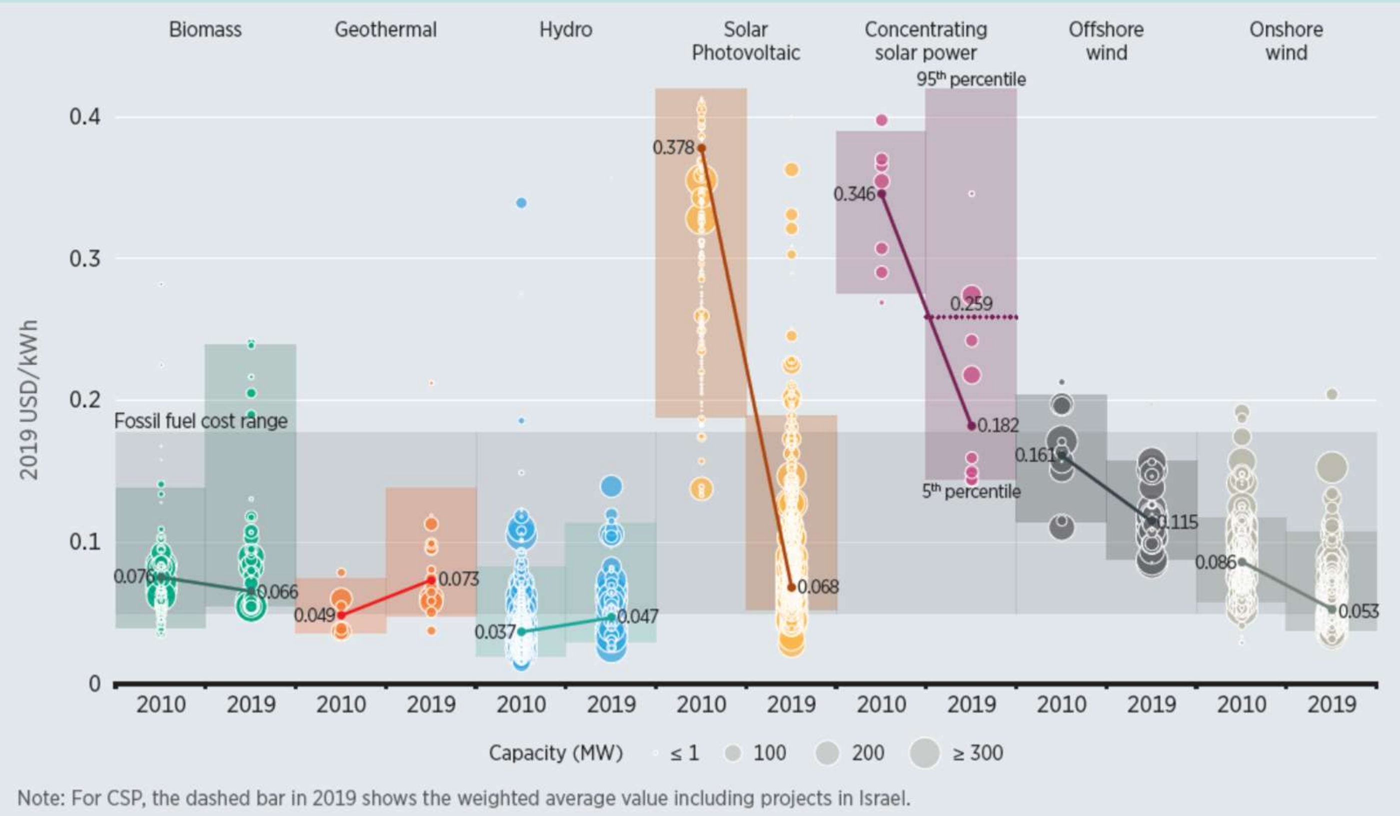
Competitive LCOE



Estimated Levelized Cost of Electricity generation (LCOE) by geothermal plant technology for a 25-year economic life (IRENA, 2017).

Geothermal power generation is **competitive with generation by fossil fuels** (the cyan band).

Competitive LCOE against other renewables



Global LCOEs from newly commissioned utility-scale renewable power generation technologies, 2010-2019 (IRENA, 2020).

Geothermal power generation **is still competitive with other renewables**

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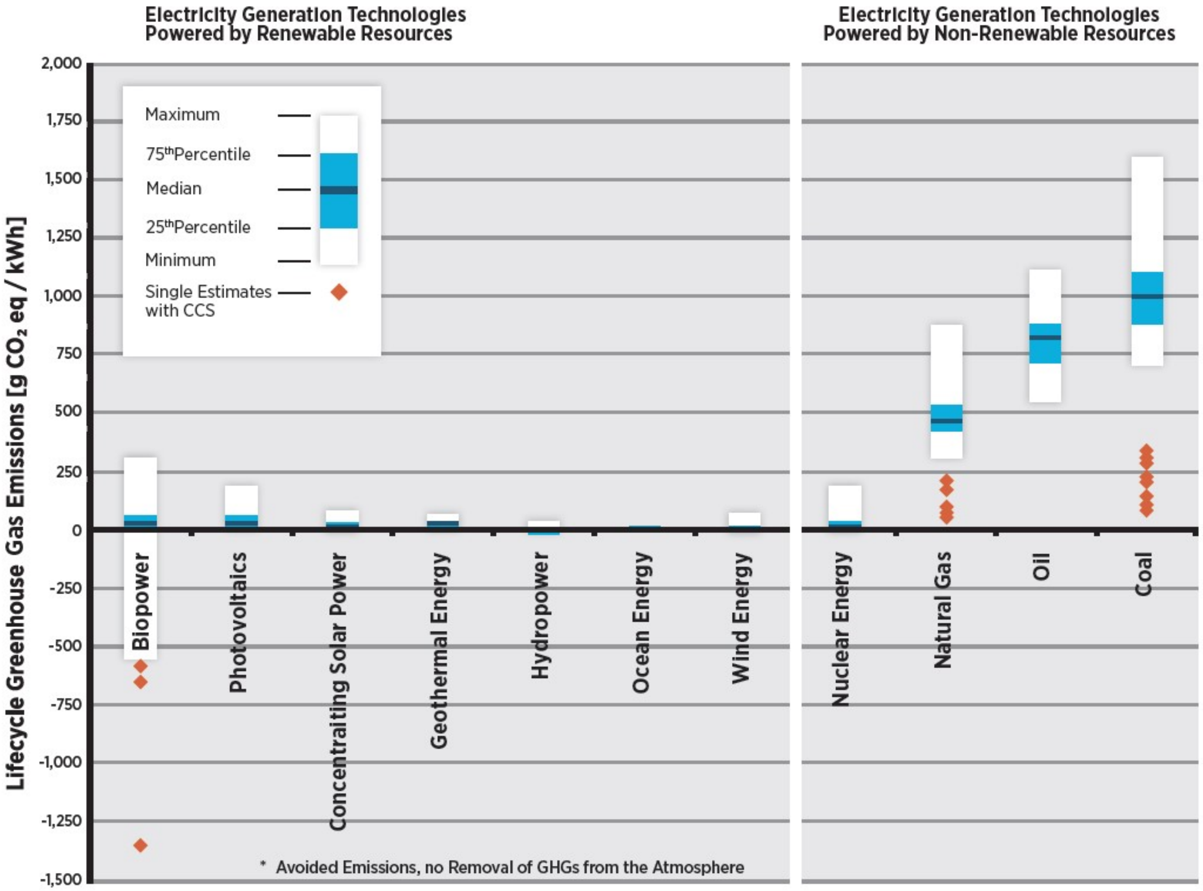
GHG emission of geothermal power generation



Lifecycle greenhouse gas emissions for different electricity generation technologies (IPCC, 2011).

Geothermal power generation has GHG emissions over its lifecycle comparable to those of other renewables and definitely lower than fossil fuels.

Reduction of CO2 emissions is to be considered for geothermal power generation.

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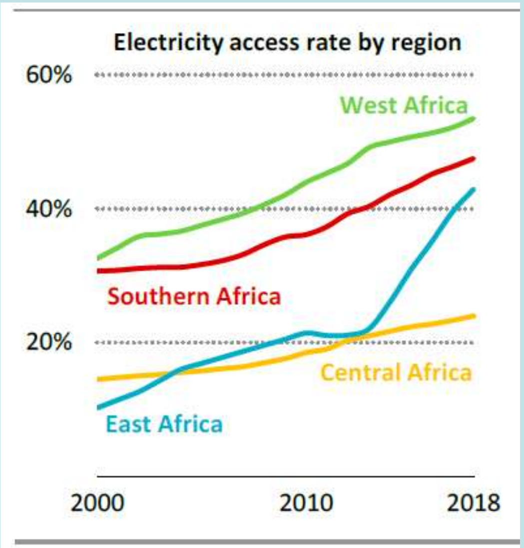
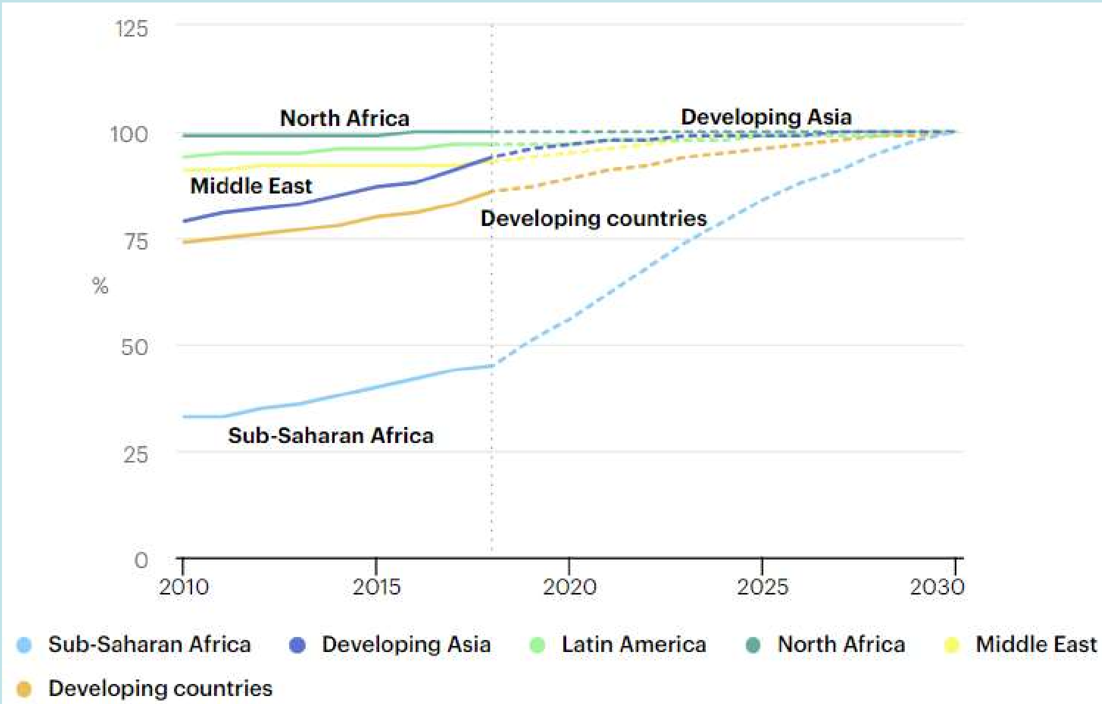
Huge electricity access increment for East Africa



Electricity access progress in sub-Saharan Africa from 2000 to 2018 (IEA, 2019).

Large increment of electricity access expected for sub-Saharan countries from 2020 to 2030.



Access to electricity in the Sustainable Development Scenario, 2010-2030 (https://www.iea.org/data-and-statistics/charts/).

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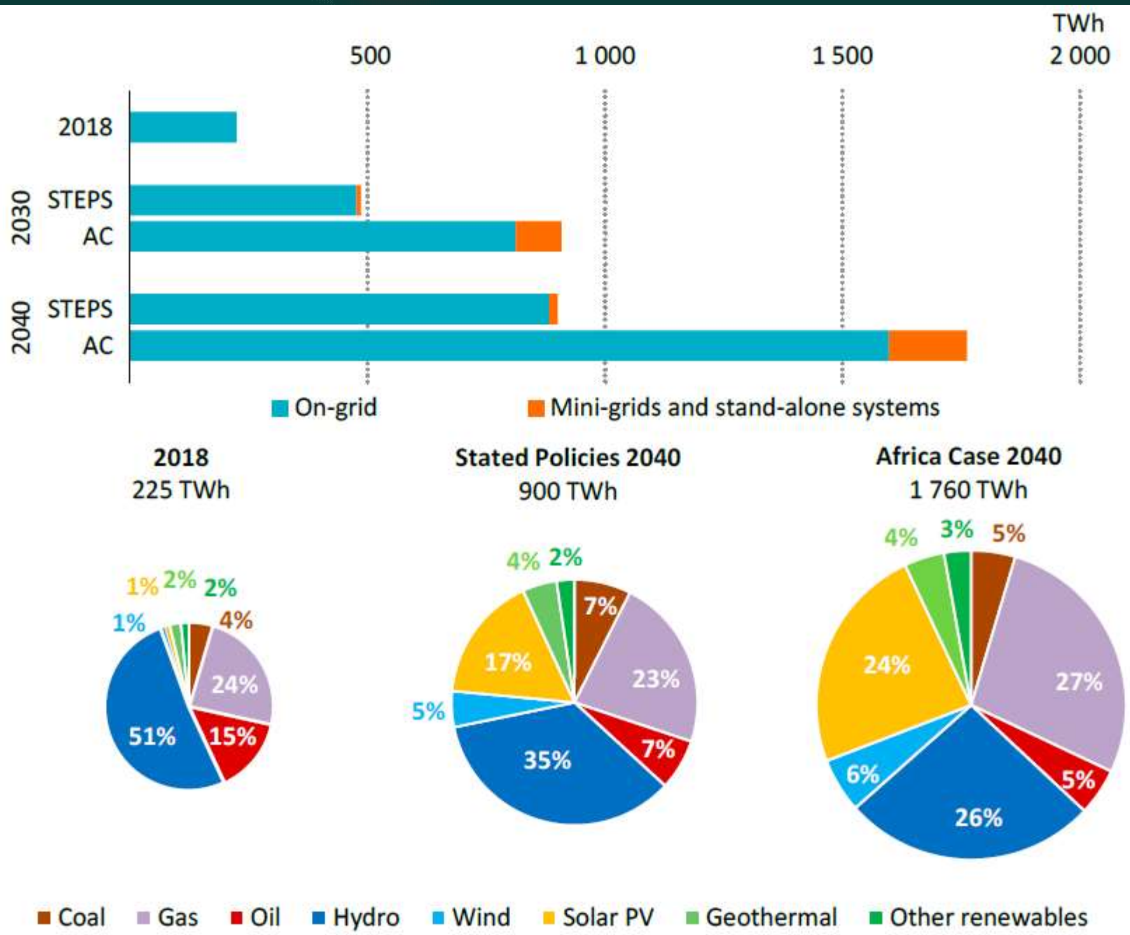
Huge geothermal development predicted by IEA



Electricity supply by type, source and scenario in sub-Saharan Africa (excluding South Africa), 2018 and 2040 (IEA, 2019).

Despite a limited role in the energy mix of sub-Saharan countries from now till 2040, geothermal energy is expected by IEA (2019) to have a **huge development in East Africa** thanks to the very large predicted increment of overall power generation (about 10 times).

Pros/Cons of geothermal power generation

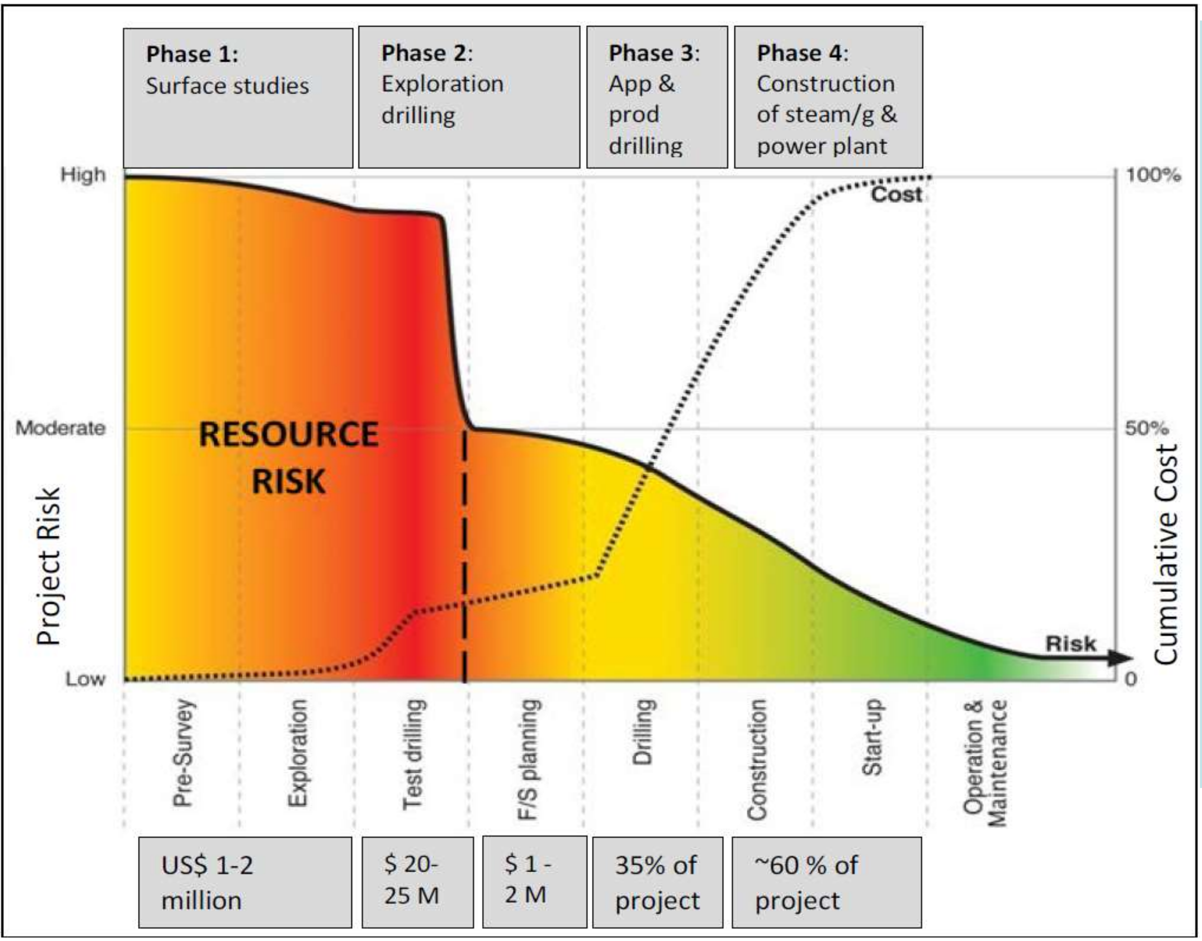
ADVANTAGE	DOWNSIDE/CHALLENGE
Globally inexhaustible (renewable)	Resource depletion can happen at individual reservoir level
Low/negligible emission of CO_2 and local air pollutants	Hydrogen sulfide (H_2S) and even CO_2 content is high in some reservoirs
Low requirement for land	Land or right-of-way issues may arise for access roads and transmission lines
No exposure to fuel price volatility or need to import fuel	Geothermal "fuel" is non-tradable and location-constrained
Stable base-load energy (no intermittency)	Limited ability of geothermal plant to follow load/respond to demand
Relatively low cost per kWh	High resource risk, high investment cost, and long project development cycle
Proven/mature technology	Geothermal steam fields require sophisticated maintenance
Scalable to utility size without taking up much land/space	Extensive drillings are required for a large geothermal plant

Pros and Cons of Geothermal Power (ESMAP, 2012).

PROS: stable base load (>90% availability; relatively low cost per kWh; proven/mature technology.

CONS: mining risks; high exploration investments before resource confirmation; long project development cycle; sophisticated expertise required.

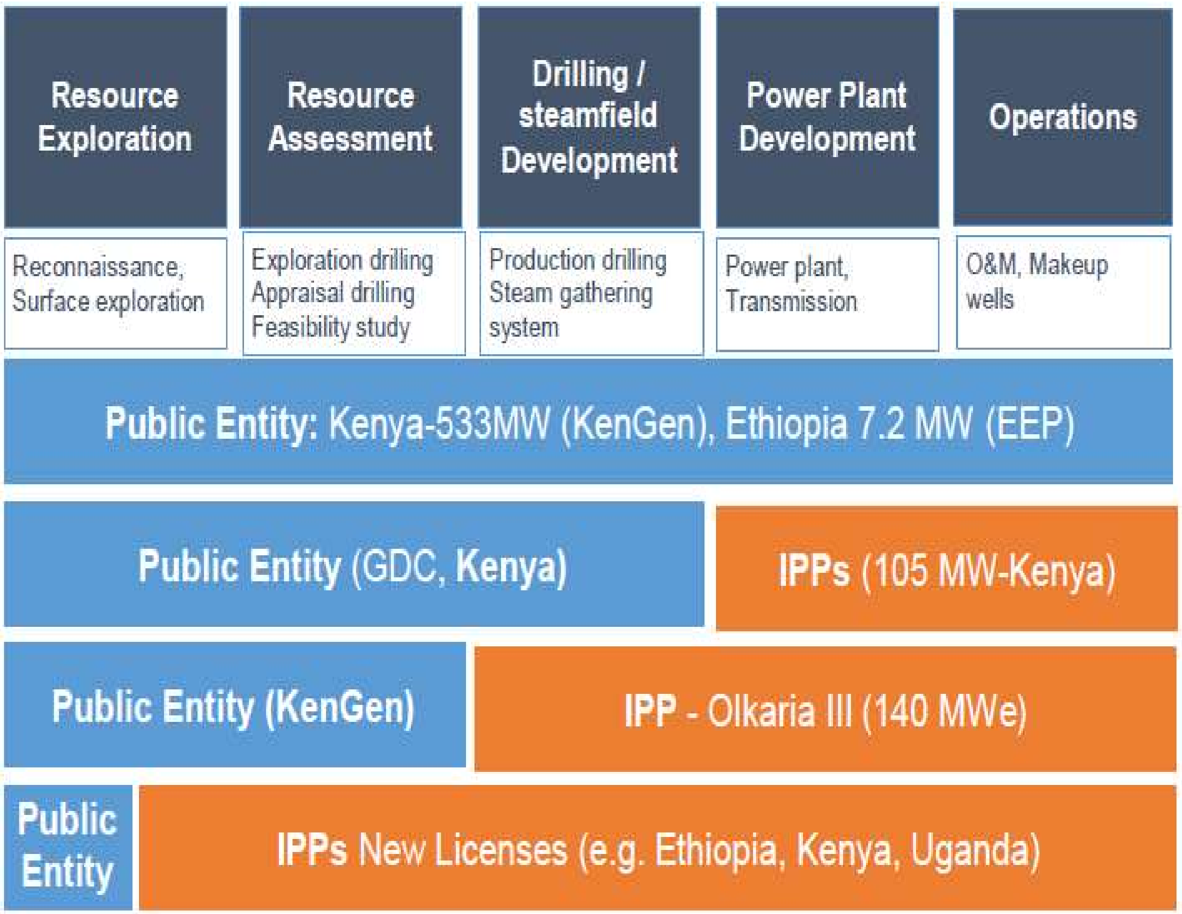
Mining risks



Project Cost and Risk Profile at Various Stages of Development (Gehringer and Loksha, 2012).

Expensive deep exploratory wells needed for resource confirmation:
High test drilling costs to be afforded

Business models



Geothermal projects development in East Africa (Omenda, 2018).

Kenya example: switching from complete development by public entities towards shared development with private operators.

Full development by IPPs is now considered in Kenya, Ethiopia and Zambia.

IPP: Independent Private Producers

International Stakeholders

- Many **International Stakeholders** have been and are still active in supporting geothermal development in East African Countries with technical assistance, training and capacity building, legislative framework development, funding of exploration, development and EPC projects.
- They are involved with different roles and at various stages of the geothermal resource development chain.
- Many of them are collaborating on common initiatives often sharing funding contributions and management responsibility.

EPC: Engineering, Procurement and Construction

International Stakeholders

A non exhaustive list of **International Stakeholders** (whose role has been analysed in the JRC report) includes:

United Nations (UNDP, UNECE, UNEP, UNU-GTP, ARGeo), European Union, African Union (RGP, GRMF), Nordic Development Fund, Icelandic Ministry of Foreign Affairs, Agence Française de Développement, African Development Bank, World Bank (ESMAP, GGDP), New Zealand Ministry of Foreign Affairs & Trade, International Renewable Energy Agency (GGA), International Energy Agency, Japan International Cooperation Agency, Federal Institute for Geosciences and Natural Resources (BGR), KfW, US Government (USAID, Power Africa, EAGP, USTDA), IGA, GRC.

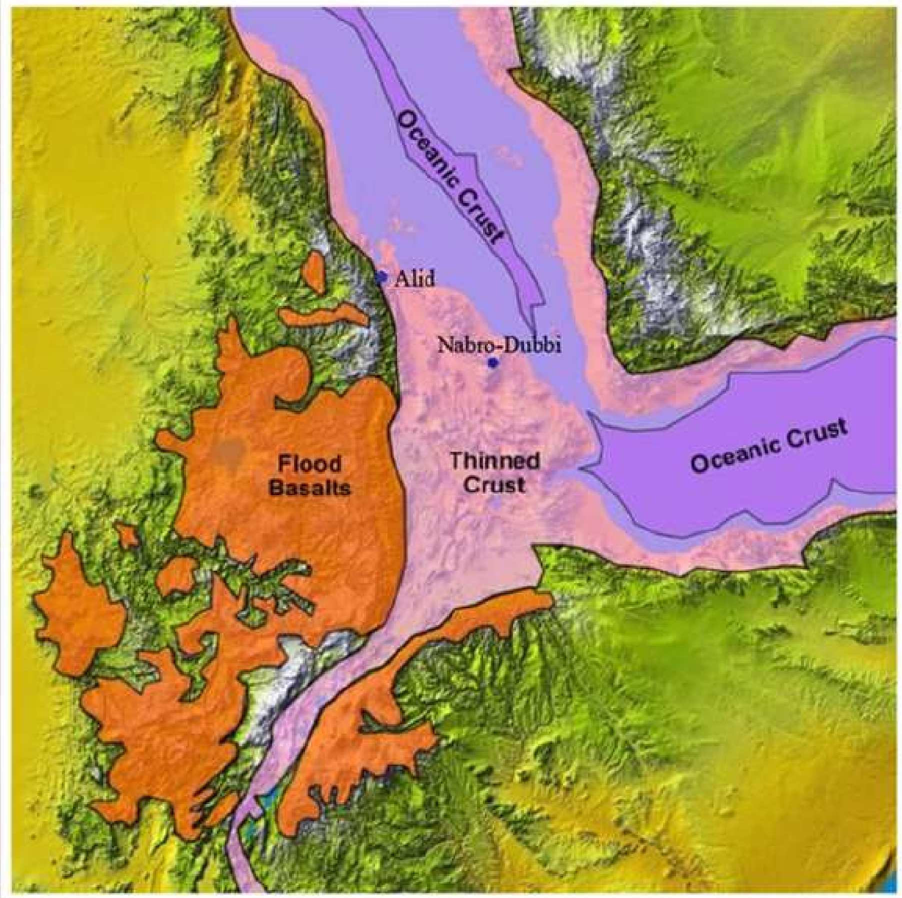
Eritrea Country Status

Eritrea is located in the Afar depression, along the Read Sea coast.

Geothermal exploration since the '70s (UNDP, 1973).

2 identified geothermal areas: **Alid** dome and **Nabro-Dubbi** volcanic complex.

Surface exploration performed only at Alid dome prospect in different phases (1996, 2005, 2009, 2015).



(Source: Yohannes, 2015)

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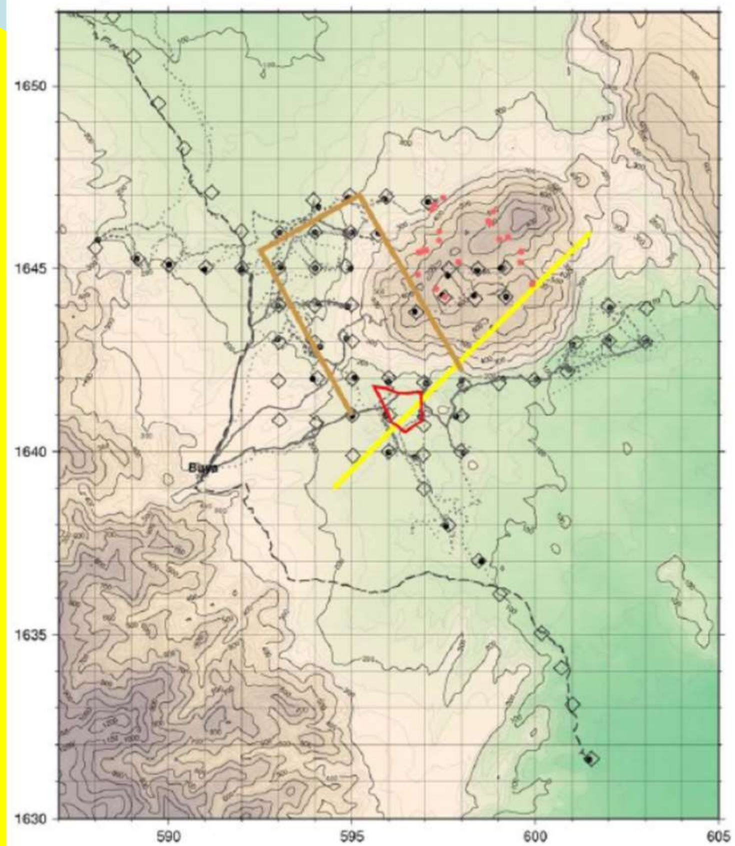
Eritrea Country Status

The most explored area is the **Alid** volcanic centre located within the axis of the Danakil Depression that extends NNW from the Afar triple junction.

Alid is a very late-Pleistocene structural dome formed by shallow intrusion of rhyolitic magma, some of which vented as lavas and pyroclastic flows, the youngest dated at 33k year.

Surface exploration included detailed geological and geochemical surveys (by USGS-MEM in 1996), structural survey (2005), geophysical surveys (2009). The conceptual model infers a boiling brine beneath a vapor-dominated reservoir with temperatures up to 270°C.

Within the Geothermal Exploration project (GEP) mapping of surface manifestation and a gravity survey were performed, but failing to complete the whole planned activities. Despite that GEP expressed the willing to support Eritrea for the Alid development with **70 MW expected potential**.



(Source: Yohannes, 2015).

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Eritrea Country Status

- Population 5.7 M (2019)
- Rural: 80%.
- TPES: Biomass 77%, Oil 33% (2017).
- Installed power: 195 MW (2019), ~100% thermal.
- Electricity consumption: 70 (kWh/yr capita, 2017)
- Access to electricity : 47 % (2017).

- Estimated geothermal potential: **100 MW**.
- Clear potential for Solar PV (no Hydro).
- **National stakeholders**: Ministry of Energy and Mines (MEM); GSE (Geological Survey of Eritrea); EEC (Eritrea Electric Corporation).

- Eritrea has a potential for renewable energies: geothermal and, solar.
- Installed power is still limited (195 MW) serving less than 50% of the population.
- A geothermal plant of 50 MW would already be able to cover a substantial fraction of the electric network base load.

- The most advanced project is the surface exploration of Alid dome prospect managed by GSE.
- Surface exploration need to be completed in order to be able to site exploration wells for the subsequent drilling exploration phase.
- International stakeholders (NDF, UNEP, EU) are interested to support Eritrea in the exploration of Alid dome.
- National stakeholders clearly needs a strong support related to technical assistance, project management, and consultancy services in order to be able to successfully proceed with Alid resource development.

Djibouti Country Status

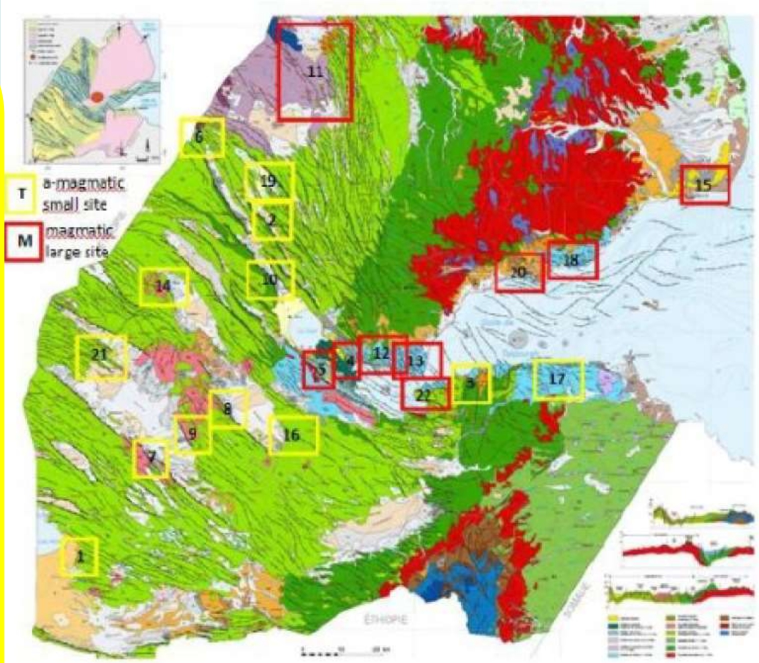
Djibouti is located in the Afar depression – emergence of Gulf of Aden Rift

Geothermal exploration since the ‘70s.

22 identified geothermal areas.

Exploration wells drilled at Hanlè (1987), Asal Rift (1975, 1987-88), Gale le Koma (2016), Fialé (2018-19).

Detailed surface exploration at Artà, North Ghoubet, Garabayis, Lake Abhè.



(Source: *Awaleh et al., 2020*).

Geothermal sites	
1. Lake Abhe	12. Nord Ghoubbet (Afaî-Bolli Daar)
2. Sakalol	13. NE Ghoubet (Assa Foo)
3. Arta	14. Modayto (N Gaggade)
4. Asal Fialé	15. Obock
5. Asal gale-le-koma	16. Okililaeou (SE Gaggade)
6. Balho	17. PK 20-Ambado
7. Daggadé (W hanlé)	18. Roueli
8. Dimbir-Didir (W Gaggade)	19. Sakalol
9. Garabayyis (E Hanlé)	20. Tadjoura
10. Karapti-san	21. Agna-Galafi (NW Hanlé)
11. Manda Inakir	22. Sud Est Ghoubbet

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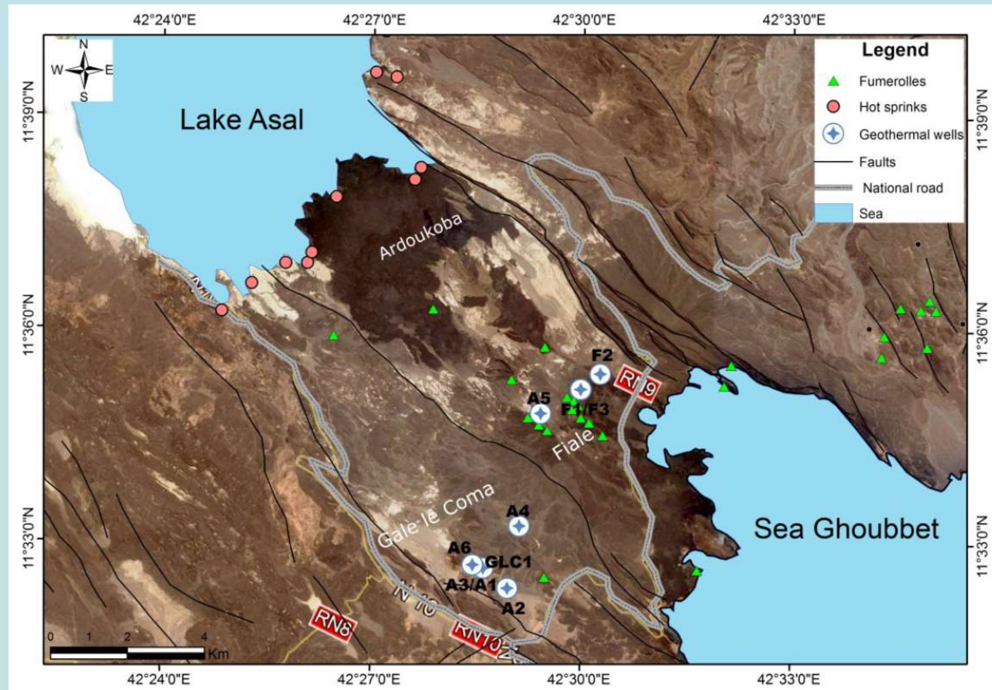
Djibouti Country Status

The most explored area is the **Asal Rift** located between Lake Asal and the Ghoubbet Gulf.

Gale le Koma: 5 deep wells drilled in 1975 (Asal 1 & 2) and in 1987-88 (Asal 3, 4 and 6) discovered a high salinity (116,000 ppm), high temperature (255-270°C) liquid dominated reservoir. Its exploitation was hindered by high sulphide and silica scaling occurring in the borehole and surface facilities, respectively. The shallow well **GLC-1** was drilled in 2016 to tap a shallow reservoir with lower salinity (~50,000 ppm) and temperature (~130-140°C). ODDEG is planning to drill additional wells.

Fialé: well Asal 5 was drilled in 1988 founding 359°C at 2,100 m, at the time the highest measured temperature in Africa, but no permeability. Three exploratory wells (F1, F2 and F3) have been drilled by ODDEG in 2018-19 founding BHT of 300°C and moderate permeability. Evaluation of production test and performance of a feasibility study is underway for the installation of a 50 MW power plant.



(Source: *Aden et al., 2020*)

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Djibouti Country Status

- Population 0.974 M (2019)
- Rural: 22%.
- TPES: Biomass 32%, Oil 68% (2008).
- Installed power: 123 MW (2019), 99.8% thermal.
- Import from Ethiopia: up to 42 MW.
- Electricity consumption: 427 (kWh/yr capita, 2016)
- Access to electricity : 60.2 % (2017).
- Electricity consumption is 4 times higher in Summer than in Winter due to air conditioning.
- Estimated geothermal potential: **800-1,000 MW** (Abdillahi et al., 2016).
- Potential for Wind and Solar PV (no Hydro).
- **National stakeholders**: Ministry of Energy and Natural resources; ODDEG (Djibouti Office for Geothermal Energy Development); CERD (Djibouti Center for Studies and Research); EDD (Electricité de Djibouti).

- Djibouti has a potential for renewable energies: geothermal, solar and wind.
- Installed power is still limited (123 MW) serving mostly the 2/3 of population living in Djibouti city.
- Summer electricity consumption is 4 times that of winter due to air conditioning.
- A geothermal plant of 50 MW would already be able to cover the base load of the electric network serving Djibouti city.
- The most advanced project is the drilling exploration in Fialé caldera managed by ODDEG, with the final goal to assess the feasibility of field development and installation of a 50 MW geothermal power plant.
- Geothermal exploration is in charge of ODDEG which is investing in equipment (2 drilling rigs), capacity building and exploration.
- International stallholders are actively supporting and financing surface studies and exploratory drilling.

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Ethiopia Country Status

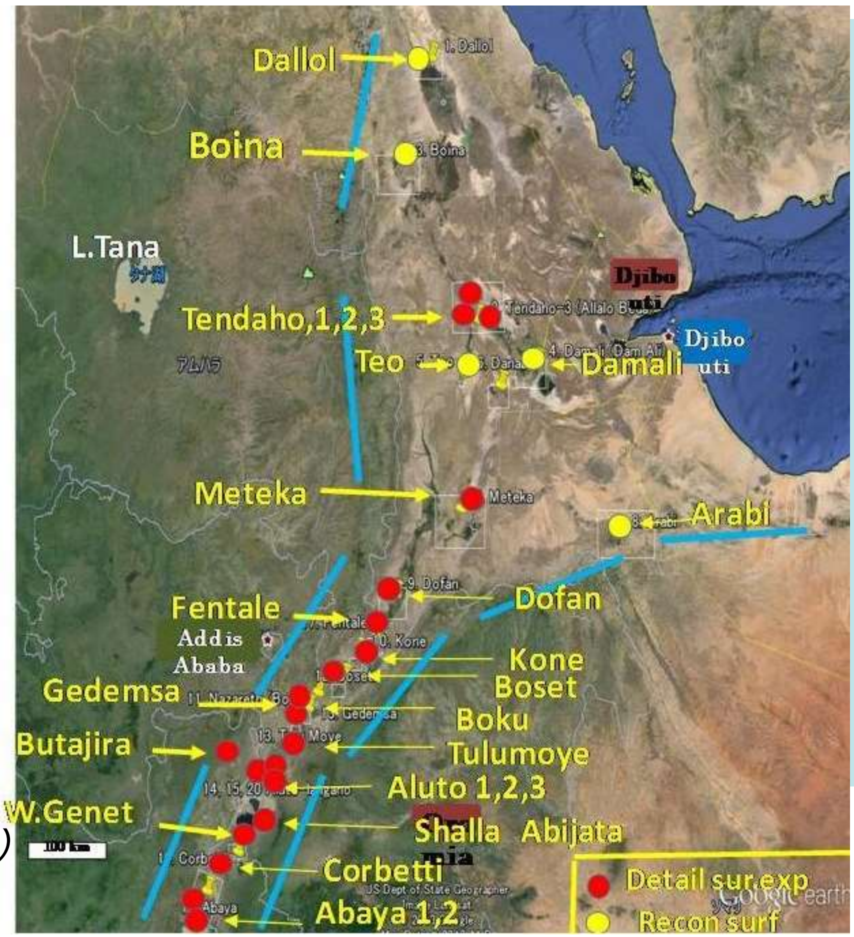
Ethiopia includes both the Afar Depression and the Main Ethiopian Rift Valley (MER).

Geothermal exploration since the '70s: **more than 25 geothermal prospect** identified with reconnaissance and surface studies.

Exploration and development wells drilled at Aluto (8 in the '80s; 2 in 2014-15) and Tendaho (4 in 1993-95, 2 in 1997-98).

8 geothermal licenses assigned to private operators along the MER.

3 prospects operated by the Ethiopian Electric Power company (EEP).



(Source: Kebede et al., 2020)

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Ethiopia Country Status

8 licenses have been already issued to 5 different private operators since 2009 and 2015.

Only reconnaissance and surface exploration surveys performed so far, mainly because of the lack of a clear regulation framework.

Geothermal Proclamation in 2016 and **Geothermal Regulations** in 2019 have clarified the legislative framework.

Updated Power Purchase Agreement and Implementation Agreements have been signed for Corbetti and Tulu Moye in April 2020.

Existing licenses have plans for power plant developments up to about **1,400 MW.**

Company Name	Locality	Issue Date	Original Area/km^2
Reykjavik Geothermal Consulting Co.	Abaya	Dec. 11, 2009	513.94
Corbetti Geothermal Plc	Corbetti	Dec. 11, 2009	735.8276
Cluff Geothermal Limited	Fentale	July 15, 2015	1,255.696
OrPower Twelve Inc	Boku	April 20 , 2015	342.697
OrPower Twelve Inc	Shashemene	April 20 , 2015	1,005.726
OrPower Twelve Inc	Duguno	April 20 , 2015	1249.506
OrPower Twelve Inc	Dofan	April 20 , 2015	1,255.65
Tulu Moye Geothermal Operation Plc	Tulu Moye	August 29 2018	588.3726

(Source: Mekonnen, 2020)

Ethiopia Country Status

3 prospects are operated by **EEP** with advanced plans for the drilling of deep wells:

- **Aluto-Langano**: drilling of 8 wells in Aluto I and Bobessa sectors within the Aluto caldera, for 35 MW power development. On-going project funded by the WB
- **Alalobad:** plans to drill 4 exploration wells with funds from the WB, for a 35 MW development.
- **Dubti (Tendaho)**: plans to drill 6 wells to develop the shallow reservoir already identified for a 10-15 MW development, with funds from EU and AFD

2 fully equipped drilling rigs under procurement for the Aluto project and future EEP drilling operations

(TD-4 production tests at Dubti Geothermal Field (1995), Tendaho Rift, Afar Region - Ethiopia

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Ethiopia Country Status

- Population 112.1 M (2019)
- Rural: 79%.
- TPES: Biomass 93%, (2017).
- Installed power: **4,522 MW** (2019), **90% hydro** 2% thermal, 8% other renewables.
- Electricity cons.: 84 (kWh/yr capita, 2016)
- Access to electricity : 44.3 % (2019).
- Estimated geothermal potential: **10,800 MW** (Kebede et al., 2020).
- High potential for Hydro, Wind and Solar PV.
- **National stakeholders**: Ministry of Water, Irrigation and Electricity; EEP (Ethiopian Electric Power); EEA (Ethiopian Energy Authority); GSE (Geological Survey of Ethiopia).

- Ethiopia has a huge potential for **Hydro with 10,390 MW** under construction at the end of 2019.
- **220 MW of other renewables** are under construction at the end of 2019.
- Geothermal energy shall contribute to the future energy mix with **3,500 MW by 2030** (Mekonnen, 2020).
- **New regulatory framework** seems to be finally able to speed the investments by private operators.
- Public institutions have still a direct role in geothermal exploration, but focusing their efforts of facilitatingthe intervention of experienced private operators seems to be a better option for an accelerated resource development in Ethiopia.

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Kenya Country Status

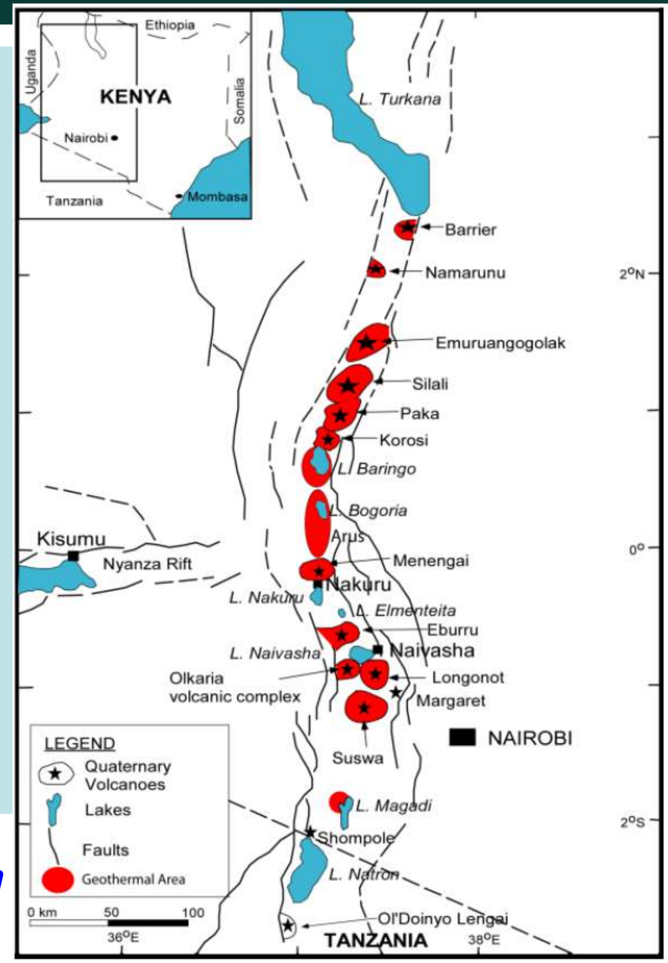
Kenya is is crossed N-S by the Kenya Rift Valley belonging to the Eastern Branch of EARS.

Geothermal exploration since the early '70s at Olkaria, with the first well drilled in 1973. First plant of 15 MW operating since 1981.

Total installed geothermal power amount to **865.4 MW at the end of 2019** (862.9 MW at Olkaria and 2.5 MW at Eburru). The fields were developed by **KenGen** state owned company.

Geothermal exploration is in charge to **GDC** (Geothermal Development Company) since 2008. GDC is developing Menengai, Korosi-Paka-Silali block and Suswa

Other 5 prospects are actively developed by private operators.



(Source: Omenda et al., 2020)

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Kenya Country Status

PPP approved geothermal projects: 2460 MW

890 MW at Olkaria **(KenGen)**

110 MW at Menengai (3 IPP, 35 MW each).

360 MW Menengai Phase 2 (**GDC**).

800 MW at Baringo-Silali Phase 1 (**GDC**)

300 MW at Suswa (**GDC**)

No	Project	Contracting Authority	Project Cost (M$)	PPP Model & Duration	Status
1.	50MWe Olkaria Wellheads Geothermal Projects	KenGen	-	Built, lease, operate & maintain	operational
2.	35MWe Sosian Menengai Geothermal Power Plant Project	GDC	79.15	BOO (25 yrs.)	Commercial/ financial close
3.	35MWe Quantum Menengai Geothermal Power Plant Project		79.15	BOO (25 yrs.)	Commercial/financial close
4.	35MWe Orpower Geothermal Power Plant Project		82.00	BOO (25 yrs.)	Commercial/financial close
5.	140MWe Olkaria Geothermal PPP project - Phase 1	KenGen	2,000	BOOT (25 yrs.)	Procurement
6.	420MWe Olkaria Geothermal PPP project - Phase 2			TBD	Proposal stage
7.	280MWe Olkaria VII & VIII		-	TBD	Drilling stage
8.	360MWe Menengai Phase 2	GDC	-	TBD	Drilling stage
9.	800MWe Baringo-Silali Phase 1		-	TBD	Drilling stage
10.	300MWe Suswa Geothermal Plant		-	TBD	Preliminary stages

BOO - Build-Own-Operate, BOOT - Build-Own-Operate-Transfer, BLOM – Built-Lease-Operate-Maintain, TBD: To be determined

(Source: Kiptanui and Kipyiego., 2020)

PPP: Public Private Partnerships

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Kenya Country Status

Active exploration activities at:

Barrier by Olsuswa Energy Ltd **(500 MW)**

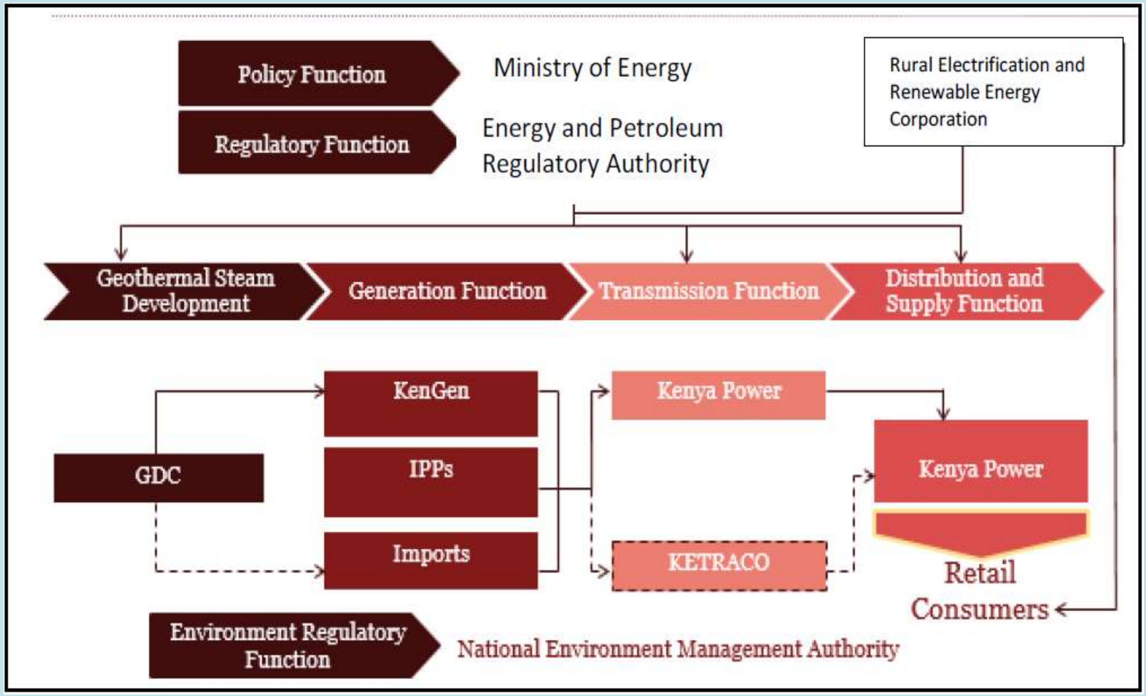
Longonot by Africa Geothermal Intl. Ltd **(140 MW)**.

Homa Hills by Capital Power Ltd **(45 MW)**.

Arus by Arus Energy Ltd (**80 MW**)

Akiira by Akiira Geothermal Ltd (**140 MW**)

Prospects at planning stage: Lake Baringo, Elementaita, Namarunu, Emuruangogolak, and Lake Magadi.



Kenya Energy sector Institutional setup, with specific reference to the geothermal sector (Source: Omenda et al., 2020)

PPP: Public Private Partnerships

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Kenya Country Status

- Population 52.6 M (2019)
- Rural: 73%.
- TPES: Biomass 63.9%, Fossil 19.7%, **Renewables 16.4%** (2017).
- Installed power: **2,938 MW** (2018), **29.6% geothermal**, **28.5%** hydro**,** 27.4% thermal, 14.5% other renewables.
- Electricity cons.: 163 (kWh/yr capita, 2016)
- Access to electricity : 64 % (2019).
- Estimated geothermal potential: **10,000 MW** (Omenda, 2018).
- High potential for Wind and Solar PV.
- **National stakeholders**: Ministry of Energy and Petroleum; KPLC (Kenya Power & Lighting Company); KETRACO (Kenya Electricity Transmission Company); KenGen (Kenya Electricity Generating Company, GDC.

- Geothermal energy is now the first source for power generation in Kenia.
- The Gov. of Kenya plans to have an installed geothermal capacity of **5,000 MW** by **2030.**
- Already approved PPP amounts to **2460 MW.**
- A reliable regulatory framework is already enforced, allowing public, private and PPP geothermal developments.
- **KenGen** and **GDC have developed management and professional capabilities** to develop geothermal resources from green fields to plant operation.
- Both companies **have their own drilling rigs** fully equipped to drill and test geothermal wells in Kenya and neighboring countries.

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Tanzania Country Status

Tanzania is reached by the south end of the Eastern Branch and crossed by the Western Branch of EARS in the West.

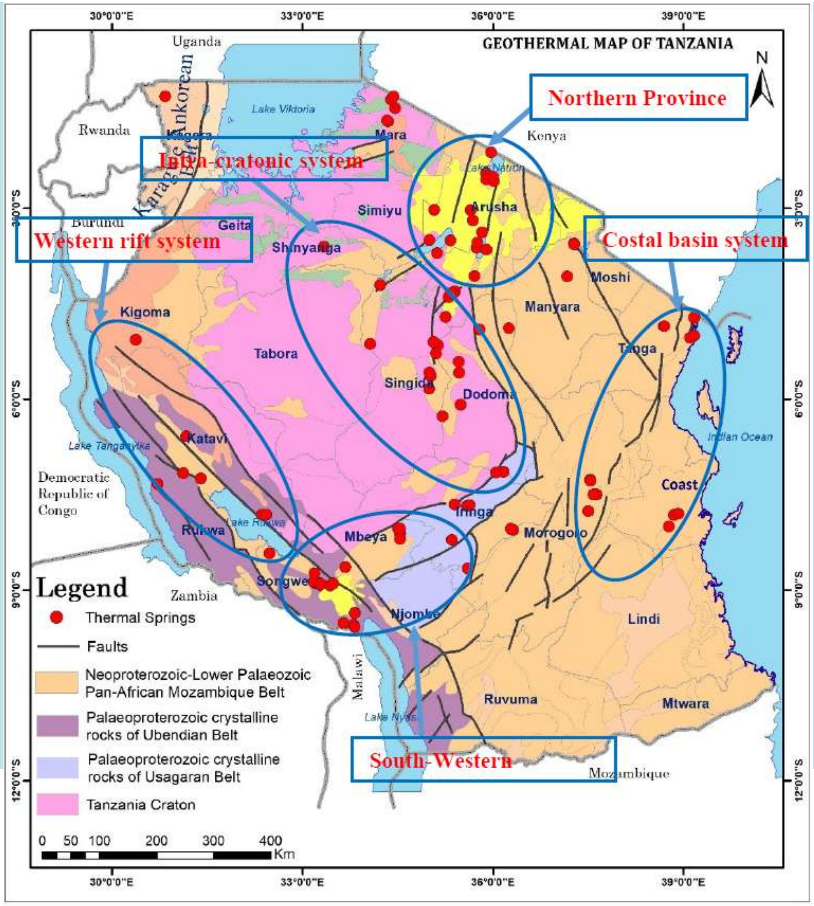
Geothermal exploration started with a country assessment in late '70s.

Over 50 clusters of geothermal springs identified in four zones: South-Western and Northern Volcanic Provinces; Coastal basin systems; Intra-cratonic systems; Western rift.

Geothermal development in charge of TGDC, with 4 flagship projects initially identified: Ngozi, Songwe, Kiejo-Mbaka and Luhoi .

3 main strategic areas to ensure sustained geothermal development: (i) establishing a suitable business environment for geothermal development through formulation of legal and regulatory framework, (ii) strengthening local technical capability and (iii) improving research and development of the geothermal sector..

(Source: Kajungus et al., 2020)



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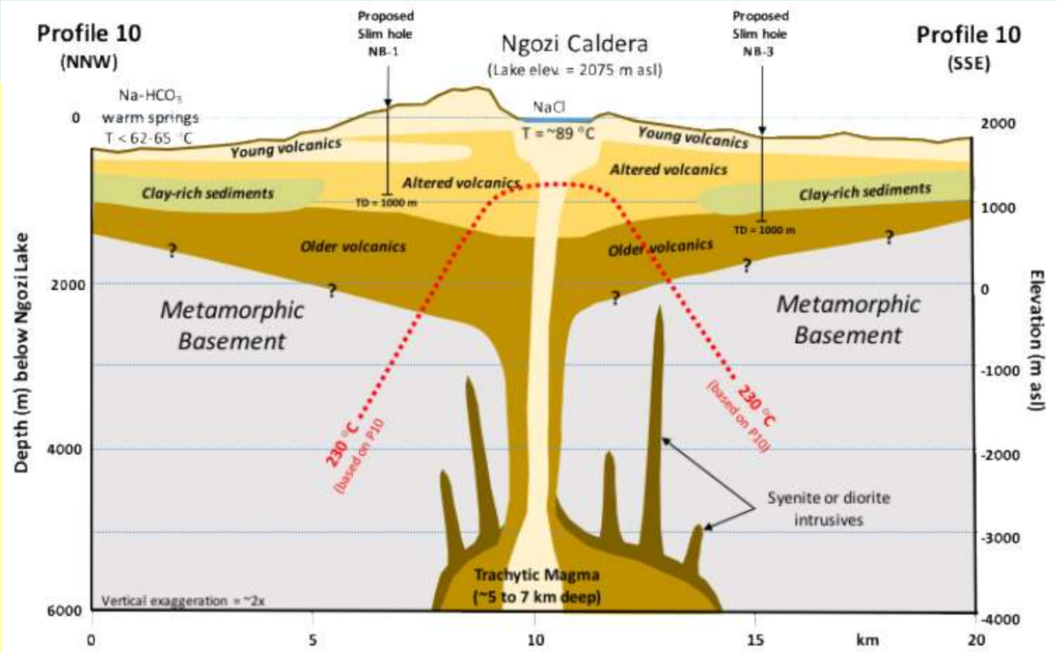
Tanzania Country Status

Activities conducted so far on the 4 flagship prospects gave the following results.

- **Kiejo-Mbaka:** inferred reservoir T of 140°C; 4 exploratory wells planned; GRMF grant secured.
- **Songwe**: fault controlled system with 110°C inferred T; drilling of TGH suggested.
- **Luhoi**: subsurface T of 95-145°C have been inferred.

- **Ngozi:** a liquid dominated geothermal reservoir is inferred beneath Ngozi crater, with an estimated T of about 230°C. 5 locations fro test drilling have been suggested. TGDC is planning to drill 3 slimholes to depths of 1,500 m within a project cofinanced by a GRMF grant.
- Ngozi potential has been preliminarily evaluated at 30 MW (Alexander et al., 2016).

- Exploration activities have been funded by GRMF at **Natron** prospect.



(Source: Alexander et al., 2016).

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Status of Geothermal Industry in East African Countries

Tanzania Country Status

- Population 58.0 M (2019)
- Rural: 66%.
- TPES: Biofuels 82%, Oil 12%, Gas 3.3%, Coal 1.7%, Hydro 1%. (2017).
- Installed power: 1,602 MW (2019), 63% thermal, 37% hydro.
- Electricity consumption: 133 (kWh/yr capita, 2019)
- Access to electricity : 33 % (2017).
- Estimated geothermal potential: **500 MW** (Omenda, 2018), **5,000 MW** (Kajugus et al. 2020).
- Very large increment of installed power already planned, with 200 geothermal MW expected.
- **National stakeholders**: Ministry of Energy MOE); national energy utility (TANESCO); Tanzania Geothermal Development Company (TGDC); Rural Energy Agency (REA).

- The Power System Master Plan (2016 update) stated an ambitious national grid electricity target of 10,000 MW by 2025.
- Geothermal potential had to contribute for 200 MW with 4 flagship prospects.
- 3 flagship prospects proved to be fault controlled, hosting low to medium T. 2 of them could sustain power production using ORC, but their potential is still to be confirmed.
- Ngozi volcanic hosted prospect hosts a liquid dominated reservoir with inferred T of 230°C, and a potential estimated at 30 MW.
- Hydrothermal resources of medium T are more common in Tanzania than high T volcanic hosted resources. The 5,000 MW potential reported by Kajugus et al. (2020) seems to be too optimistic.
- A very limited contribution from geothermal resources to the country electric power requirements shall be expected in the near future.

Joint Research Centre

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Status of Geothermal Industry in East African Countries

Comoros Country Status

Comoros are a small archipelago of 3 volcanic islands (Grande Comore, Mohéli, Anjouan) located between Mozambique and Madagascar in the Indian Ocean. Mayotte is administered by France.

Geothermal exploration since 2008, with an acceleration since 2014.

3 identified geothermal areas in Grande Comore: La Grille, Grotte, Karthala.

Detailed surface exploration surveys concentrated on Karthala Volcano.

(Source: https://www.britannica.com/place/Comoros)

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Status of Geothermal Industry in East African Countries

Comoros Country Status

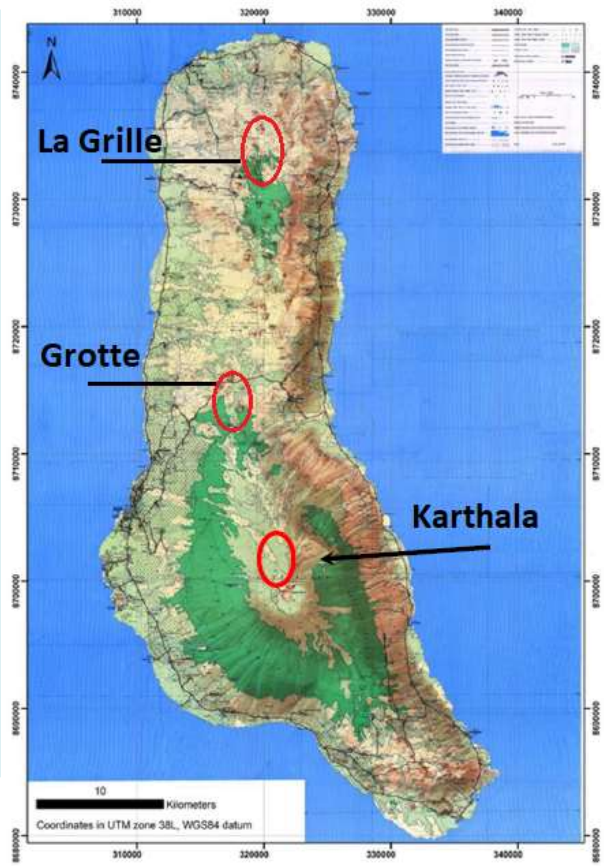
The most explored area is the **Karthala volcano** located in the Southern half of Grande Comore, a basaltic shield volcano with an active hydrothermal system on its flanks.

First field works done by KenGen (2008): 5 MT measurements at the island scale and a geochemical survey (5 water and 1 gas sample).

Surface exploration performed by the Geological Survey of Comoros in partnership with AU, UNDP and NZ MFA&T in 2014 under a GRMF grant. Reservoir temperature estimated up to 270°C with a potential at more than 40 MW.

The Comoros Geothermal Project aimed at drilling 2 exploration wells in partnership with UNDP and NZ MFA&T, with drilling and infrastructures supported by a GRMF grant, is underway even if still in the initial phase of infrastructures preparation and planning of drilling operations.

Final goal is to develop the Karthala resource with a 2x5 MW power plant.



(Source: Allen, 2013)

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Status of Geothermal Industry in East African Countries

Comoros Country Status

- Population 0.851 M (2019)
- Rural: 70%.
- TPES: Biomass 58%, Oil 42% (2008).
- Installed power: 22 MW (2017), ~100% thermal.
- Electricity consumption: 84 (kWh/yr capita, 2014)
- Access to electricity : 80 % (2017)
- Estimated geothermal potential: **>40 MW**.
- Potential for Solar PV.
- **National stakeholders**: Ministry of Energy, Mines and Handicrafts (NOE); Geological Survey of Comoros; NEC (National Electricity Company of Comoros).

- Comoros has a potential for renewable energies: geothermal and solar.
- Installed power is still limited (22 MW), of which 16 installed at Grande Comore.
- A geothermal plant of 10 MW would already be able to cover the full base load of the electric network at Grande Comore.
- Further development of the resource beyond 10 MW could cover future increment of base load or be justified by the interconnection with the other islands of the archipelago.
- The ongoing Karthala Geothermal Project, despite some delais with respect to the original implementation schedule, seems to be the proper way to develop the geothermal resources of Grande Comore.
- The installation of a 2x5 MW geothermal plant would completely change the present electric market in the country.

Uganda Country Status

Uganda is located at the north end of the Western Branch of EARS and is crossed NS on its western part by the Rift Valley.

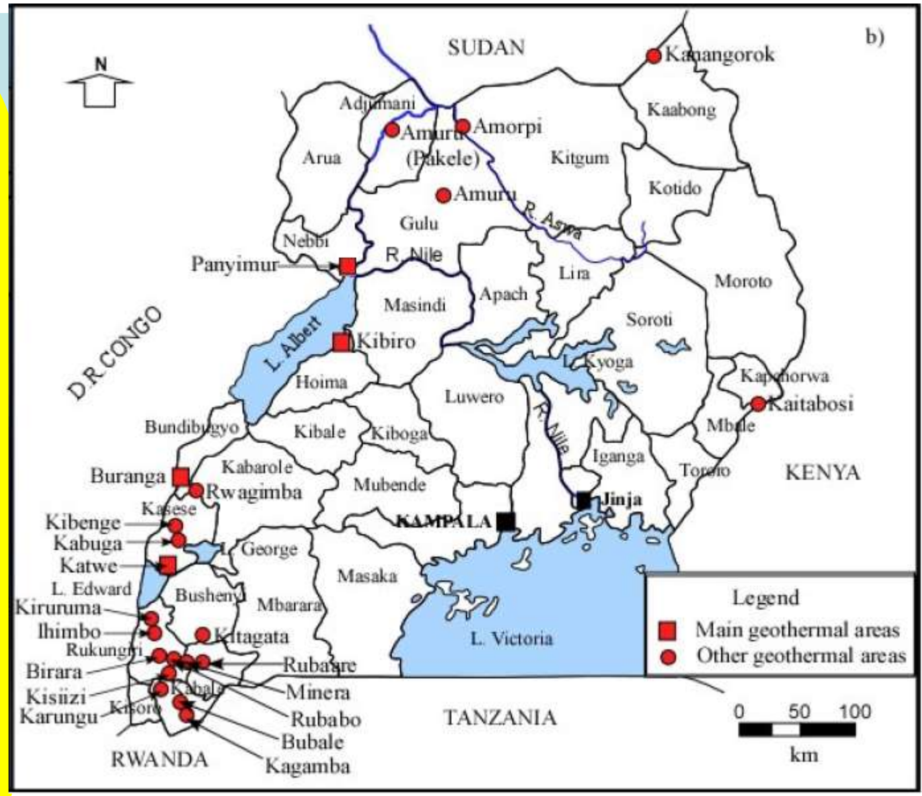
Geothermal exploration since the ‘20s.

First comprehensive exploration study was the Geothermal Exploration Programme Phase 1 (1993-94), involving geological and geochemical surveys at Kibiro, Katwe-Kikorongo and Buranga..

4 potential areas, all in western Uganda, have been identified for detailed exploration: Katwe-Kikorongo, Buranga, Kibiro and Panyimur.

4 additional areas considered for detailed surface exploration: Rubaare, Kitagata, Ihimbo, and Kanangorok.

Exploration conducted in 2015-2018 within support of EAGER led to a change in towards approaches more suitable for fault controlled geothermal systems which are characteristic of the Western Branch.



(Source: Bahati et al., 2005)

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Status of Geothermal Industry in East African Countries

Uganda Country Status

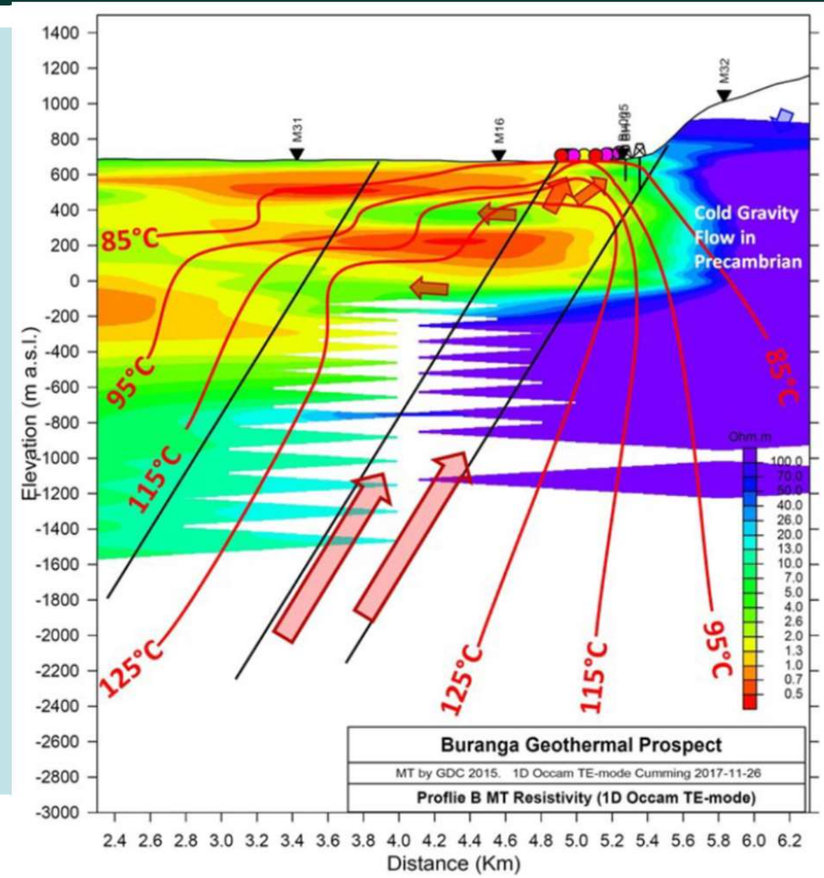
Exploration activities conducted on the 4 most promising prospects gave the following results.

- **Katwe** is likely to be a deep circulation system located near Lake Kitagata (Isabirye et al., 2020) with resource T in the range 107-136°C. Targeting of TGH suggested.

- Two reservoirs have been inferred at **Kibiro**, with the shallower one having probably enough capacity to be used for power generation. GRMF grant secured for surface studies.

- Subsurface T of 120-150°C have been inferred for the **Buranga** surface manifestations, with T up to 200°c inferred within the prospect. GRMF grant secured for surface studies.

- **Panymur** has been identified as a fault controlled system with subsurface T not exceeding 150°C. GRMF grant secured for surface studies including drilling of TGH.



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(Source: Bahati and Natukunda, 2020; EAGER-GRD, 2018).

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Status of Geothermal Industry in East African Countries

Uganda Country Status

- Population 45.7 M (2019)
- Rural: 76%.
- TPES: Biomass 93%, Oil 6% (Hydro 1%) (2008).
- Installed power: 1,161 MW (2020), 21% thermal, 79% hydro.
- Electricity consumption: 76 (kWh/yr capita, 2016)
- Access to electricity : 22 % (2019).
- Estimated geothermal potential: **450 MW** (Omenda, 2018), **1,500 MW** (Bahati and Natukunda, 2020).
- Large increment of installed hydro power already planned.
- **National stakeholders**: Ministry of Energy and Mineral Development (MEMD) ; Uganda Electricity Transmission Company Ltd. (UETCL); Geothermal Resources Department (GRD-MEMD).

- Uganda has large resources of hydro (4,500 MW), biomass cogeneration (1,500 MW), peat (800 MW), and 6.5B barrel of recoverable oil reserves.
- Geothermal potential for power generation is evaluated at 450-1,500 MW, but these estimates are mostly based on preliminary reconnaissance data and surface exploration of 4 prospects.
- Geothermal prospects in Uganda are fault controlled, similar to the large number of operating and drilled fields in the US Basin and Range region.
- Until now all the 4 studied prospects have not yet reached an exploration stage suitable for the targeting and drilling of deep exploration wells.

- Hydrothermal resources of medium T are likely to exist in Uganda, suitable for electric power generation using ORC plants.
- A limited contribution from geothermal resources to the country electric power requirements can be reasonably expected in the future.

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Status of Geothermal Industry in East African Countries

Rwanda Country Status

Rwanda is located along the Western Branch of EARS and is crossed NS on its western part by the Rift Valley.

Geothermal exploration since the early ‘80s.

4 priority geothermal areas initially identified: Kinigi, Karisimbi, Giseny and Bugarama.

Several surface exploration studies performed in different prospects by BRGM, Chevron, BGR, KenGen, ISOR, IESE, WestJEC.

(Source: JICA, 2015)

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Status of Geothermal Industry in East African Countries

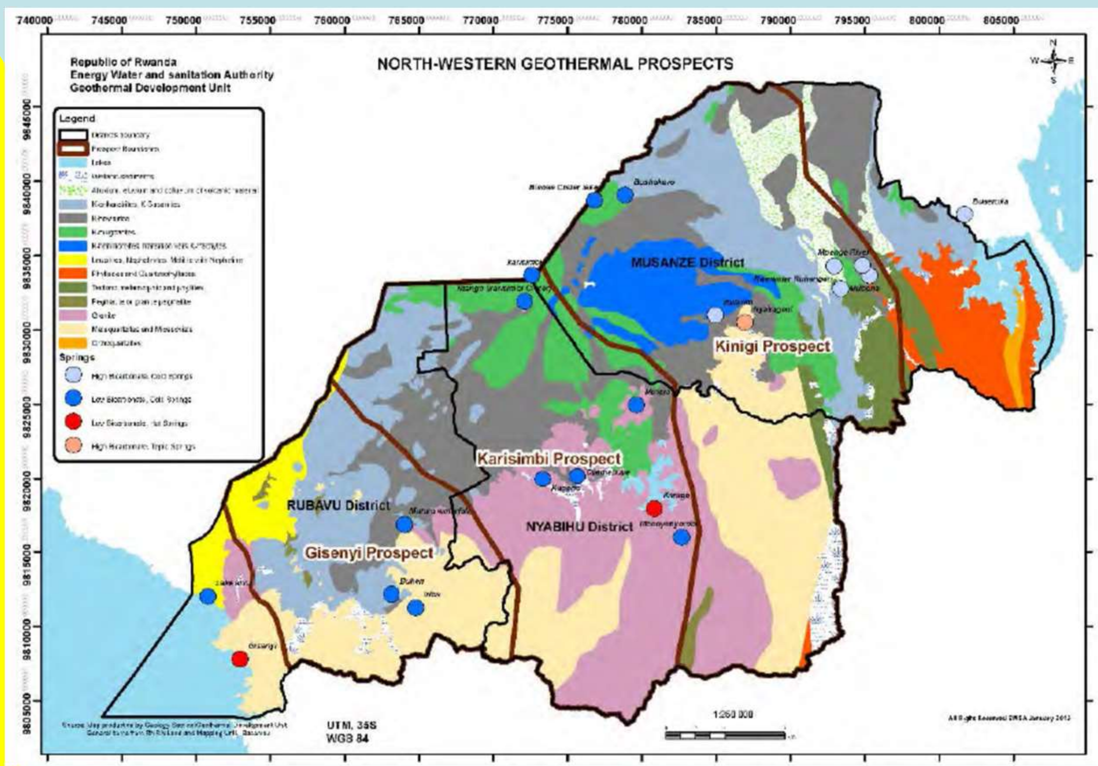
Rwanda Country Status

Exploration activities conducted on the 4 most promising prospects gave the following results.

- The exploration activities performed so far in **Karisimbi**, where 2 deep exploratory wells have been drilled, and **Kinigi** failed to confirm the existence of active geothermal systems in both prospects.

- A low temperature reservoir (<115°C) is inferred to exist at **Bugarama** prospect, thus with temperatures at the lower extreme for energy generation even with ORC plants.

- Surface exploration at **Gisenyi** geothermal prospect suggested the possible presence of a shallow geothermal reservoir at 100°C above a deeper reservoir with temperature from ~160°C to 200°C, but additional MT surveys and the drilling of slim holes has been recommended to confirm the indication of surface exploration.



(Source: JICA, 2015)

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Status of Geothermal Industry in East African Countries

Rwanda Country Status

- Population 12.6 M (2019)
- Rural: 83%.
- TPES: Biomass 91%, Oil 9% (Hydro 0.2%) (2008).
- Installed power: 221 MW (2018), 40% thermal, 47% hydro, 7% peat, 6% solar.
- Electricity consumption: 43 (kWh/yr capita, 2016)
- Access to electricity : 51 % (2020).
- Estimated geothermal potential: **90 MW** (JICA, 2015), evaluated within the study for a national electricity development plan.
- Plans to increase installed power to 556 MW in 2024, by developing peat, solar, hydro and methane.
- **National stakeholders**: Ministry of Infrastructure (MININFRA); Rwanda Energy Group Ltd (REG); Energy Development Corporation Ltd (EDCL).

- Rwanda has further potential for power production using hydro, peat and methane.
- Geothermal potential for power generation seems to be low, in some way confirming the trend of other countries located along the Western Branch of EARS.
- At present no prospects with promising indications for exploratory wells drilling are available.
- Hydrothermal resources of low and medium T exist in Rwanda, possibly with some potential for electric power generation using ORC plants.
- A quite limited contribution from geothermal resources to the country electric power requirements can be reasonably expected.

Burundi Country Status

Burundi is located on the NE border of lake Tanganyka along the Western Branch of EARS and is crossed NS by the Rift Valley.

- First inventory of 15 hot springs in late '60s (Deestra et al., 1969).
- Reconnaissance study at country level by ISOR identified 14 areas with geothermal manifestations in 1982.
- Additional surface surveys were performed in 2010 on 10 known geothermal areas..
- New surveys were performed by ISOR in 2013 in the Ruhwa geothermal area, with geothermometers suggesting T of 110-120°C.
- An exploitable resource with T in the range 100-160°C has been inferred in the Rusizi valley.

(Source: Sinzinkayo et al., 2015)

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Status of Geothermal Industry in East African Countries

Burundi Country Status

- Population 11.8 M (2019)
- Rural: 87%.
- TPES: Biomass 97%, Oil 2%, Hydro 2% (2008).
- Installed power: 88 MW (2020), 40% thermal, 57% hydro, 3% solar PV.
- Electricity consumption: 32 (kWh/yr capita, 2016)
- Access to electricity : 9 % (2019).
- No published estimates are available about the geothermal potential of Burundi.
- Total potential for Hydro estimated at 300 MW, with plants for a total of 121.5 MW under construction..
- **National stakeholders**: Ministry of Water, Energy and Mines (MWEM); Directorate General of Hydraulics and Rural Electrification (DGHER); REGIDESO (Directorate for Production and Distribution of Water and Electricity).

- Burundi has further potential from hydro, solar and wind.
- Geothermal potential is unknown and seems to be limited to medium T resources linked to fault controlled systems of limited capacity.

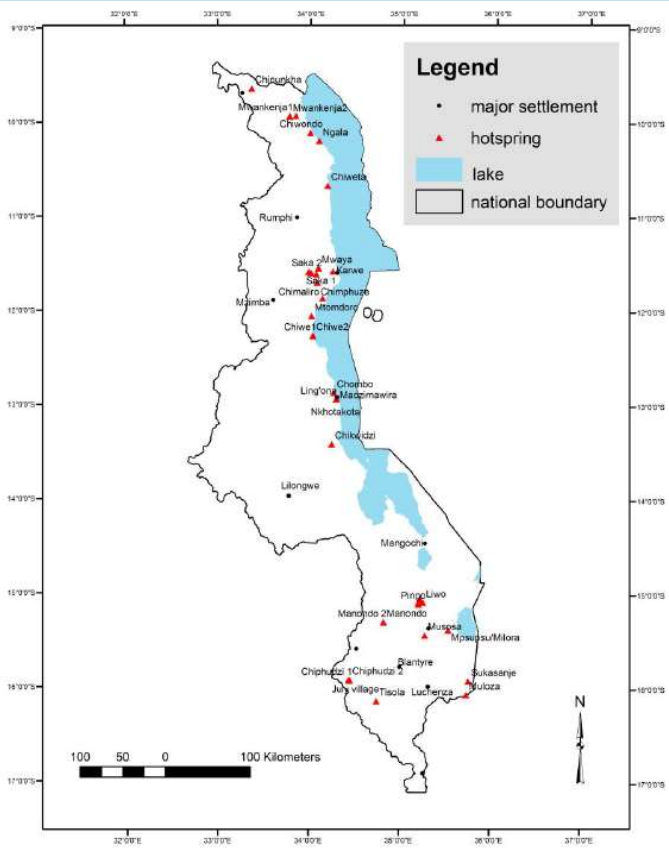
- A very limited contribution, if any, from geothermal resources to the country electric power requirements can be reasonably expected.

Joint Research Centre

Malawi Country Status

Malawi is located at the extreme SW of the Western Branch of EARS along the Rift Valley.

- Geothermal exploration active since early 2000.
- 55 hot springs identified and mapped by reconnaissance surveys (2003, 2015).
- Investigations made on several areas by a consortium between Malawi geothermal Projects Ltd and GDC in 2010, with 3 licenses issued for Chiweta, Kasitu-Chiwe and Mawira-Ling'ona (prospects). Licenses revoked in 2013.
- Further reconnaissance activities performed by BGR and the Geological Survey Department (GSD) of Malawi and by JICA in collaboration with Mitsubishi and GSD.
- The Geothermal Exploration Project (GEP) carried out by ICEIDA, with co-financing by the Nordic Development Fund (NDF), began in 2013 and finished in 2018.



(Source: Kaonga et al., 2014)

Joint Research Centre

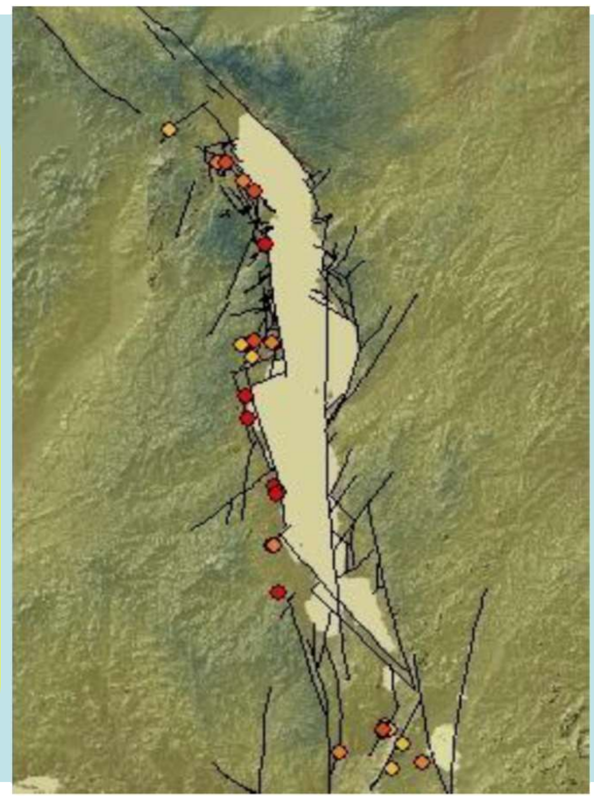
Malawi Country Status

The most important activity has been the Malawi Geothermal Project performed between 2013 and 2018 with 3 subsequent phases:

- **Phase I**: reconnaissance of all geothermal manifestations with geological and geochemical surveys, and ranking of geothermal sites.
- **Phase II**: 6 prospects selected: Chiweta, Kanunkha, Kasanama, Mawira, Chupudzi and Kasitu. Detailed work including remote sensing, geological mapping and geochemical surveys performed. Ranking of selected prospects.
- **Phase III**: detailed investigations on the 2 most promising prospects, Chiweta and Kasitu (detailed geological, geochemical and geophysical surveys).

Conceptual model developed, suggesting geothermal reservoirs with inferred temperature between 110° and 135° C at maximum depth of 500-750 m with electric potential of 7 and 15 MW for Chiweta and Kasitu, respectively.

Drilling of exploration slim-holes on the two most promising sites, with not yet definite plans for follow-up.



(Source: Gondwe et al., 2012).

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Status of Geothermal Industry in East African Countries

Malawi Country Status

- Population 19.0 M (2019)
- Rural: 83%.
- TPES: Biomass 84%, Oil 11%, Hydro 4% (2008).
- Installed power: 555 MW (2017), ~45% thermal, 55% hydro.
- Electricity consumption: 67 (kWh/yr capita, 2016)
- Access to electricity : 13 % (2019).
- Estimated geothermal potential: **200 MW** (Kaonga et al., 2014), based on preliminary reconnaissance data.
- High potential for Hydro (1,300 MW) and plans for a coal power plant (300 MW) and 38 MW from cogeneration plants.
- **National stakeholders**: Ministry of Natural Resources, Energy and Environment; Geological Survey of Malawi; ESCOM (Electricity Supply Corporation of Malawi); MERA (Malawi Energy Regulatory Authority).

- **Malawi** has further potential for hydro and plans for coal power development
- Geothermal potential figure is highly uncertain as it was based on preliminary reconnaissance data.
- The Western Branch of EARS is characterized by medium temperature fault controlled resources of limited capacity.
- The Malawi Geothermal Project, after the ranking off all known sites with geothermal manifestations came to the conclusion that the 2 most promising prospects might have a potential between 7 and 15 MW.
- Hydrothermal resources of low and medium T exist in Malawi, with potential for electric power generation using ORC plants.
- A limited contribution from geothermal resources to the country electric power requirements can be reasonably expected.

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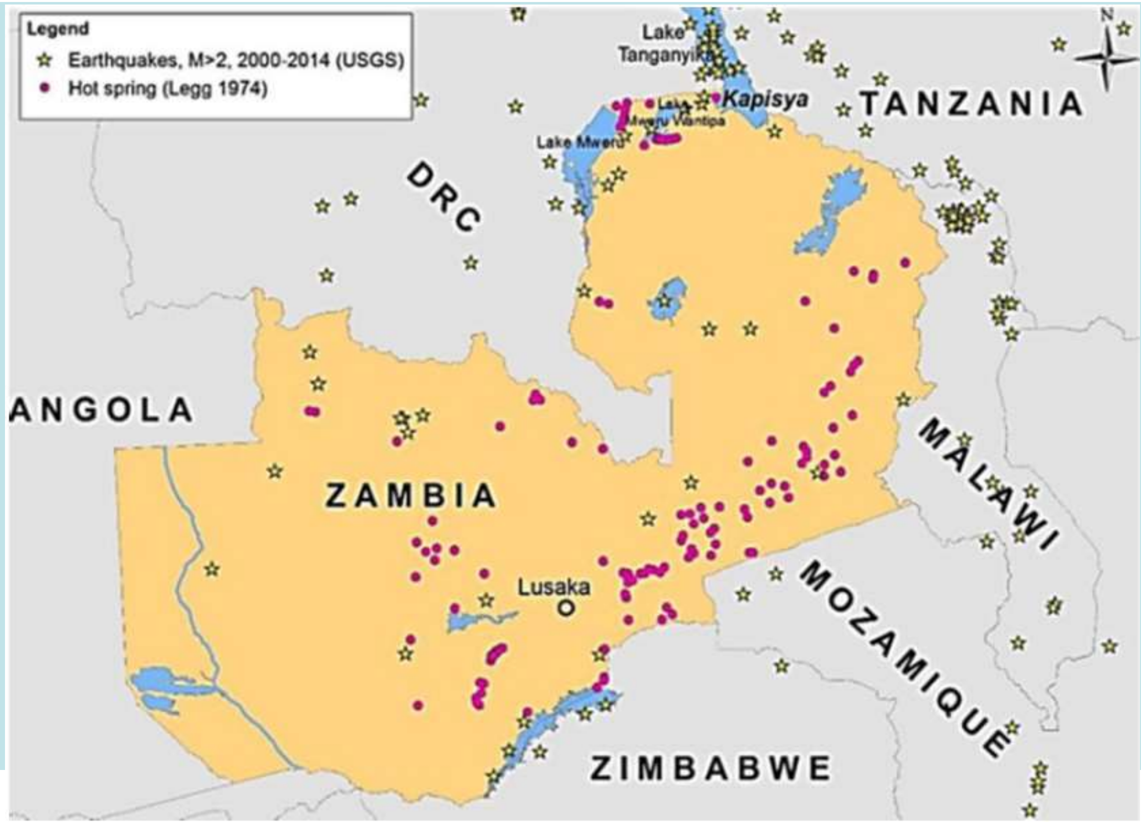
Zambia Country Status

Zambia is located at the extreme S of the Western Branch of EARS and is crossed by its SW extension.

Reconnaissance surveys since the '50s. Inventory of 50 hot and mineralized springs performed by Legg (1974). Already recognized that hot springs are all connected to major, mostly deep, faults.

5 sites identified as priority areas by ZESCO: Chongo and Kapisya in the North, Lubungu and Mupiamanzi in the West, Chinyunyu in the East. Surface surveys conducted only at Kapisya and Chinyunyu.

Kalahari GeoEnergy Ltd, a private developer, is performing detailed exploration surveys in **Bweengwa River** prospect which lies within the Kafue Trough, in the southern part of Zambia.



(Source: *Agnelli, 2020*)

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Status of Geothermal Industry in East African Countries

Zambia Country Status

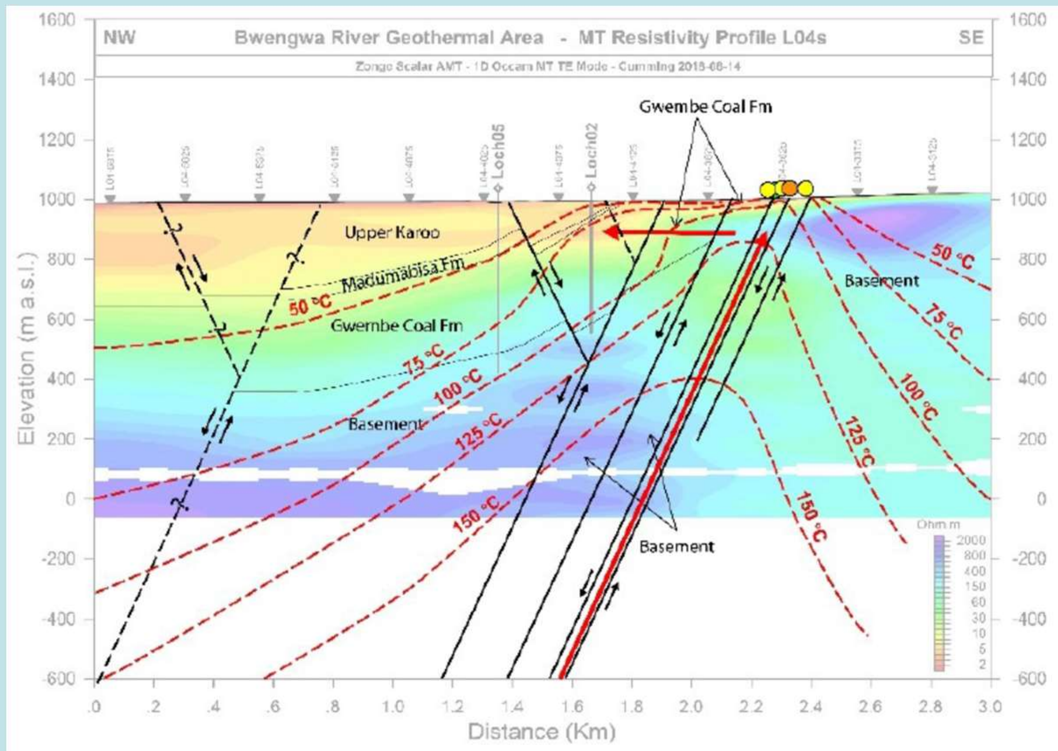
The **Bweengwa River** prospect is the most advanced geothermal development in Zambia.

- Exploration activities from 2012-17 included geological, geochemical and geophysical surveys; drilling and logging of 14 Temperature gradient wells (TGH).

- Further exploration activities in 2018-19 included remote sensing surveys, detailed structural mapping, and drilling of 8 TGH.

- Conceptual models developed and verified with acquired data suggest the prospect hold a fault-controlled geothermal resource with inferred T in the range 130-150°C and estimated potential of up to 15 MW which could be exploited with ORC plants.

- On April 2020, Kalahari GeoEnergy has secured a convertible loan of 3.2 M USD drill 3 slim-holes in the Bweengwa River prospect.



(Source: Hinz et al., 2020).

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Status of Geothermal Industry in East African Countries

Zambia Country Status

- Population 18.3 M (2019)
- Rural: 57%.
- TPES: Biomass 93%, Oil 6% (Hydro 1%) (2008).
- Installed power: 2,897 MW (2017), 17% thermal, 83% hydro.
- Electricity consumption: 730 (kWh/yr capita, 2017)
- Access to electricity : 40% (2019).

- Estimated geothermal potential to be developed: **50 MW**.
- Large development of installed hydro power already planned.
- **National stakeholders**: Ministry of Energy (MOE); Zambia National electricity utility. (ZESCO).

- **Zambia** has large resources of hydro and already planned to develop other renewables: 450 MW of solar and 150 MW wind.
- Geothermal development has been planned to amount to 50 MW only.
- Geothermal prospects in Zambia are fault controlled, and are by medium temperature resources of limited capacity.

- Until now only the Bweengwa River prospect has reached an exploration level adequate for the targeting of deep slim-holes.
- Other fault-controlled hydrothermal resources of medium T are likely to exist.
- A limited contribution from geothermal resources to the country electric power requirements can be reasonably expected in the future.

Conclusions

The two branches of the EARS have quite different power potential: **about 95% is concentrated in the Eastern Branch** with mostly **high temperature volcanic hosted geothermal systems**.

The **Western Branch is characterized mostly by medium temperature fault controlled** geothermal systems of limited capacity.

The geothermal resources identified in the Western Branch requires additional surface studies in order to target deep exploration wells, with the only exception of **Bweengwa River** and **Ngozi** prospects in Zambia and Tanzania.

The contribution of geothermal energy to the future power mix of **Western Branch countries appears to be limited**, although useful to support the base load of national electric netweorks.

Conclusions

Alid prospect in Eritrea needs further surface exploration studies in order to target deep exploration wells. If successful, its development would satisfy an important fraction of country's base load.

Fialé caldera is the most advanced geothermal prospect in **Djibouti**. Its successful development would satisfy most of the winter base load of country's network.

The **Karthala prospect** in **Comoros** is ready for deep exploratory drillings. With an estimated potential of 40 MW, it has a capacity exceeding the present and future base load of the country.

Conclusions

The **new regulatory framework** in **Ethiopia** will facilitate the resource development by several IPP which are already holding 8 licenses. Drilling at Tulu Moye and Corbetti caldera is already planned.

EEP is managing the **Aluto drilling project** aimed at developing the Aluto geothermal field and exploring the Bobessa sector within the same caldera. EEP is also planning drilling activities at **Dubti and Alalobad** within the Tendaho graben.

Kenya has the most advanced geothermal market in East Africa, allowing the operation by public, private and PPP operators. **Total installed power amounts to 865 MW.**

KenGen and GDC public companies have so far explored and developed most of the geothermal resources thanks to strong management and professional capabilities.

Already approved PPP projects have planned installed power amounting to **2,460 MW**.

The Gov. of Kenya planned to have **5,000 MW installed by 2030**.

Thanks

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