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Proposing a New, Specific Methodological Approach to Medium Enthalpy Shallow Geothermal Resources for Africa's Rift Valley

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ABSTRACT

As the knowledge of geothermal resources continues to progress along the East African Rift Valley (EARV), it is becoming more and more evident that several kinds of systems are present in this geologically-gifted region. The problem we are facing is that a single methodological approach is considered by both financial agencies and operators. This is the approach initially defined by Latin America Energy Organisation (OLADE), aimed at developing major sites of national interest serving the electric grid, which quantifies and qualifies the steps of geothermal reconnaissance, prefeasibility (or surface studies), feasibility (exploration drilling and tests), followed by field development power plant construction and operation. The size order of each step is well-defined in terms of surface, methods and costs.

However, the reality of the geology of EARV shows that all geothermal systems do not fit this approach. A characteristic of the rift environment is that there are sites in which a shallow geothermal resource can be tapped at a few hundred meters depth only, even at high or at least medium (90-180°C) temperatures. The most attractive of such sites being those in which steam is leaking at the surface from open faults and fissures; a situation that is common along the axis of the EARV. Indeed, such indices can be taken as surface manifestations of a deep reservoir bearing high temperature resources that are favored by developers. However, they could also be considered per se as geothermal targets of economic interest. And, in a-magmatic geothermal system (no heat source index at less than 1My) they do not necessarily relate to large deeper geothermal resources.

Schematically, one can distinguish two kinds of geological contexts:

- "Central" volcanic units in which a caldera, and/or a set of silicic domes less than 1My old, reflect the presence of a shallow magma chamber and high temperature heat source, that are suitable for large-size (up to over 100 MWe) geothermal development serving the national grid. For such systems the above-mentioned and presently dominating classical approach is pertinent.
- Fault- and or dyke-controlled systems allowing medium- to high temperature convective fluids to percolate to the surface. In such systems, the size of the resource is definitively not the same (between 100 kWe and 10 MWe), and the exploration, development methodology as well as the tools should differ and adjust according to both the geological target and cost-efficiency. Inevitably, the geothermal developments here should also directly rely upon the social demand on site.

While underlining the need for such a new, different and specific approach to be implemented through existing entities like African Rift Geothermal (ARGeo), Geothermal Risk Mitigation

Fund (GRMF) or the Africa Geothermal Centre of Excellence (AGCE), the African Development Bank (AfDB) and bilateral donor agencies (such as the French AFD) involved in supporting the development of geothermal energy in the region, this paper describes some proposals for this alternative methodology. It implies parallel conducting of geo-scientific, technological and early surface/demand studies, because such sites should frequently be considered in terms of local development (serving a variety of needs, not only electricity) rather than as feeding-the-grid (and feed-in-tariffs) option only. The alternative exploration implies lighter tools (such as surface hydrothermal sampling, drone-borne, shallow electrical surveys allowing 3D mapping of the fluid plumbing and shallow drilling), with drastically reduced costs and portable, small-size Organic Rankine Cycle (ORC) power-plants adjusted to the fluid characteristics.

The approach proposed shows these alternative geothermal systems to be even more competitive than the one currently engaged, when considered as such with an appropriate methodology from the earliest stages.

1. Introduction

In most parts of the world, geothermal energy is being developed despite geological conditions that are not as favorable as in the EARV. Direct use applications are found to be economic even in normal gradient areas, in stable continental platforms or low geothermal gradient areas, as, for instance in France, Germany, Sweden or Switzerland. In such conditions, it is rather strange that wide areas where steam is available at the surface, as is the case in many places in the EARV, are still underdeveloped and unused for geothermal applications. At the best, they are used by the local communities living around them, with very low efficiency, for liquid water applications (artisanal steam condensation).

This results from development policies engaged by financial agencies, donor countries, and private investors, all privileging only options in which large-size geothermal plants will exploit deep-seated resources and produce electricity to feed the national grid. Legal procedures, financial and insurance devices and text-book methodologies are all centered on this perspective only. As a result, large perspectives of development are presently left aside, in a context in which the world's best geothermal resources remain untouched in places where the local populations are kept out of economic development perspectives. This, when they are in fact in need of adaptation and resilience to climate change heavily affecting these areas, inducing famines and migrations.

The aim of this paper is to break this wall of indifference within the global geothermal community working in Africa and to raise the issue of these development perspectives, by providing contributions geared towards addressing this issue.

2. A common type of geothermal resource in EARV

In most places on earth a temperature of 100°C is not reached unless drilling to at least 3km deep takes place. However, in many places along the EARV, this temperature – or similar ones – can be found at the surface. Ironically though, this tremendous advantage is not considered as an option for development as it should! All along the active axis of the rift, particularly the eastern branch, fumaroles, steam vents, hot grounds, and hot springs are found, frequently associated in clusters along geological discontinuities like lithologic contacts, faults or caldera walls (Fig. 1, 2 & 3). It also happens that these structures are rather discrete, as leaky fissures a few cm wide, crossing through alluviums, necked basaltic plateaus or along littoral lines (Fig. 4 & 5).

Although present and considered as indices of interest in "classical" high-temperature geothermal sites, they may occur in various geological environments, not necessarily related to recent volcanic units and active magma chamber (i.e. potential large size geothermal systems). Basically, they may occur along two kinds of geological environments:

1. Active faults or open fissures affecting the rift floor: This is particularly common along the Eastern branch of the EARV and quite frequent in Afar, where in Afar language, they are defined by a specific idiom "fiale" (Fig. 6 to 9)
2. Along the normal faults at the bottom of the escarpments that limit the rift valley: Particularly when hanging blocks determined the formation of a marginal graben, a situation found in both the Eastern and Western branches (Fig. 10 to 12).

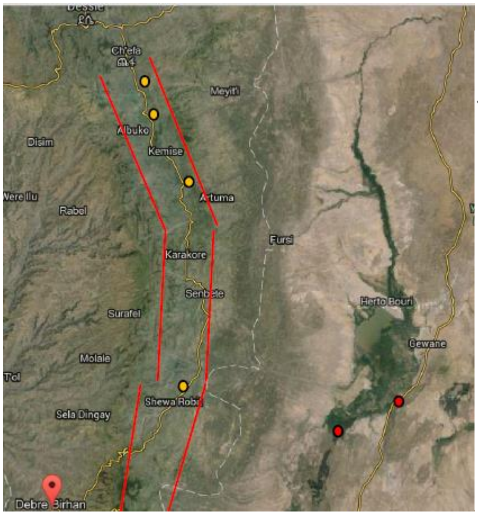
Fig. 1 (left): Steam vent along a normal fault affecting a rhyolite dome, Olkaria, Kenya (Photo J. Varet, 2014). Fig. 2 (right): Steam vent along caldera wall, Alutu, Ethiopia (steam is condensed as liquid water and collected by women and girls; from Onyango and Varet, 2014).

Fig. 3: Thermal springs developed along a normal fault affecting the rift floor, north of Fantale (Photo J. Varet, 2016).

Fig. 4: Thermal springs emerging along the normal fault limiting the Western shore of Lake Bogoria, Kenya (Photo J. Varet, 2011).

Fig. 5: Steaming open fissure, sub-parallel to the nearby graben seen in the back, affecting the basaltic necked surface of the Afar stratoid series. Condensing towers were built to collect the water. Elidaar, Central-Western Afar (Photo J. Varet, 2014).

From left to right: Fig. 6: Open steaming fissure, Fiale, Asal, Djibouti. Fig. 7: Steaming open-fissure, Olkaria, Kenya. Fig. 8: Steaming open-hole Ta'Ali N.Afar. Fig. 9: Steaming normal fault Ta'Ali N. Afar (Photos J. Varet).



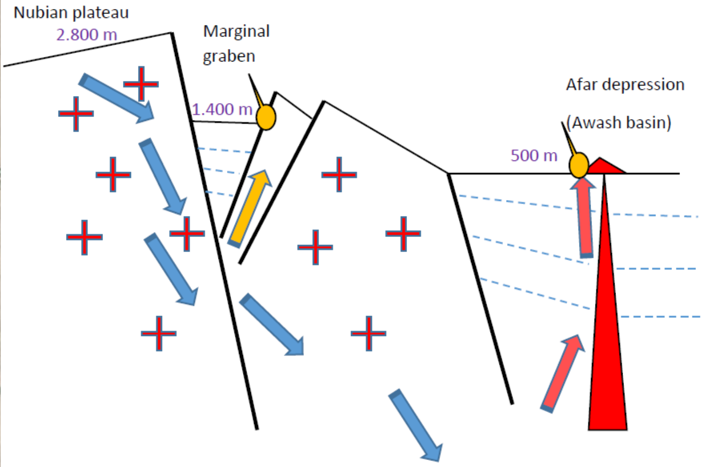


Fig. 10 (left): Google map showing the limit of the Nubian plateau: on the right (West) the Nile hydrographic basin, on the left (East) the Afar depression and the Awash River basin (Ethiopia), Marginal grabens developed along the escarpment. Location of major hot-springs sites (from North to South: Harbu, Shekla, Borkena and Shewa Robit) are shown in yellow. Also shown the nearest hot-springs sites in the Afar depression (in red). The limit of the Amhara and Afar regions is also drawn (white dotted lines).
Fig 11 (right): Geological interpretative section of the hydrogeological system feeding the hot-springs and geothermal systems in the marginal graben and Southern Afar volcanic ranges.

Fig. 12: Hot-springs aligned along Kilwa fault along the Eastern shore of Lake Kivu (Rwanda). The structural context is very similar to the above scheme, with normal faults limiting the Butare Horst with springs occurring along the hanging block (Uwera & Varet, this volume).

Along the western branch of the rift valley, steam vents and fumaroles are not so frequent, and thermal manifestations take rather the form of hot springs, generally linked with tectonic structures of the rift like the border faults, a structural context similar to the one found along the faults of the Eastern Rift escarpments.

These thermal indices are generally well-known from the local people, who have proper names to call them in their languages (see table 1) and generally use them traditionally for drinking water production, water or steam bathing, and eventually cooking or other local applications (Fig. 13 to 16). However, despite several attempts and noticeable progress (ARGeo, International Renewable Energy Agency <IRENA>, Mariita et al., 2016), we still lack a complete inventory of these geothermal manifestations, as state-owned organisations mandated with such roles will generally favor large size sites suitable for electricity production feeding the national grid. There is no doubt that the availability of this kind of information would help to convince stakeholders of the real perspectives open in this specific type of geothermal applications in Africa, and eventually elsewhere in the developing world. Besides pilot devices installed by GDC at Menengai, the only known example is found at Eburu, Kenya (Fig. 17), although it is currently not in use. An inventory similar to the one suggested above has been done in Djibouti by *Office Djiboutien de Developpement de l'Energie Geothermique* (ODDEG) with *Ressources Géologiques pour le Développement Durable's* (Géo2D's) assistance under *Bundesanstalt für Geowissenschaften und Rohstoffe* (BGR) financing.



From left to right: Fig. 13: Artisanal steam condensing well, Dabbahu, N. Afar, Ethiopia; Fig. 14: Condensing tower, N. Ghoubbet, Djibouti; Fig. 15: Condensing pipes, N. Eburru, Kenya (Photos J. Varet).


Fig. 16 (left): Hot-springs engineered for washing clothes and bathing near Gawani, southern Afar, Ethiopia. Fig. 17 (right): Drying plant using geothermal steam, Eburru, Kenya. When visited in 2017, the plant was not maintained and is therefore no longer in use. (Photos J. Varet).

English	**Afar**	**Maasai**	**Pokot**	**Luo**
Water point	Lê	Enchoro	Kompa pogh	Wath
Lake	Bad	Olare	Wöiwöi	Nam
Well	Ela	Ewell/Empakaa	Akwicha	Soko
Hot spring	Ni'il Lê	Enchoro nairowua	-	Bala tedo
Hot ground		Oloirowua	Nakorkorion	Wang' bala
Degasing water	Kahouh Ye	Empakaa	Ighöt	Ich bala
Steam vent	Boïna	Impakaani	Köpö/kompa ighöt	Hotogoro mar muya
Steam bath		Oldisol	-	Pi bala
Smoking mountain	Erta Ale	Oldoinyo opuru	-	God yiro
Smelling bad	Abhe	Enguwuan	Arar (rotten eggs)	Tik marach
White clay	Ado Bodo	Enkoboti	Munyan nyo rel	Lop bala marachar
Red clay	Asa Bodo	Ereko	Munyan nyo pïrir	Rongo
White ash		Enturuto/Ewutwut	Orion	Pundo
Algae		Enkonyoro	Kröngrwö	Tuodo
Geothermal grass	Fiale	Olekijujuri	Sus (general term for grass)	Lumb Bala
Crater, hole	Bodu	Ekapunia	Kötöng'	Bugo
Open fissure	Adale	Olbaata	Körerut	Midimidi
Fault	Andidou	Olbattata	Körerut	Okak

Table 1: Local terms and idioms to describe geothermal surface manifestations in languages of selected local populations in the EARV (collated by Géo2D from its field work and research at community level)

According to our own estimates as Géo2D, it is likely that more than 275 such sites should exist in the EARV, with an average of 1 MWe or 5 MWth equivalent each, ranging from 100 kWe to 10 MWe. This estimate is based on data collected in Djibouti, Ethiopia, Kenya, Eritrea, Rwanda and Tanzania. In Djibouti alone, the smallest country on our list (below), Géo2D has identified at least 20 such sites. From our preliminary observations, it is expected that around 100 and 50 such sites should be found in Ethiopia and Kenya respectively (Table 2).

Country	Number identified	Total number (estimate)
Ethiopia	50	100
Kenya	25	50
Djibouti	20	20
Tanzania	18	20
Eritrea	2	5
Other	10	50
Total	125	275

Table 2: Estimate of the number of small-size sites displaying superficial geothermal resources in the EARV (Géo2D's estimates from observation and work in the field over the years)

3. A radically different approach first based on local demand

The fact that large-sized geothermal systems are currently favored by investors, can be said to be linked to the consideration that such devices allow to feed the national electricity grid, with guaranteed feed-in tariffs that secure the payment of the initial investment. Small-size projects on the contrary are based on serving local demand and their success therefore relies upon the best-fit between the parameters of the geothermal resource (temperature, flow rate and composition of the fluid) and the nature of the demand (water needs, direct thermal uses, electricity consumption…). They also rely upon the direct interest of the local consumers, eventually at community level, which requires that financial capabilities are available to support the necessary investments, at least in the initial stages.

Therefore, in area where such resources are known to occur, the first stage of the approach is to collect information from the local inhabitants on their traditional knowledge and uses of these resources. Then to study with them how a better use of these resources, when improved with appropriate technologies like drilling and other devices using heat exchangers, would allow for applications like fish farming; diary processing; abattoirs; drying, cooling and cooking processes (for cereals, fruits, vegetable, meat, fish, etc); green-houses; direct uses of the thermal water for washing or sanitary applications (Table 3) and other more sophisticated devices like binary plants for electricity production (Fig. 18), would answer their needs and allow to improve their incomes (particularly through food preservation and sales of derived products).

Besides the questions of knowledge of the underground resource and of access to technical know-how, another issue to be addressed is also the financial aspect. At present, the proper mechanisms have been made available by international, regional and bilateral financial agencies for the "classical" large-size projects, while similar mechanisms are still lacking for projects of local interest. Donor agencies work with the central governments and international banks favor private investors who have at hand the necessary initial capital.

Number	Temperature range (°C)	Direct use application
10	120-140°C	Canning of food
9	80-110°C	Milk processing
8	80-100°C	Cooking
7	60-90°C	Food drying (cereals, vegetable, fruits, meat, fish)
6	70-80°C	Cold storage
5	50-70°C	Air conditioning
4	40-60°C	Green housing
3	30-50°C	Spa
2	25-40°C	Bathing, washing
1	18-28°C	Fish farming

Table 3: Possible applications of geothermal resources according to temperature for local uses in the EARV.

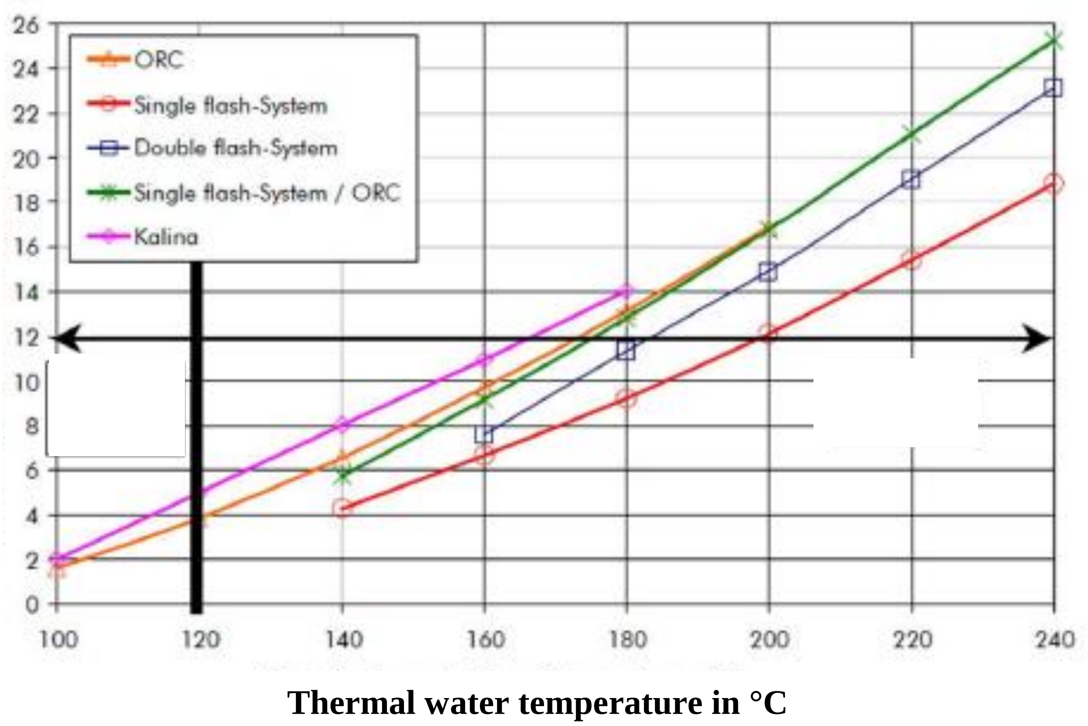


Fig. 18: Various options available for electricity production from geothermal fluids (temperatures range 100-240°C). Specific power of electricity production in KW or ton/hour (t/h) of thermal water against Thermal water temperature in °C. Kalina and ORC allow for the best production in the range of 90-180°C. Abscissa provides the power production in kW per t/h of geothermal fluid. Eg.: at 120°C, 250t/h provide an installed power of 1 MWe. (Source: GTN, 2003)

On the side of the local entities, the first step is for them to be informed of the potential use of geothermal resources and to define the kind of production and use they want to develop. Then the next step is to establish an ad-hoc legal entity, either a local enterprise, an association, a cooperative, a municipality owned enterprise or a form of public-private partnership. However, from Géo2D’s experience, at present, whatever their status, such local entities – once established – are facing two kinds of difficulties:

- The lack of economic experience at local level (for example municipality), due to lack of devolution (non-application of subsidiarity principle) in Africa.

- To be recognized as clients of interest either by the national public sector or the financial agencies.

4. Shallower and more economic

The lack of references for such systems in Africa is a real handicap for the credibility of the approach. Despite the fact that numerous such devices are operating under various forms world-wide, as in the western United States (Basin and Range), in various places in Europe, New Zealand Japan or China, there is still a need to demonstrate that such operations are feasible and economic in the African context.

In a classical High Temperature project, geothermal wells drilled at an average depth of 2,500m, will deliver fluid at 250°C, allowing for the production of electricity by discharge in a turbine of steam under a pressure of 5 bars at least. As shown by the synthesis produced by ESMAP, the investment for drilling represents a third of the total cost of the production system, and an equal amount as the power plant (Fig. 19). The global investment varies from 2.8 to 5.5 M$ per MWe installed, and the resulting production cost will range from 0.04 to 0.08 $/kWh.

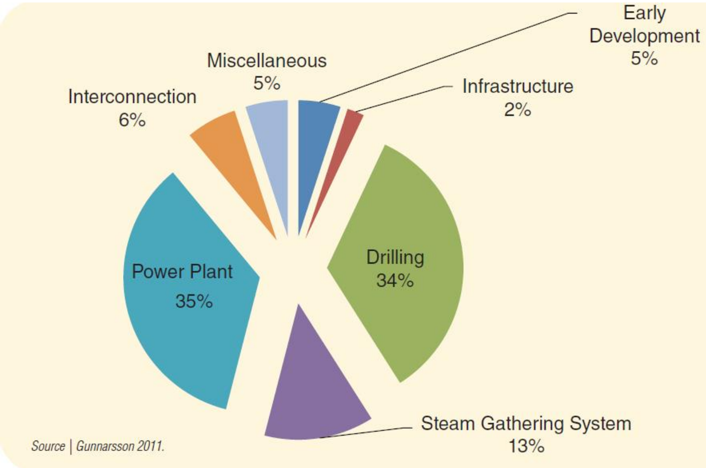


Fig. 19: Investment cost breakdown of utility scale geothermal power development based on data from Iceland (ESMAP, 2012)

Table 4 provides the costs breakdown for the successive phases of development of the projects. The high upfront costs are a common characteristic of these kinds of geothermal project, until the feasibility stage is reached (points 1 to 4 of table 4). Successive investments at low or no risk are given in lines 5 to 7. As an average, the initial investments at risk reach 13 to 18% of the total project costs.

PHASE / ACTIVITY		LOW ESTIMATE	MEDIUM ESTIMATE	HIGH ESTIMATE
1	Preliminary Survey, Permits, Market Analysis[16]	1	2	5
2	Exploration[17]	2	3	4
3	Test Drillings, Well Testing, Reservoir Evaluation[18]	11	18	30
4	Feasibility Study, Project Planning, Funding, Contracts, Insurances, etc.[19]	5	7	10
5	Drillings (20 boreholes)[20]	45	70	100
6	Construction (power plant, cooling, infrastructure, etc.)[21]	65	75	95
	Steam Gathering System and Substation, Connection to Grid (transmission)[22]	10	16	22
7	Start-up and Commissioning[23]	3	5	8
	TOTAL	**142**	**196**	**274**
	In US$ Million per MW Installed	2.8	3.9	5.5

Table 4: Indicative costs for geothermal development (generator capacity of 50 MWe). Figures are in US$ millions (from ESMAP, 2012).

Although we lack sound statistical data, we can propose a tentative costs breakdown in the case of superficial (or close to the surface) resource. (Our estimates are provided in Table 5). Upfront costs are considerably reduced due to lower exploration expenses, that is mainly due to lesser geophysical (the most expensive part of the surface exploration (line N°2) and reconnaissance drillings (line N°3). These lower initial costs at risk also induce a lesser line N°4, (insurance in particular).

PHASE / ACTIVITY		LOW ESTIMATE	MEDIUM ESTIMATE	HIGH ESTIMATE
1	Preliminary Survey, Permits, Market Analysis[16]	0,5	0,7	1,0
2	Exploration[17]	0,5	1,0	2,0
3	Test Drillings, Well Testing, Reservoir Evaluation[18]	3	5	10
4	Feasibility Study, Project Planning, Funding, Contracts, Insurances, etc.[19]	2	3	5
5	Drillings (20 boreholes)[20]	20	30	40
6	Construction (power plant, cooling, infrastructure, etc.)[21]	80	100	120
	Steam Gathering System and Substation, Connection to Grid (transmission)[22]	10	15	20
7	Start-up and Commissioning[23]	4	6	8
	TOTAL	**120**	**161**	**206**
	In US$ Million per MW Installed	2,4	3,2	4,1

Table 5: Indicative costs for geothermal development based on shallow (300 – 800m) geothermal resources (generator capacity of 50 MWe). Figures are in US$ millions (source: authors).

In case of direct uses, the investments devoted to the various applications (like greenhouses, fish ponds, milk processing plants, abattoirs, drying devices for fruits, vegetable or meat/fish, washing machines, swimming pools, etc) surface geothermal costs will be highly variable but generally reduced (fluid piping, pumping, heat exchangers, injection wells, etc.). However, when electricity production is considered, the equipment (ORC plant) will represent an investment per MW installed that will be higher than for back-pressure turbines; generally by a factor of 1.5 to 2, depending on the size of the plant.

In these cases of isolated sites not connected to the national grid, the investments to be considered will also include the installation of a mini-grid and distribution pipes for water. A consideration would be to involve other relevant actors at national and/or local regional levels. However, when the same category of investments is considered, similar to the case of high temperature classical plants, it appears that, as a whole, shallow geothermal devices (500-800m) allow for investments and production costs that should be competitive with classical operations (as seen in Table 5). These shallow geothermal devices are therefore highly competitive with respect to traditional fuel-driven devices (Diesel Power engine).

5. Implying a new methodological approach and appropriate technical tools

The methodological approach for such sites should differ from the one used for “classical” high temperature projects aiming at large-size electrical production feeding the national grid. It should adjust the needs in terms of philosophy, technologies and costs.

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5.1 ***Reconnaissance studies***

A reconnaissance study at countries or region level should depart from the general geological knowledge of the area. This implies in particular to collect any data available from the literature on the existing hot-springs, fumaroles and steam vents. Besides natural vents, data obtained from the wells having been drilled in the area are frequently of high value. It happens quite frequently that a few sites were abandoned because they had temperatures that were too high.
In areas where surface manifestations are numerous, as it may happen along the rift axis or active faults, the use of a drone equipped with Infra-Red censor is a technique of high interest as it allows to precisely map surface and sub-surface hydrothermal leakages for a moderate cost.

These investigations should result in a map and associated data base, with precise coordinates and names of the sites, with indications of temperatures and flow rates, as well as other parameters (like electrical conductivity), or chemical composition when available. A first visit should allow to interview local people. This step generally allows obtaining the useful complementary data.

Besides these geological parameters, socio-economic data should be collected on the same sites, in particular the number of people living in the vicinity of the site (at a distance of 1 to 5 km), with indication of their current economic activity (pastoralist, fishing, agriculture, tourism, etc…). A gender-based approach is important in collecting this data.

This generally requires direct field visits and controls on the sites, allowing to engage interviews with the local population and to provide first information on the resource and its potential use locally. Visiting the local authority and exchanging information with them is also recommended at this stage. Such approach was developed in the frame of the GeoPower Africa project on a few sites in Kenya, Ethiopia and Tanzania (Mariita et al., 2016).

The cost of such reconnaissance studies should not exceed US$ 100,000 for an inventory at sub-country level.

5.2 Pre-feasibility studies

On the sites where a well-defined geothermal resource is found, with an equally well defined socio-economic need identified in the immediate vicinity, engaging a prefeasibility study should be considered. This requires in-depth study of the community's needs – present and future – considering the socio-economic impact of the geothermal production and processes of transformation feasible on site. Just like at the reconnaissance studies stage, a gender-based approach is vital at this pre-feasibility studies stage.

In turn, this also requires the mobilisation of the community concerned through the creation of a proper tool, like a local geothermal association, a community owned enterprise, a cooperative, or even a direct interest of the municipality or county. It may also be that a private entity develops interest for such a project in partnership with the community.

Basically, the prefeasibility should allow – given the kind of socio-economic uses identified, the temperature level and flow rate required - to precise the geological target and its costs of access. This will necessitate geological (in particular detailed structural mapping), hydrogeological and geochemical (liquid and gas analysis) as well as shallow geophysical surface studies. Here again the use of a drone can be efficient for infra-red or even magnetic or radiometric imagery. Appropriate electrical methods (like TEM[1]) should be engaged on the sites of emergences in order to precisely map the hydrothermal plumbing at shallow depth (a few hundred metres). This should allow to precise the location of the wells, their depth and characteristics (production diameters, vertical or inclined, etc).

As a whole, the cost of the pre-feasibility study should not exceed 250,000 US $. However, one should consider that these costs should be reduced once the first projects will have been developed and local entities will emerge with the necessary technical capabilities avoiding the import of foreign expertise.

5.3 Feasibility studies

The feasibility implies to engage the exploration drilling. However, differing from classical geothermal sites, this will require shallow drilling only, i.e. at depth of a few hundred metres only. It will be possible to engage such drilling with local drilling contractors experienced in water drilling. The main difficulty being to acquire the necessary complementary equipment and know-how for high temperature drilling (i.e. BOP[2] or deviated fluid return), as hot water or steam will spring out in near surface conditions.

This approach also requires adapted initial civil works in order to establish the availability of drilling pads supporting high temperatures.

[1] TEM: Transient Electromagnetic Method
[2] BOP: Blow Out Preventer

Drilling up to 5 exploration wells at an average depth of 500m (for a total of 2.500 metres depth) should not exceed 2.5 million US$, and the total cost of the feasibility study including the design and cost estimate of the surface installations should not exceed US$ 3 million.

Compared with classical geothermal sites, as mentioned earlier, the risks are much less and the exploration drilling should eventually answer the needs of the whole project.

5.4 Site development

The site development should hence be reduced to eventually a few complementary drillings and mainly include the costs of the surface installation, including the ORC binary plant as the main investment, in the range of US$ 1.5 million to 2 million per MWe installed. As stated above, the costs for direct uses will vary considerably depending upon the application considered, but will be reduced if the geothermal part only is considered (geothermal pipes, heat exchangers, reinjection wells).

As a whole, the geothermal site development should not exceed US$5.5 million for an average unit of the order of 1 MWe including the production of a few MWth and – whenever required – also production of water by condensation of the steam. This corresponds to a price of 8 cents per kWh, that is very competitive with respect to any other option, like the diesel engine the geothermal plant would generally replace in such remote sites.

6. Conclusion: a realistic, but until now unexplored perspective for geothermal stakeholders

Using shallow high-temperature geothermal resources is an option that should really be considered in Africa, considering the exceptionally favorable geological conditions that prevail particularly along the EARV. The fact that such development has not yet taken place results from the situation that sites where the conditions are the most favorable – with steam vents available at the surface – are dominantly located in the low-land of the rift valley floor where a drier climate implies pastoralist type of activities which until now has not favored other applications except steam condensing for liquid water production and consumption, handled artisanally by local communities.

However, climate change and more severe environmental conditions necessitate an evolution of the way of life of the concerned communities, implying adaptation and search for resilience options. Geothermal offers such options as it provides a form of energy and eventually (of water provision) – that is not climate dependent but which allows a constant supply all year round regardless of surface conditions.

Hence, geothermal opens up a real opportunity for the concerned African communities. The challenge and barrier that remains to be addressed is first putting in place corresponding public policies at local, regional, national and international levels; and then implementing them. It is worth noting that it took several decades since the initial exploration works were engaged in the EARV (UNDP, 1970-1972), before the proper tools were developed by the relevant entities such as ARGeo with Global Environment Facility (GEF) and United Nations Environment Programme (UNEP), GRMF with African Union (AU), African Development Bank and World Bank (WB), bilateral agencies, etc) and for the classical HT geothermal developments to now be under consideration for development. It is now also high time that such shallow geothermal resources as discussed in this paper are finally made accessible for development in the interest of the concerned local communities - the ones eventually the most exposed and vulnerable to the effects and impact of climate change, hence the ones that should be considered as priority targets by relevant multilateral and bilateral entities working in the domain of geothermal development.

The objective of this paper has been to pave way for such developments, by highlighting this perspective to geothermal development in suitable sites in Africa, that until now remain unexplored, thus opening up the subject for further debate and hopefully initial action.

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