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LEAP-RE
Long-Term Joint EU-AU Research and Innovation Partnership on Renewable Energy

Socio-anthropological studies for community?s appropriation, case studies synthesis, best practice guide

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Summary

Geothermal Village (GV) is a concept developed in 2012 after years of researching geothermal resources in the East African Rift Valley. The region is home to different types of geothermal resources with potential for social development. While governments focus on large-scale electricity generation from high enthalpy resources, GV promotes a bottom-up approach involving the community in utilizing geothermal energy for direct use as well as electricity generation. The project was carried out in Kenya, Ethiopia, Djibouti and Rwanda and involved an interdisciplinary collaboration to support the future development of geothermal stand-alone and off-grid systems where local communities can be engaged along the overall process and can benefit in the long-term. This deliverable includes a context analysis, socio-anthropological studies, stakeholder mapping and analysis of business model archetypes. The combination of these different expertise from social sciences and related outputs will provide a support to the development of GV sites in African regions.

Approval

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Abbreviations and Acronyms

Acronym	Description
AGAP	Afar Geothermal Alternative Power
APDA	Afar Pastoralism Development Association
CBO	Community Based Organization
DRE	Decentralized Renewable Energy
EDCL	Energy Development Corporation Ltd
GV	Geothermal Village
HHGCBO	Homa Hills Geothermal Community Based Organization
ODDEG	L'Office Djiboutien de Développement de l'Energie Géothermique
RE	Renewable Energy
REC	Renewable Energy Community
SSA	Sub-Saharan Africa
WP	Work Package

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Summary

Introduction: the GV concept and premises, aim & structure of report

Geothermal Village (GV) is a concept developed in 2012 after years of researching geothermal resources in the East African Rift Valley. The region is home to different types of geothermal resources with potential for social development. While governments focus on large-scale electricity generation from high enthalpy resources, GV promotes a bottom-up approach involving the community in utilizing geothermal energy for direct use as well as electricity generation. The project was carried out in Kenya, Ethiopia, Djibouti and Rwanda and involved an interdisciplinary collaboration to support the future development of geothermal stand-alone and off-grid systems where local communities can be engaged along the overall process and can benefit in the long-term. This deliverable includes a context analysis, socio-anthropological studies, stakeholder mapping and analysis of business model archetypes. The combination of these different expertise from social sciences and related outputs will provide a support to the development of GV sites in African regions.

Geothermal Village similar experiences: an analysis of similar cases in Sub-Saharan Africa

The GV project can learn from existing experience of RECs in Africa. In details, GV can combine solar and geothermal: while geothermal is valuable, solar is more readily available and easier to maintain. Then, GV can also embrace a circular economy, by exploring and integrating not just PV but also biofuel power plants fuelled by the community for a more sustainable model. GV must involve communities and learn from existing efforts and involve local communities in ownership, management, and capacity building, showcasing the broader impact beyond just energy access, like improved education and gender equality. Furthermore, GV needs a skilled workforce and can develop it through partnership with existing organizations (i.e., CBOs) to train locals for project implementation and maintenance. Finally, regarding economic sustainability, GV can explore financial innovation, looking beyond traditional donors and consider micro-credit or diaspora investment, and develop a plan to help communities maintain the project after initial support. By incorporating these lessons, GV can become a more sustainable and impactful model for bringing renewable energy to off-grid African communities.

Introduction GV cases & methodology

The four GV cases are in Kenya – Homa Hills, Djibouti – Lac Abhé, Rwanda – Mashyuza in Bugarama, and Ethiopia – Era Boru in Afar region. The analyses performed to support the development of GV concept in the four pilots consist of the following actions. Action 1

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analyzed the socio-economic context of target countries. Action 2 covered the analysis of socio-anthropological aspects and community appropriation dynamics of local populations involved in the geothermal projects and the identification of other suitable stakeholders. Action 3 addressed stakeholders' analysis through the implementation of stakeholders mapping and the development of stakeholder engagement strategies. Action 4 focused on the identification and analysis of best practices in initiatives and projects for supporting renewable energy developments at community level in Africa, if possible related to geothermal energy. Finally, action 5 identified and designed business model archetypes and related guidelines for the development of GV concept in the four pilots and other contexts.

Kenya – Homa Hills

Household economic vulnerability is widespread in Homa Hills. The results of the analysis carried out says that about 62% of respondents are in households that have gone without enough food to eat several times or many times. Food vulnerabilities are similar across the regions. About 63% of respondents are in households that have gone without enough clean water several times or many times. About 77% of respondents are in households that have gone without enough cooking fuel several times or many times. Energy access challenges are similar across the regions. About 7% of the households consider themselves destitute. About 1% of households consider themselves quite well off. Energy regularly used for various needs is cooking by biomass 97%, cooking by LPG 8%, cooking by electricity 1%. Regarding the use of the energy for lighting, 59% of respondents use solar energy, 22% electricity, 12% kerosene and 5% biomass. The use of geothermal or hot springs resources by households is diffused for traditional healing 74%, but also livestock (72%), health (67%) and religious (61%).

In terms of socio-anthropological aspects and analysis, the Homa Hills geothermal site is located in Homa Bay county's (primarily inhabited by the Luo), Karachuonyo North sub-county (total population 178,686: 85,403 male and 93,273 female) in the administrative locations of Kanam B, Kakdhimu East and Kokoth Kataa. Most of the population lives below the poverty line; further exacerbated by high female-headed households incidences occasioned by HIV/AIDS-caused widowhood. There are about ten current and numerous potential uses of the geothermal resources that relevant to a GV concept project. Homa Hills Geothermal Community-Based Organisation (HHGCBO) – associated to the GV project through a third-party agreement with Scientific and Engineering Power Consultants Limited (SEPCO), a project partner is the entity for engagement in the event of a GV concept project. Women numbers in the entity's governance structure either just meets Kenya's

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two-thirds gender rule requirement or slightly falls short of it. Capital Power, a private developer who has also shown political will to support a GV concept type of project that benefits the local population holds the resources' exploration licence. Men are advantaged in economic and decision-making power as in exposure to formal Western education. Part of this scenario is likely to change owing to Kenya's regulatory changes. Homa Hills' economic activities include farming, fishing, fish-mongering, animal husbandry, retail trading, wage/formal employment Over-fishing, smoke-induced respiratory tract infections, water-borne diseases, deforestation – all of which have implications for gender roles - are some environmental issues that a GV-concept project could respond to. Solar panels, a predominant electricity source provides limited and unreliable power supply. The sites are within reasonable distance to services such as schools and medical facilities, providing opportunities for such to be powered by geothermal with time.

In terms of stakeholders within and outside of the community, two observations stand out. First, of all country cases, the GV community in Kenya is the largest and most extended one, owing to the fact that there are several geothermal resources spread out over the Homa Hills territory. The community thus potentially comprises many people and many social groups, rendering the creation of a community around GV particularly challenging. The geothermal CBO's efforts in recruiting members and creating a GV community have paid off, but there is still a long way to go. Secondly, a private developer owns the license to search/ investigate the geothermal resources in Homa Hills, meaning the Homa Hills community is dependent on this developer for developing GV. The relation between the geothermal CBO and this private developer, and especially the development plans of the latter, is thus of major importance in determining whether and under what conditions a GV can be developed.

The economic business model for the GV project in Homa Hills includes three potential solutions to ensure sustainability and community involvement: partnering with a larger energy company, fundraising within the community, or securing international financing. The project aims to address the community's primary needs such as access to electricity and water, job opportunities, education, and healthcare. The community and the HHGCBO, along with partners like Capital Power Ltd and public authorities, will play a key role in guaranteeing the future project's success. The community is willing to contribute to the project's economic sustainability through fundraising and payment of a fee for the services. Initial environmental assessment will include the benefits coming from the use of clean energy sources and the possibility of including recyclable or reuseable materials in the phase of construction. GV can also fight climate change effects and land degradation. The

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project's social business model emphasizes improving health, quality of life, and community involvement in governance and operation to ensure long-term sustainability and benefits for the community.

Ethiopia – Era Boru

In the Afar geothermal region, the density of the population is relatively sparse because of its hot climatic conditions; 69% of the land area has a population density of less than 50 persons per square kilometer. Only 42.3% of the population are literate, 13.6% lower than the country. Households in the Afar region have relatively larger size than elsewhere among the pastoralists in Ethiopia. Cattle, shoats and camel are the major livestock holdings. On average, livestock holding per household in the Afar region is 6.8 cattle, 15 goats, nine sheep, and 2.2 camels, far higher than the national averages (3.6 cattle, 3 goats, 2.3 sheep and 0.3 camels). The population in the Afar region have relatively low access to major services and facilities. They were particularly and relatively poorer in accessing urban centres, safe drinking, safe drinking water, sanitation facilities, and human and veterinary health/medical services. The top five important sources of vulnerability in the region were price/inflation, drought, increasing temperature, scarcity of water, and human disease. The top six vulnerable assets in the region were camels, cattle, and shoats, transport and health services, and food. Sources of energy for lighting and cooking are an important welfare indicator and the Afar communities in Era Boru lacks both. The community is just affording on dry bushes and biomass to cook.

The Era Boru geothermal site is situated in Teru *Woreda,* Afar Regional State (predominantly Afar-inhabited). Afar's total population stands at around 1,812,002 (991,000 men and 821,002 women; 346,000 urban dwellers: 1,466,000 pastoralists). About 500 people live around the Era Boru site, most of whom live below the poverty line. Afar Geothermal Alternative Power (AGAP) associated to the GV project through a third-party agreement with Géo2D (a GV project partner) is the local entity for geothermal development issues engagement. About eight current and at least six potential uses emerged in relation to the Era Boru site. Legally, the land belongs to the local community. AGAP has a trade licence from the Regional State government and engaged the process of obtaining an exploration lease. Traditionally, widows get remarried to a close relative of their deceased husband, thus reducing their vulnerability. Men are the ones with both decision-making and economic power. AGAP's membership and governance structure have very few women. Economic activities of this relatively sedentary population (with pastoralism as the key one) include some wage-employment and trading (including livestock and livestock products); with such items being sold at throw-away prices during drought. Handicrafts sale is a potential economic activity. There is general low exposure of

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the local population to formal Western education and more so for girls, owing to cultural attitude, Female Genital Mutilation/Cutting (FGM/C), early marriage etc. The national electric grid has not yet reached Era Boru. Deforestation from firewood use at household level, reduced access to potable water for humans and livestock, perennial droughts are among the Era Boru scenarios that a GV concept project can help alleviate. The nearest school and medical facilities are about are about 40 kilometres away in Teru town.

Not unlike the Djibouti case, the GV community in Era Boru is situated in a remote area, with hardly any (easy) access to basic services. The Afar families that reside here rely on traditional, innovative use of geothermal resources for its water needs. They have organized themselves in a community-driven social enterprise called AGAP that is set on developing GV, among other initiatives, to secure access to more amounts of water and other basic services (e.g. electricity, telecom). AGAP has close connections with APDA, which is well-connected regionally (across the communities of the Afar regional state) and nationally (with relevant geothermal-related authorities/ agencies). Yet both rely on external funders to help set up GV, as own budgets and that from local and regional state entities are very limited. The tarred road that is currently being build and that will pass through Era Boru will facilitate connections between the Era Boru community and external stakeholders and – coupled with GV – could open up opportunities such as realizing a small market.

The economic business model for the GV in Era Boru presents two feasible schemes, involving international financing bodies or linking to a larger geothermal energy plant. The primary needs of the community include access to clean water, electricity, health services, roads, schools, and job creation. Partners and actors, such as APDA, AGAP, government entities, and universities, play crucial roles in the project. The GV aims to provide clean energy and water, improve health, and create job opportunities. The social business model focuses on improving the quality of life for the Afar people by providing clean energy and water, reducing disease from biomass use, and enhancing community skills. Local communities and employees will be involved in governance, with synergy between AGAP and APDA driving project sustainability. The project considers the socio-anthropological characteristics of the Afar people and aims to create long-lasting benefits for the community.

Djibouti – Lac Abhé

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Household economic vulnerability is prevalent in the study region comprising several villages (Koutta Bouyya and the village close to Lake Abhé - Lac Abhé, in French). About 60% of the respondents reported that they lacked food to eat just a few times or never. About 57% of the respondents reported that they lacked enough water for home just a few times or never. 36% indicated that they lacked water always. About 34% indicated that they lacked medicines or medical treatment always. About 33% indicated that they lacked fuel many times. About 16% indicated that they lacked cash income always. Livestock activities predominantly affect livelihoods to a very large extent in Lake Abbe (100%) and Koutta Bouyya (86%). About 27% of the households owns cattle, mostly around Koutta Bouyya sub-region. Households generally use biomass resources for lighting (39%), followed by solar (25%) and Kerosene (7%). A good percentage also use sport lights (30%). Households generally use biomass resources for cooking (89%), followed by LPG (11%). A good percentage of LPG users are from As Eyla (24%). The geothermal resources are mainly accessible to households in Lake Abbe (75%). Both As Eyla and Koutta Bouyya sub-region households don't have access to the geothermal resources.

The Lake Abbe geothermal site, inhabited by the Afar is in Djibouti's Dikhil region (population estimate is 111,457 habitants). Field data gives the population around the site as between around 200 and 4,000. Most live below the poverty line. There are indications of a preference by the local population for handling geothermal development issues at the Lake Abbe site through their traditional governance structure rather than a registered geothermal entity. There are about seven current and at least eleven potential uses of the Lake Abbe geothermal resources. The license of land with geothermal resources in Djibouti is issued to ODDEG. As the culture of the local population here is close to that of the Afar of Ethiopia, it is understood that the widows are likewise remarried by the husband's relative, which then reduces their vulnerability. Older men hold decision-making and economic power. With pastoralism as the main economic activity, other occupations of the population include employment in the nearby school and tourists' camp facility, handcrafts and butter selling as well as making of leather rugs and wineskins from livestock hide. Exposure of the local population to formal Western education is generally low, especially among girls. Potable water, deforestation and reduced lake water levels are some of the key environmental vulnerabilities that a GV concept project could respond to. Apart from a newly established primary school near the site, other basic social services such as a functional health facility, telephone network and electric grid are far away.

Regarding stakeholder profiles and relations, the Lac Abhé community is the smallest of all GV sites, situated in a remote corner of Djibouti and with hardly any (easy) access to basic services such as potable water and electricity. Some (national state and development) agencies with capacities to provide such services have pledged to help the community, but

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this has not been followed up by implementation as yet. GV has the potential to provide some such services, but it requires responsible state agencies like ODDEG to prioritize and make available resources that, together with external funding, could forge a next stage in GV – the building of a demonstration plant.

The economic business model for GV in Lac Abhé involves two possible schemes focusing on sustainability, with options for national or international financing. The primary needs of the community include access to clean water, electricity, healthcare, roads, and job creation. The involvement of partners like CBO (although not yet present), NGOs, associations, and ODDEG is crucial, with the community's active role emphasized. The economic sustainability of the project in Lac Abhé depends on external funding due to the community's limited monetary resources. Environmental and social benefits are highlighted, such as providing clean energy and water, improving health and quality of life, and enhancing community skills. The social business model aims to involve the local community in all aspects of the project, from design to operation, to ensure it meets their needs and brings positive impacts. Nevertheless, an element of risk is connected to the possible reluctant attitude of the community if the project appears as imposed.

Rwanda – Mashyuza in Bugarama

Economic vulnerability of households is predominant in Bugarama. About 56% of respondents are in households that have gone without enough food to eat several times or many times. About 55% of respondents are in households that have gone without enough clean water several times or many times. About 42% of respondents are in households that have gone without enough fuel to cook several times or many times. Energy vulnerabilities are similar across the regions. About 60% of respondents are in households that have gone without enough cash income several times or many times. About 10% of the households consider themselves destitute. About 7% of households consider themselves quite well off. About 2% of households consider themselves wealthy. About 56% of households consider themselves poor. Energy regularly used for various needs are: cooking biomass 98%, cooking LPG 2%, cooking electricity 1%, lighting electricity 64%, lighting biomass 5%, lighting solar 59%, lighting kerosene 12%. About 69% use geothermal resources. About 69% use geothermal resources for traditional healing 3 %, Livestock 25%, Health 92%, Religious 58% and Agriculture 66%.

The Bugarama/Mashyuza geothermal site located in Rwanda's Nyakabuye sector, where more than a third of the estimated total population of 33,200 (15,739 males; 17,461 females) that simply identifies as Rwandese lives below the poverty line. Cooperative(s)

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seem to potentially be the entity(-ies) through which a GV concept project would be carried out in the event of such an opportunity(-ies). From observation, it seems that by and large, the existing cooperatives, formed around farming activities have a near balanced ratio of women to men, but with slightly more men than women. About nine current and at least sixteen potential uses came up in relation to the Bugarama/Mashyuza site. The license for the land around the Mashyuza geothermal site is in the hands of CIMERWA cement factory. There is relatively high incidence of female-headed household, resulting from the country's genocide history; a situation likely to translate to heightened vulnerability of such households. By and large, men are the ones with decision-making and economic power, even though the country's constitution refers to gender equality. Economic activities related to the Bugarama/Mashyuza site include small-scale trading of household items, wage/formal employment, livestock husbandry with farming of crops; mainly fruits, vegetables, cereals (particularly rice) and coffee as a principal activity. Comparatively, more men than women have exposure to formal Western education. There is access to basic services such as a school, medical facility, telecommunication as well as the electric grid near the Mashyuza geothermal resource.

Out of the large number of stakeholders already or potentially involved in the GV site in Rwanda, one relationship stands out: the one between the community and the cement factory Cimerwa. Cimerwa's land ownership around the Mashyuza hot springs and its (limestone) mining activities have a profound impact on the community and on the prospects for a GV – both socially and environmentally. Building a GV will rely to a great extent on how the relation between these two evolves and how potential negative effects (e.g., impact of blasting) can be ameliorated and opportunities (e.g., Cimerwa's support) be seized. An entity that represents the community, like in the Kenya and Ethiopia cases, could help bring about a suitable arrangement. Other than that, GV could potentially serve different stakeholders within and outside the community, including small farmers, rice cooperatives and factories and residents through the provision of basic services (e.g., water).

The economic business model for GV in Bugarama foresees involves three possible schemes, involving the elements of sustainability: partnering with larger-scale energy plants, joint-ventures with local industries and cooperatives, or third-party financing from international bodies. The community's primary needs include access to clean water, infrastructure, healthcare, and poverty reduction through job creation and education. External experts are needed due to the community's limited skills. Key actors include the rice cooperative, EDCL, CIMERWA, local and national government, and international investors. The GV will provide electricity, water, and drying stations for rice and coffee,

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benefiting the community. Sustainability is crucial, with the possibility of involving private or public funding to support the project. Also, in Bugarama, the GV project aims to improve health, quality of life, and skills within the community, involving local communities and employees in the governance and operation of the GV.

Conclusions and final remarks

Through our field work in various regions across East Africa for the GV project, the research teams involved have studied economic scenarios, socio-anthropological factors, stakeholders and business models, both in the sites selected and related to other similar experiences. Our conclusions are that, even with specific features and differences among the sites, from a socio-economic point of view, GV represents an effective possibility of bringing energy access while achieving social and environmental objectives for the local communities.

Of course, the future economic and social business models must prioritize sustainability and community ownership. Finally, the environmental GV business model focuses on promoting clean energy sources and responsible resource management, aiming to tackle climate change and improve environmental health for future generations.

Each site has its own peculiar needs and resources that shape the economic sustainability approach taken. Some communities appear to be able to contribute, or to find synergies with local industrial actors (i.e., Bugarama), while other not. Moreover, from partnerships with energy companies to community fundraising efforts, GV developers must be committed to empowering communities through the supply of clean energy and improved livelihoods.

Along the common tools to be adopted, an active community involvement is at the core of GV mission. Community means not just the "village", but all the actors: entrepreneurs of each dimension, public authorities, CBO or NGO, cooperatives if existing. The prosperity both economic, social and environmental can only be achieved when all the members of the communities are actively engaged in shaping their own futures.

The second common driver that can promote GV in all the sites is the possible combination of GV with other RE sources. Both PV and biomass power plants (with local production of collection of biofuels) can advance the economic sustainability of the GV and product synergies that can enhance the overall wellbeing for the community, with positive social benefits.

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By fostering collaboration between different stakeholders and empowering local leadership, GV can pave the way for a sustainable and equitable future in the rural communities of Kenya, Ethiopia, Djibouti, and Rwanda, and in East Africa and beyond.

Keywords

Geothermal Village, Geothermal Energy, Off-grid, Renewable Energy Community, Engagement, Stakeholders, Business Model, Decentralized Renewable Energy, East Africa, Kenya, Ethiopia, Djibouti, Rwanda.

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1. Introduction: the GV concept and premises, aim & structure of report

1.1 Aim and structure of the report

Geothermal Village (following, also GV) is a concept launched around 2012. It was born out of decades of geological research into the geothermal resources found across the East African Rift Valley (EARV). The EARV[1] is an active plate boundary that runs from Eritrea in Northeast Africa all the way down into Mozambique in Southwest Africa. It splits into two 'branches', the Eastern and Western branch. Both feature a different geological makeup and are home to geothermal resources with different properties (e.g. different enthalpy/ temperature).

Geothermal offers much potential for social development in the African regions where it is present. The most prominent - and by governments most favoured - type of use is large-scale electricity generation from high enthalpy geothermal resources. This variant is already developed extensively in Kenya, for instance in Olkaria – see Deliverable D9.4 of LEAP-RE – and other governments seek to copy this type of geothermal development.

GV, in contrast, focuses on an alternative use of geothermal resources and an alternative type of development. GV builds on some principles, as cascade use of the geothermal energy, including electricity generation – where possible - and direct-use; then, the process to develop the GV must be bottom-up and community should be involved from the beginning and also in the future management of the plan. For more details, see chapter 1.2.

[1] There have been some concerns raised recently around the otherwise common use of the term East African Rift Valley (EARV), because some countries feel "left out" in the term. Therefore, although the term East African Rift Valley has still been used here to maintain consistency with the citations (references) used, the term African Rift Valley may eventually be considered more inclusive by countries that are geographically not considered to be part of East Africa. This situation could also be attributable to the fact that most of such countries, for example Rwanda, can be considered to be new-comers in geothermal development issues with first exploration attempts having taken place from around 2010 compared to countries like Kenya where geothermal development dates back to the 1970's.

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The framework of GV is such that the project brings together skills across the entire geothermal value chain, starting from societal acceptance, resource exploration, resource exploitation, stakeholder analysis and local economic development. The project's structure therefore brings in an interdisciplinary team comprising of social scientists, geoscientists and engineers.

Deliverable D11.3 "Socio-anthropological studies for community's appropriation, case studies synthesis, best practice guide" aims at describing the contexts in which the GV can develop, considering all the aspects involved and of interest to human and social scientists. The report starts with the present introduction, which contains the vision of the Geothermal Village and the methodological parts, each developed by the responsible partner (see bullet points below). After chapter n.2, dedicated to experiences similar to the GV in the African context and the possible lessons to be learned (developed by SSSA), chapter 3, 4, 5, and 6 will present, for each site, the following data:

- economic, social and environmental context information (UoN).
- the social and anthropological characteristics of the populations living near the GV, including the uses and habits connected to the use of geothermal energy (Géo2D).
- the stakeholders and actors who will need to be activated and mobilized to develop the GV, and their characteristics (UniTo).
- the guidelines for a GV business model, which considers all the characteristics of the site and the population, and the best solutions (win-win) for the GV sites (SSSA).

Finally, the report ends with a summary and conclusions chapter.

1.2 Geothermal Village as concept and vision: key premises

Above, we introduced GV as a concept. By this we mean GV does not yet exist on the ground. It still only exists 'on paper' and as a vision. Figure 1 provides an image of what a GV might look like and indicates a range of potential geothermal direct-use applications. It is an ideal-type visualization. Hence, the form and contents of GV in specific places will differ from this image and depends on the local geophysical and social context and dynamics. Yet, a picture says more than 1000 words and so we use this to make explicit some important premises and ideas that underlie GV and which informs the analysis in this deliverable. These premises and ideas notably relate to the notion of 'community'. Indeed, we emphasize that GV is a geothermal development concept in which communities take centre stage. That is, GV ought to be a geothermal development driven by and for local

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communities. But community is a difficult term to define and delineate, so what do we mean by 'community' in our deliverable?

First and foremost, we consider community as residing in and/or with tight historical relations to a specific geographic place, at the local level. We are thus predominantly occupied with social relationships and people's needs and interests as they relate to the immediate territory and lands, they inhabit. A prominent reason why we relate community to place/territory is because of GV's focus on geothermal direct use. Direct use implies proximity; it means that geothermal resources are used/exploited in the benefit of people living (relatively) near these resources (as the drawing portrays). That said, we do not deny the myriads of social relations that exist between (people/entities in) one place and (those in) another, however close or distant. Nor do we deny the forces of globalization and processes of political and economic integration that render a place increasingly unbounded rather than bounded (Van Veelen et al. 2019). We simply agree with and depart from the basic notion that "local relationships and issues continue to play an essential role in the daily life of residents" (Robinson & Green 2010: 2).

The problem with this notion of 'community of place' is the notoriously complex element of *boundary*. Indeed, where does a 'GV community' begin and end? Who stands to benefit from GV, by what mechanisms, based on whose decisions? There is no objective boundary to be drawn, nor are boundaries – once adopted, formalized, agreed upon – static. Even, or especially, administrative boundaries are arbitrary or disputed, something we also observed in our research. Although some delineation is necessary, we cannot and do not maintain a sharp boundary on who is in and out of the GV community. We rather depart from one key premise: the geothermal resource on which a specific GV depends. The part of community that stands to benefit from GV is constrained by three main and interdependent factors (next to the energy potential of the source itself):

1. proximity to the geothermal resource
2. technological/infrastructural devices (both fixed or mobile) and their potential for direct-use applications
3. financial means to pay for [2].

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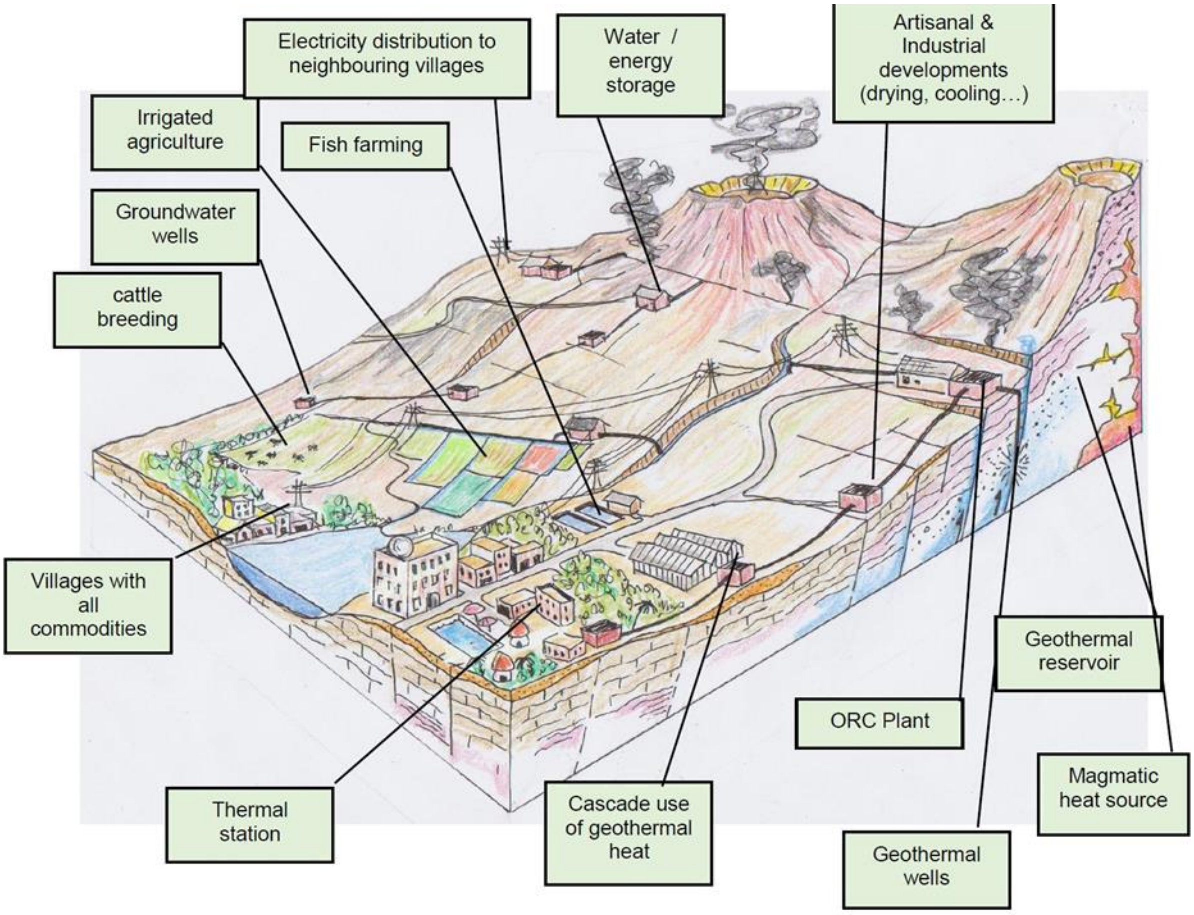

Figure 1: Ideal-type visualization of geothermal village (source: Varet et al., 2014)

In principle we work on the premise that the more limited financial resources (3) are, the less extensive will infrastructure (2) be, and the more important proximity (1). Vice versa, if financial resources (3) are more abundant, then the constraint of proximity (1) can be overcome by more extensive infrastructure (2). Of course, time is another important element; GV will likely start small and will extend in size and scope as time progresses and resources accumulate. The more it grows, the more people or entities can be involved as recipients of GV services. Against this background, the drawing shows us an imaginary GV that is in an advanced stage; it features quite extensive infrastructures, neatly delineated and developed patches of land, a concentrated village, etc. This is quite unlike actually existing and more fragmented landscapes in the four prospective GV sites. Still, it provides an image of the scale of possibilities that may be realized in existing villages. So, a second important factor of community we touched upon is the desired and expected *outcomes* of GV.

Closely related to GV outcomes are questions that relate to the *process* of making and maintaining a GV community. Here, we agree once more with Robinson & Green (2010: 2)

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that "community is constituted when residents in a specific geographic place are mobilized to act on locality-oriented collective interests" (ibid.: 2). That is, processes and issues unfold at the local level that are of concern to the entire or a segment of the population in a given place. These can range from local environmental issues (e.g. gulleys) to the lack of/ need for essential services. These cause people to relate and perhaps to act together, even if there is no consensus on the problem or solution. GV, too, aims to meet collective interests through collective action, whether for social, economic or other ends. Among our key research tasks was to find out what collective interests are and how collective action could be pursued from the perspectives of different members of the communities. When we say 'different members', we refer to communities' heterogeneity and divisions that shape dynamics within and between communities. Such divisions are generated on the basis of gender, class, ethnicity, religion, education levels, age, marital status among other social categories, and these shape people's lived experience.

Given these divisions, who exactly is to benefit from GV and who decides who is to benefit? Questions such as these are complex and need to be taken up in the community itself. In general sense, the GV concept is underpinned by the notion of energy justice and its core tenets. This includes procedural justice, which is about a fair and equal decision-making process. Second, recognitional justice is about the recognition and inclusion of vulnerable and historically marginalized groups, such as women and indigenous people. A third tenet is distributional justice, ensuring that positive outcomes are distributed equally (Jenkins et al. 2021). Merely acknowledging these popular tenets is, however, insufficient for tackling injustices in incumbent energy and political economic systems. Such injustices often have roots in historical processes and are reproduced today through mechanisms/projects of the (sub)national state, development aid or corporations (Sovacool et al. 2023; Dunlap & Tornel 2023). For instance, paying particular attention to gender relations, it is necessary but insufficient to just focus on bringing more (modern forms of) energy to the household. While it relieves households of burdens that generally fall on women's shoulders, it does little to patriarchal or other systems that may continue to exploit women (Sovacool et al. 2023: 2-3). In other words, instrumental 'single-issue' interventions should go hand in hand with interventions tackling structural injustices. GV (research) is premised on analyzing and tackling such injustices. By doing so, it aims to help develop an energy system that opens up rather than narrows down pathways for human flourishing (Sayer 2009). This necessarily requires a research lens that considers agencies and processes at other scales than just the local.

In sum, GV targets communities in specific geographic places and focuses both on development-in-the-community (i.e. relating to GV outcomes) and development-of-the-

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community (i.e. relating to the GV process). Collective interests and collective action are central aspects, as are justice-related concerns related to gender and other social categories. All this is important to keep in mind when reading this deliverable, as it explains why analyses may take a certain direction.

1.3 The GV cases' introduction

The Geothermal Villages cases are found in Kenya – Homa Hills, Djibouti – Lac Abhé, Rwanda – Mashyuza in Bugarama, and Ethiopia – Era Boru in Afar region. The cases are different between them in terms of energy potentiality and also in terms of uses. Nevertheless, there are some common features. The cases in Kenya and Rwanda are similar in terms of living condition of the population and habits in using the geothermal resource (healing and religious uses), although Kenya has a higher wealth standard in the community and seems to be less rural and more connected to the urban area, as Homa Bay town and Kisumu. The cases of Lac Abhé and Era Boru are within the same Afar triangle – and people – divided just by the border between Djibouti and Ethiopia. The habits in using the geothermal sources are prevalent in converting hot water in irrigation water (Djibouti) and hot steam in drinking water, both for people and animals (Ethiopia).

1.4 Summary of the project activities

In order to conduct the studies of the Geothermal Villages, several methodological steps were followed. On action 1 on context analysis, after preparatory process, there followed data collection of data and analysis of the Socio – economic context of target countries. On action 2 on social aspects and dynamics, the steps followed were preparatory work for data collection and engagement with the project's local stakeholders; development of data collection method and plan; collection and analysis of socio-anthropological data from local populations; identification of suitable local stakeholders, and promotion of community appropriation of local geothermal projects. For action 3 on Stakeholders analysis, there was stakeholder mapping; developing stakeholder engagement strategies. Action 4 focused on best practices in renewable developments. It entailed identification of best practices in renewable developments and analysis of best practices in renewable developments. Finally, action 5 was on Business model archetypes development. This entailed identification of business model archetypes and definition of guidelines for business model.

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1.5 Methodological Approach to Action 1 Context Analysis

1.5.1 Sub-action 1.1 Collection of data on the Socio – economic context of target countries

Sub-action 1.1 was developed in two steps: Step 1 entailed the Development of data collection method and plan; Step 2 entailed Data collection.

The Process of achieving step 1 was the following. UoN took lead developing the data collection tools, which was shared with the SSSA team for further comments and input before discussing with other partners. UoN played a lead role in providing information on appropriate sources of data for the socio-economic context analysis for Kenya. Géo2D played a role in providing information for the geothermal related sources of data for Kenya and Ethiopia. For the other 2 countries (Djibouti and Rwanda), UoN relied on and reached out to each of the respective local partners and other reliable contacts in those countries for information on sources of data for the respective country's socio-economic context and geothermal-related data. UoN led the undertaking of a review in all the 4 countries under study. For Rwanda and Djibouti, this was done in collaboration with the Social Scientists of EDCL and ODDEG respectively.

Regarding the Process of achieving step 2, data was collected at two levels that included desk literature review and data collection at the field level. Specific information collected through literature review covered socio-economic data at national level for each of the four geothermal countries. Examples of sources were the last national census, Human Development reports, Household Budget Surveys, Economic Surveys, Mid Term Review Reports, and the World Bank data sources. Socio-economic data was also collected at primary/local level for each of the four countries under study. The data included county/ district/ regional state reports or their equivalence depending on the governance structure of each country. The data covered information on lower administrative levels (at times up to village level). Also covered was the legal framework of each of the 4 countries related to geothermal (Acts of Parliament, Policies, regulations, etc). In addition, data on strategies and visions of government agencies (ministries, etc), parastatals, project implementers related to geothermal initiatives in each of the 4 countries was collected. strategies and visions of government institutions at local level (county/district/regional or their equivalence depending on the governance structure of each country) within the geothermal sites under study. Such data comprised key agencies engaged in geothermal development in the 4 countries under study; legal framework of identified geothermal-related agencies operating at continental and region levels (for example GRMF); all the documents needed

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for regulatory and institutional context; institutional data sources (and census in particular although a bit old); data for basic social analysis (education, income, occupation, age, households composition etc etc..); and finally, data for socio-economic analysis (such as employment, enterprises and workers by sector, trade).

Field data collection was done through: Interviews with identified key informants (KIIs) at institutional and local community levels: FGDs with community members at local community levels: Questionnaires (especially administered at community level) to fill in information gaps identified after doing the literature reviews: interviews to specific representatives of stakeholders groups (communities, policy makers, entrepreneurs.): focus group discussions with national / regional stakeholders (1 per country): surveys to the most involved (potential recipients) communities. Data was collected using structured questionnaire entrenched in ODK collect using in Tablets. Each data collection assistant was well versed in both English and French languages.

The data collection instrument covered the following issues:

Demographic characteristics	**Access to Services**	**Energy Use Sources**
• Age • Level of education • Household size • Livelihoods • Incomes • Economic activities • Vulnerability - various	• Education • Roads • Health • Water	• Biomass • Solar • LPG • Electricity
Use of Geothermal	**Membership to social networks**	**Environmental Issues**
• Water sources • Irrigation • Religion • Health	• Women group • Business /professional • Welfare association	• Pollution • Land degradation • Deforestation

1.5.2 Sub-action 1.2: Analysis of the Socio–economic context of target countries

The sub-action 1.2 was developed in two steps:

- Step 1 entailed Data organization and analysis
- Step 2 entailed Informing Action 3, 4 and 5.

The method of data analysis for step 1 was: text analysis of policy document, basic descriptive statistics, basic multivariate analysis to grasp relationship among a few

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variables (quantitative and or qualitative), Clustering and or factorial to identify groups (of areas, population) / latent factors that seem characterizing the specific context.

1.6 Methodological Approach to Action 2 Socio-anthropological aspects and dynamics

This section outlines some of the key social aspects and dynamics within the populations inhabiting the Homa Hills, Lac Abhé, Bugarama/Mashyuza and Era Boru geothermal sites in Kenya, Djibouti, Rwanda and Ethiopia respectively, where LEAP-RE's Geothermal Village Research project (GV) activities were carried out. The inclusion of a Social Aspects and Dynamics component within the GV project was informed by earlier geothermal-related research work that *Ressources géologiques pour le Développement Durable's* (Géo2D's) Social Sciences component had been part of (and the findings of these earlier studies), which underscored an existing gap related to the social dimension in geothermal development matters along the African Rift Valley (see for example, Varet et al. 2014; Onyango & Varet, 2014; Gardo et al., 2016; Onyango & Varet, 2016). As seen from these publications, by the time of writing the GV proposal, local populations on two of the sites covered in the GV project (Era Boru and Homa Hills) had set up geothermal Community-Based Organisations (CBOs) – the Afar Geothermal Alternative Power (AGAP) and Homa Hills Geothermal Community Based Organisation (HHGCBO) respectively. The aspect of local geothermal CBOs will be discussed in a bit more detail under the respective sites.

The data was principally collected through socio-anthropological methods, achieved by intermittent visits and stays in the field done between October 2021 and November 2023,[1] whereby community meetings, Focus Group Discussions (FGDs) or Key Informant Interviews (KIIs) were conducted. HHGCBO, *L'Office Djiboutien de Développement de l'Energie Géothermique* (ODDEG), Energy Development Corporation Ltd (EDCL) and AGAP of Kenya, Djibouti, Rwanda and Ethiopia respectively were key partners and instrumental in facilitating the fieldwork and/or stay. Their role in this regard is therefore highly appreciate because without their input and involvement, the activities of this sub-task would never have been possible. Initial field visits were conducted by Géo2D to introduce the project to stakeholders and hold preliminary discussions with them in the four sites starting with Lake Abbe, Era Boru, Homa Hills and Mashyuza in October 2021, November 2021, December 2021 and May 2022 respectively (see Onyango, Houssein & Ali, 2022). For Rwanda, it was the Geoscience arm of Géo2D that carried out the initial stakeholder's meetings in Rwanda because there was the need to first of all work in close consultation with EDCL to choose the best site with geological considerations also in mind. Both geothermal studies and development are less developed in Rwanda compared to countries

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such as Kenya (Karangwa, 2018; Turinimanana, 2018; Rutagarama, 2014). The initial stakeholders' meetings were followed by more in-depth socio-anthropological fieldwork in November 2022, February 2023, October 2023 and November 2023 in Homa Hills, Lake Abbe, Mashyuza/Bugarama and Era Boru respectively. Apart from the Mashyuza/Bugarama field work done (where *Università di Torino* <UNITO> went to the field earlier in June 2023) with *Scuola Superiore di Studi Universitari e di Perfezionamento Sant'Anna* (SSSA) and Géo2D going together later, UNITO, SSSA and Géo2D went to the field together for the other three fieldwork. The field data is complemented with observations made and desk literature review. Ultimately, this section is therefore intended to give - from a socio-anthropological perspective - an overview of identified social dynamics issues relevant to community-based geothermal development in a Geothermal Village (GV) context as relates to the geothermal populations on the four mentioned sites. As a summary, although there are some characteristics that cut across all the populations, there are also some differences in this perspective. All the populations have high poverty incidences. The resources in Homa Hills seem to have the most category of uses. Although the resources on the other sites have comparatively fewer uses, they are essential for the very survival of the communities in question, especially the pastoralist populations. Especially in the cases where the uses are crucial to the population's survival, there are gender implications because such uses are generally tied to gender roles. Currently, all these populations can access the geothermal resources on the lands they inhabit without any problem. However, owing to differences in licencing and land tenure issues in the four countries, the geothermal population around Era Boru site in Ethiopia are least vulnerable to future legal prohibitions regarding access and use of the geothermal resources on the land they inhabit. In terms of changes resulting in lack of access and use of the sites by the local population resulting from industrial (human) activities the Bugarama/Mashyuza site is the most exposed. There were reports of high incidences of female-headed households among the Homa Hills and Bugarama/Mashyuza sites populations, even though the reasons occasioning these situations were different. Gender inequality in favour of men exists within all the four populations and seems most pronounced among the populations living around the Era Boru and Lake Abbe (Lac Abhé) sites - both Afar populations and both also pastoralists. This is also the case in relation to non-exposure to formal Western education, whereby the Era Boru and Lake Abbe sites have comparatively higher incidences of lack of exposure to formal Western education, compared to the populations around the other two sites. Gender inequality seems least apparent with the population around Bugarama/Mashyuza. The existence of gender inequality, resulting from various issues and manifested in different ways within these populations and which accords women lower status compared to men, is one of the strong justifications for having gender as a key pillar in the GV concept. There is also diversity in terms of economic activities that can be linked

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to geothermal development within the four populations. Just like the uses, the economic activities present within the populations also open up perspectives for business models linked to Direct Use geothermal activities. The economic activities tend to be linked to gender roles, and so in addition, have a direct relation to gender. In regard to access to services, Era Boru seems to most lag behind, followed very closely by Lake Abbe. All the populations are affected by household vulnerabilities and environmental factors related to water and energy in varying ways. These also are both directly linked to and have direct implication for gender roles. The incidences of the households with electricity are highest among the population in Homa Hills and least in Era Boru. The ensuing sections under social aspect and dynamics discussion, covers, in more detail the above social perspectives specific to each of the four geothermal sites.

Some terminological clarifications:

- The term "geothermal population" refers to a group of people inhabiting a given geographical area around a geothermal site and sharing a culture.
- The term formal Western education is used in this report to refer to a way of learning through a structured education system – characteristically competitive in nature – which is generally based on a written curriculum broken down into syllabuses that need to be covered at specified stages of the system – therefore often time-bound. Being competitive, what is taught is generally examinable and used to systematically cut off participants at each given stage. It is based on European and North America models of learning. Individualism and scientific inquiry are part of its emphasis. In this report, it is distinguished from Indigenous education, still common among some of the populations worked with in the GV project (particularly the Pastoralists) and which can be described as the often orally-transmitted knowledge systems of a given local population, passed down from the older to the younger generation. Parts of it are structured, similar to the case of formal Western of education. Principles of Indigenous education include learning that supports the well-being of the self, family, community and land. It is holistic, reflective, experiential and relational (therefore focused on connectedness, reciprocal relationships and sense of place). Traditionally high levels of this education; meaning proficiency in Indigenous knowledge position individuals (especially men) favourably in society. Indigenous knowledge has been the basis for local-level decision-making in most rural communities but formal Western education has progressively been replacing it. Parts of it are structured, similar to the case of formal Western of education (Open Library, undated).

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1.7 Methodological Approach to Action 3 Stakeholder Analysis

Each of the country chapters (ch. 4 – 7) contains a stakeholder analysis. By stakeholders, we mean individual or collective actors who already have obtained or likely will obtain – for different reasons and whether willed or not – 'a stake' in GV. What that stake is differs per stakeholder type, but in generic terms, we refer to actors who are affected by and/or are themselves affecting GV developments (Reed et al. 2017: 3). More specifically, we pay attention to three aspects:

- Stakeholders *already* involved in GV research and preparations;
- Stakeholders who are not yet, but could *potentially* or should *necessarily* be involved in future GV developments;
- Social relations between actors, including the (power) processes and things that shape and mediate relations.

This section briefly outlines some additional premises that underlie the stakeholder analysis in each of the case study chapters.

1.7.1 Purpose: why stakeholder analysis?

We conduct a stakeholder analysis (SA) to increase understanding of the social and political economic system *in* which, and the key actors *with* which, GV ought to be realized (Bendtsen et al. 2021: 2). This serves an *instrumental* purpose: to assess with whom and how GV can be set up and developed. We aim to map the local system and stakeholders, but since this local system is nested in larger systems with higher-level (i.e. (sub)national) actors, the latter will also be examined. Our SA also has a *normative* aim, following the vision outlined in section 1.2. This aim has to do with the actor group that is central in GV, namely the local community in each country. These communities ought to be the direct beneficiaries of GV, that is, the actors who stand most to gain from potential GV developments. Whenever possible, we take their stakes/interests, positions and dynamics as departure points for our SA and position other stakeholders in relation to them. This can help visualize and strategize how to maximize the space for communities to gain from GV (Mushove & Vogel 2005).

1.7.2 Categorization of stakeholders

We categorize stakeholders based on different properties. First, we make a distinction between the community and 'external' stakeholders. Regarding the former, following the

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notion that communities are heterogenous rather than homogenous entities, we list one or more key groups that make up, define and shape dynamics within the community – or indeed those community groups that play a key role in current or future GV developments. External stakeholders are actors who stand in some kind of relationship to the community and who may to a greater or lesser degree affect the course of events. This can range from actors who have a proximate, close and formal relationship with the community (e.g. local leaders working for the government) to actors at a distance having (hitherto) weak ties with the community. External stakeholders can in turn be subdivided into actors on the local or regional levels, and those acting on the national level. The extent to which attention is paid to actors on either of these levels depend on the political economic context of each site and country. For instance, in a small country like Djibouti with a centralized governance regime, national stakeholders tend to play a relatively big role in relation to regional ones. Kenya's devolved and dual (county and national) governance system means that regional actors play a relatively big role next to national ones. Finally, stakeholders are distinguished according to the nature of their organization, activity and/or identity; they can be public, non-profit or private sector actors or, in the case of the community itself, social or economic actor groups.

1.7.3 Stakeholder dimensions and engagement

There are several dimensions that we pay attention to. For each stakeholder, we briefly mention their profile (e.g. main activities or responsibilities), followed by the role and interest they (may) have in GV. Power is another dimension touched upon. It goes without saying that any social and environmental change of the kind that GV envisions plays out in a context of cooperation and struggle, with multiple actors who stand in uneven power relationships (Kalt 2024). The extent to which actors can influence the course of events depends on their discursive, material and/or political (decision-making) power (ibid.) and their relative power positions (i.e. vis-à-vis other stakeholders). This power position and power dynamics will briefly be discussed for the most prominent stakeholders and stakeholder relations in GV. Closely related are the resources available to stakeholders to forge certain developments or changes. Such resources can be material and immaterial, ranging from financial resources to knowledge. A final dimension to consider is the extent to and way in which stakeholders are or ideally become engaged, with engagement understood as a "process in which [stakeholders] are involved in making decisions that affect them, whether passively via consultation or actively via two-way engagement" (Reed et al., 2009: 3). As for the power dimension, we will consider engagement factors for the most prominent stakeholders.

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1.7.4 Methods

Our SA relied on primary data from fieldwork and qualitative methods. We may distinguish between different stages in SA, each of which required its own approach. In terms of identifying stakeholders, we followed a two-step approach. First, we made an initial (predetermined) list of actors who were easiest to identify. This either meant actors already involved one way or the other (in the longer history of GV, before this project started) or identified through secondary and grey literature. We then carried out semi-structured interviews and Focus Group Discussions (FGDs) with these actors and used these to deploy snowball-sampling. Thus, we asked each interviewee or focus group for stakeholders whom she/ he/ they considered necessary or important to approach and we followed up these leads if we considered them relevant. This meant in some cases that we interviewed actors using digital means. Finally, we analyzed our data and sketched profiles of stakeholders through a close reading and coding of interview transcripts, augmented with secondary data and literature. The different stakeholders and their dimensions are listed in tables, and a selection of them and their relations are discussed in more detail in a final section of each country's SA.

1.8 Methodological Approach to Action 4 Best practices in renewable developments

1.8.1 Identification and analysis of best practices in renewable developments

This section had as its objective the selection of best practices within the African continent and the definition of criteria for selecting of successful renewable development cases at community level. Our work has focused both on geothermal energy and other renewable energies. As a result, geothermal energy does not appear to be very present with off-grid plants in Africa, or in any case with small-scale plants and perhaps connected to communities. Hence, some similar cases in other renewable energies have been observed as leading cases for geothermal off-grid power plants.

As regards the sources, we focused primarily on the scientific literature review, with a search covering the period from 1987 to 2023, through the Scopus and Web of Science databases. Hundreds of scientific articles were analysed, by a team of two researchers, for the extraction of data through electronic spreadsheet. This database formed the basis for our recommendations. Then, grey literature was also analysed, through reports and press

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news. This second step helped us in finding elements of novelty not reported by academia publications.

The study carried out in this action was fundamental for the analysis that was carried out on the four different sites on the ground in Action 5. In fact, through the schemes that were studied in Action 4, we reached the criteria for the extraction of data that were then used for action 5, which has the objective of supporting the development of guidelines for potential business models capable of spreading geothermal-based stand-alone electric (the GV) and thermal energy systems in the four sites and in the possible other future geothermal off-grid African communities.

1.9 Methodological Approach to Action 5 on Business Model guidelines

1.9.1 Identification of business model archetypes and definition of Guidelines for potential business model

For the identification of the components of business model archetypes, SSSA has started its work from the results emerging from Action 4. Action 4, and specifically the literature review analysis, has provided a set of criteria that should be applied to the GV to maximize the possibility of success. We therefore took inspiration from the best experiences of Decentralized Renewable Energies with the involvement of communities. This work was then combined with data collection in the field, which aimed, starting from the needs and wishes of the reference community, to propose one or more solutions that were as win-win as possible, i.e. that brought greater benefit to everyone the actors involved, preserving the objectives of economic, social and environmental sustainability.

The fieldwork was done through n.5 visits in all the sites (the Homa Hills community was met twice). We employed focus group discussions-FGDs and semi-structured interviews with key stakeholders and community members interested in the GV project. Citizens, public authorities, and NGOs are included among the members. Each FGD lasted approximately three hours, while the interviews lasted an hour and a half on average. The participants in the FGD were randomly selected within the community but respecting a principle of representation of the different social categories (e.g. type of work, gender, seniority, role within the community, religious representatives, etc.). During the FGDs and interviews, a team composed by European and African researchers with different background (i.e., economist, anthropologist, sociologist, geologist) was present, plus a simultaneous interpreter and translator.

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This work was then translated through a scheme adopted from the article "The triple layered business model canvas: A tool to design more sustainable business models" by Joyce and Paquin, 2016 (see reference). This article proposes a three-level framework (Economic, Environmental and Social), with each level comprising several dimensions. The dimensions predicted by Joyce and Paquin (2016) for the following levels are summarized below:

- Economic: Value proposition, Partners, Activities, Resources, Channels, Customer Segments, Customer relations, Cost and Revenues;

- Environmental: Functional Value, Supplies and Out-sourcing, Production, Materials, End-of-Life, Distribution, Use-phase, Environmental Impacts, Environmental Benefits;

- Social: Social value, Local Communities, Governance, Employees, Societal Culture, Scale of Outreach, End-users, Social Impacts, Social Benefits.

For reasons related to the structure of the report but also of sites' context, some dimensions have been readjusted in the definition or merged.

Obviously, our proposals consider the results that emerged not only from action 4, but also from actions 1,2 and 3, therefore the specificities of context, culture and the stakeholders and actors present in the various African sites.

We believe that the work carried out can be useful not only for the next steps of the GV, but also for similar experiences that want to take inspiration from the business model archetypes proposed for the four GV sites, to spread geothermal-based stand-alone electric and thermal energy systems to off-grid African communities.

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2. Exploring Noteworthy Off-Grid Power Plants in Sub-Saharan Africa: A Case Analysis

2.1 Off-grid power plants in rural and remote areas

In the IEA's Net Zero Emissions by 2050 scenario (NZE), the goal of achieving full electricity access by 2030 involves utilizing decentralized solutions for over 50% of the population, with 90% relying on renewable energy sources. Mini-grids and stand-alone systems, particularly those based on solar power, have emerged as the most practical options for providing electricity to rural areas where the majority of those without access reside, in particular in Sub-Saharan Africa (SSA) (IEA, 2022).

Besides mini-grids and stand-alone systems, the whole decentralized renewable energies (DREs) are gaining more and more space and interest in the way to energy access. The decreasing technological costs of DREs over the past decade have made them a more attractive alternative to traditional grid extension (Mandelli et al., 2016). There are several ways of managing DREs. One of these is when the local communities own, manage, operate, and maintain the plant (Peters et al., 2019). Community-led models for developing and managing DRE projects have been identified as key factors for success. While challenges such as initial investment and technical skills do exist, collaboration within communities presents an opportunity to address these issues and improve energy access in Sub-Saharan Africa.

In fact, lack of CE has been demonstrated as a possible barrier to the DRE project's durability (Akinyele et al., 2018), such as the practice of using only outsiders to plan and execute local community projects could be a recipe for the failure of the systems (Nuru et al., 2022). A more integrated approach foresees community ownership, management, operation, and maintenance of the plant (Ahlborg & Hammar, 2014). Furthermore, Katre and Tozzi (2019) suggested that a community-led model for developing community-based projects on DREs can be instrumental for success, particularly when implemented with a bottom-up approach, as emphasized by Velasco-Herrejon and Bauwens (2020).

The example of Adwoa Adezawa, a resident of Cape Coast in Ghana near the Elmina fishing port, is just one of the possible bilateral and mutual contribution of DREs and communities in SSA. Adwoa faced challenges due to the absence of electricity in her community until the Ghana Energy and Development Access Project (GEDAP) was initiated with support

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from the World Bank and the International Finance Corporation. This project aimed to provide inclusive access to renewable energy through off-grid solar services and products. The implementation of five pilot mini-grids powered by solar energy in isolated communities has significantly improved the livelihoods of thousands of Ghanaians, including fishermen like Adwoa. The affordability of mini grids was ensured through subsidies and support for access to financing. The project also addressed legal and regulatory barriers to foster a regional market for renewable energy solutions. The success of GEDAP in Ghana has led to similar initiatives in other African countries, contributing to the World Bank's goal of providing sustainable energy access to millions of Africans by 2030 (World Bank, 2020).

But it's not just targeting communities and providing energy access what GV aims to do in the sites selected in Kenya, Ethiopia, Djibouti and Rwanda, as shown in the previous chapter. GV aims to involve communities in the design and management of the plant. In fact, involving communities in the management of renewable energy sources could not only create value and solve economic and skills-related challenges but also help overcome barriers to electrifying rural areas where there is limited interest from the private sector. In doing this, Renewable Energy Communities (RECs) can help GV in going further and far. RECs have the potential to be transformative in bringing sustainable energy to off-grid populations (Ambole et al., 2021) and advancing a just and fair low carbon transition in alignment with the UN2030 Agenda on Sustainable Development Goal 7. We will go through the potentiality of RECs in Sub-Saharan Africa in the next section.

2.2 Renewable Energy Communities in Sub-Saharan Africa: an overview of common features and challenges on objectives, management, community involvement

The results presented in this section emerged through a systematic literature review (see: Xiao and Watson, 2017) conducted by SSSA's research team within the LEAP-RE project.
Following Ambole et al. (2021), SSSA's team believes that GV can learn from other experiences regarding DREs with the involvement of communities (following, for the purpose of this report, simply RECs) in SSA. Considering that RECs, as strictly meant in Europe, do not exist in SSA, our analysis had to start from a broader horizon. Hence, in querying the databases, we had to set as keywords "renewable energy communities", "renewable energy", "bottom-up initiatives", "micro-grid", "stand-alone", "rural energy communities", "energy poverty", "Africa", etc. The databases used were Scopus and Web of Science, universally recognized in the field of management as comprehensive source of

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data. The Research Questions, both addressed to Africa and leading the analysis, investigated the presence of RECs in literature (1) and the main challenges for a sustainable business model of RECs (2). We queried the database with the timespan from 1987 to 2023 (31st December) and, following a validated method by previous scholar, we first selected the articles published (or in final process "early access") on peer-review journals (when is not clear: excluded). Then, we selected just some categories (Business, social, energy, engineering, etc), through options available in the databases. Starting from a sample of 334 articles, after the duplication check and the application of exclusion criteria in the title-abstract screening, leading us to exclude, articles not matching with the topic (due to the query database and), we reached n.41 articles for the final full-text analysis.

Our analysis was organized both with the categories from Bauwens et al. (2022), regarding community meanings, energy activities, and objectives, and in relation to management and financial issues, and success and failure factors. The first main result confirmed that RECs are not spread in SSA, at least from a , While terms like "community energy" and "energy community" are more common, "Renewable Energy Communities" is lacking dominance in the literature.
Then, following Bauwens et al. (2022) classification, our analysis indicates that the energy activities in RECs predominantly focus on demand-side components. Some studies emphasize integrated production, utilizing biofuels from the community in a circular economy approach, showcasing sustainability potential. Solar energy, particularly solar photovoltaic, provides accessible electricity and is mostly used in DREs. Geothermal and other renewables are less spread but have various applications, such as agriculture and thermal tourism. RECs in Africa can address the challenges related to the context: distributed renewable energy access drives societal development, improving local well-being, education, and gender equality while ensuring energy independence and reliable infrastructure. RECs have the potential to bring about positive change in African rural communities, addressing basic needs and aligning individual and collective interests towards achieving the UN2030 and AU Agenda 2063 goals.

Regarding the aspects related to management and community involvement, RECs hold immense potential for Africa's development. Their focus on a "bottom-up" approach empowers local communities, fostering wealth improvement and social progress. This can be seen in positive impacts on local economies and the enhancement of social conditions. Furthermore, RECs can be a powerful tool in achieving the SDGs by promoting renewable energy access in rural areas, providing an alternative to fossil fuels and tackling climate change. Despite their potential, RECs in SSA face challenges that hinder their effectiveness. A major hurdle is the initial investment required for infrastructure and project development. Additionally, the lack of clear policies to attract companies, investors or donors for long-term partnerships creates uncertainty. Furthermore, questions linger about

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the long-term sustainability of these projects. Operational costs, along with the willingness of communities to afford continued use, can pose a significant barrier. Finally, RECs must face the unknown question of grid extension, which can challenge off-grid plants sustainability.

Finally, the success of RECs in SSA hinges on a complex interplay of factors. A strong policy framework with unwavering political support is crucial for attracting investment and ensuring long-term commitment of crucial actors, as international donors but also local communities and businesses. However, RECs can't solely rely on top-down approaches. Project design and technological considerations are equally important. The chosen technologies must be sustainable, considering environmental impact and operational costs. Social challenges like community acceptance and willingness to pay for services can also make or break a project. Furthermore, economic factors like market access and affordability for local populations need careful consideration. Finally, the availability of local skills is essential for project implementation and ongoing maintenance. If RECs can address these success factors while mitigating social, economic, and environmental challenges, they can become powerful drivers of progress across Africa.

2.3 What Geothermal Village can learn from other experiences.

As exposed in the previous sections, if properly designed, RECs can address several social and environmental objectives and provide an improvement of wealth of communities. Geothermal Village can learn from RECs experience in Africa exposed before. Following, there are some suggestions. Here, it is important to clarify that the following list is not to be intended as exhaustive, rather and addition to what will be presented in the business model guidelines for each of the site.

First, GV should focus on demand-side components: while geothermal offers unique benefits, learn from the dominance of solar in current REC projects is essential. Solar success is due to solar availability but also to the low costs (compared to other REs) and easiness in maintaining and repairing. Therefore, GV should consider to be combined with solar photovoltaic plants, offering a hybrid system which is a readily available option alongside geothermal for specific needs. Furthermore, GV must be designed as easy to maintain and repair, considering the possible difficulties of local communities that live in remore areas.

Second, still on the hybrid design, GV could evaluate to embrace a circular economy approach, by exploring the integration with biofuels power plants (for the sites where biofuels is available). The biofuels should be produced by the community. This can create a more sustainable and self-sufficient model.

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Third, the GV must highlight societal development. GV can do it. GV can attract investment by showcasing not just the energy access but the broader impact it has on the community. This follows the REC model of emphasizing improved well-being, education, and gender equality through energy access.

Fourth, GV must address management and community involvement, learning from the RECs' "bottom-up" approach. GV must involve Community Based Organizations (CBOs) in ownership and management. CBOs should be engaged also in capacity building, to empower the community for long-term success.

Fifth, regarding training, GV can collaborate with CBOs that can help also in finding and creating skilled workforce. On training and workforce, GV can partner with already existing RECs or training institutions to develop a local workforce for project implementation and maintenance.

Finally, regarding the economic Long-term sustainability, GV can look for financial innovation, by exploring alternative financial models beyond traditional donors. Consider micro-credit options or engaging the diaspora for investment. Regarding operational costs and community affordability, GV should Develop a plan to ensure the community can maintain the project after initial support.

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3. Kenya – Homa Hills

3.1 General intro: a context analysis of the region and the site(s) involved, including demographic data and energy access

The area is in the western part of Kenya, on the southern side of a bay (Homa Bay) of the Lake Victoria, south of the regional capital, Kisumu, the third largest town in Kenya (400,000 habitants). It is accessible by road from Nairobi 350 km, 6h30 (Omenda Peter and others, 2022). The information has been collated with secondary data sources obtained from the County Government in Homa Bay.

Generally, the Homa Bay county is divided into two main relief regions namely the lakeshore lowlands and the upland plateau. The lakeshore lowlands lie between 1,163 – 1,219 m above sea level and comprise a narrow stretch bordering Lake Victoria especially in the northern parts of the county. The upland plateau starts at 1,219 m above sea level and has an undulating surface which has resulted from erosion of an ancient plain. Homa hills in Karachuonyo is one of the residual highlands.

The Homa Hills

The hills around here are climbable and their variation takes approximately 1 to 3 hours to reach the apex. The overall statistics show that 95% of all climbers reach the highpoint. Surprisingly enough, the hills are free from ice or snow caps and do not need any mountaineering tool. Almost every kind of ecological system is found on these hills. Watching natural phenomenon is one of the interesting activities that may trigger your ego to climb homa hills. While standing at the top of these hills, climbers enjoy watching Lake Victoria and the nearby towns such as Kisumu, Kendu Bay, Homa Bay and Kisii.

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The Hot Sprigs

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At the eastern side of the Organization features pools of super-heated water, connected to a hot underground source, with steam hissing and bubbling up constantly. You can see the bubbles of water and steam boiling up through the channel or spout-hole naturally. The salty water oozed from this area is hot enough to cook any kind of food. The spurted water is poured into Lake Victoria through a local river linked to this hot spring. The area is christened as Abundu hot-spring. Several researchers have confirmed that it is an inactive volcano that will never erupt.

Climate and Ecological Conditions

The county can be divided into seven agro-ecological zones namely: Lower Midland (LM4), marginal cotton zone occupies a strip along west of Karachuonyo, central Mbita and Gwassi areas of Suba sub-county. It supports the growth of cotton.

Homa Bay County has an inland equatorial type of climate. The climate is however modified by the effects of altitude and nearness to the lake which makes temperatures lower than in equatorial climate. There are two rainy seasons namely the long rainy season from March to June and the short rainy season from August to November. The rainfall received in the long rainy season is 60 per cent reliable and ranges from 250 – 1000 mm while 500–700 mm is received in the short rainy season. The county receives an annual rainfall ranging from 700 to 800 mm. Temperatures in the county range from 18.6°C to 17.1°C, with hot months being between December and March. February is usually the hottest month in the year.

Population Distribution

The settlement patterns in the county are greatly influenced by rainfall patterns, topography, infrastructural development, proximity to urban centres, availability of natural resources and security. However, majority of the county population is resident in rural areas. The climatic conditions are strongly influenced by altitude and physiographic features. Some of the major challenges that that the county is facing include inadequate and late release of funds, uncoordinated implementation of development activities, lack of adequate equipment, rural- urban migration, insecurity; dilapidated infrastructure; food insecurity; low income levels; low standards of education; environmental degradation, HIV/AIDS, poor marketing systems and bureaucratic procurement procedures, among others.

Tourist Attractions

The side of the lake that passes through Homa Hills is a direct continuation that routes Kisumu and Homa Bay. The Lakeshore Road passes behind Homa Hills from Kendu Bay to Kadel, connecting to Homa Bay town. The view of Lake Victoria while standing at Homa

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Hills is undoubtedly a touristic thing. Our visitors do enjoy watching fishermen pulling fish from their net, birds preying on fish, and water tides swinging at the shore. Most interestingly, visitors can liaise with us and hire a guide to take them around Lake Victoria waterfronts and benefit from seeing fishing activities around the area. In this case, the mode of traveling will be a local boat. Lake Victoria itself is statistically remarkable. Remember, it's the largest lake on the continent, the world's second-largest freshwater lake, and the world's largest tropical lake. It extends significantly into three separate African countries: Uganda, Tanzania and Kenya.

Environmental Conditions

The county is dissected by several rivers namely Awach Kibuon, Awach Tende, Maugo, Kuja, Rangwe and Riana rivers, most of which originates from Kisii and Nyamira counties. There are also several seasonal rivers and streams which originate from highlands within the county. The county has 16 islands, some with unique fauna and flora and an impressive array of physiographic features with great aesthetic value as well as breath-taking scenery and forested landscape particularly those around the islands and the coast of Lake Victoria and a peninsula like Sikri of Mbita sub-county.

Location of the Homa Hills and Hot springs shown in the maps below

Based on prior visits by the LEAP-RE teams, the location of homa hills hot springs is shown below in Figure 2 and 3.

Homa Hills Hot springs locations. Coordinates in WGS84 UTM coordinate system

Key area for investigations (project area). To be confirmed after geophysical studies and conceptual model development.

Project affected area (community). Reconnaissance should cover the entire area.

Figure 2. Key area for investigation and affected area by the project.

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Figure 3. Spots of collection of data in Homa Bay county.

Socio-economic dimensions of geothermal development - Findings of the Socio-Economic Survey: The socio-economic analysis is based on the geothermal surveys conducted homa hills area is located in the western part of Kenya, on the southern side of a bay (Homa Bay Town) of the Lake Victoria, south of the regional capital, Kisumu, the third largest town in Kenya (400,000 habitants). It is accessible by road from Nairobi 350 km, 6h30 (Omenda et al., 2022). The information has been collated with secondary data sources obtained from the County Government in Homa Bay.

A breakdown of the average household size and respondents by gender and location: Overall, about 52% of household respondents were females and 48% were males. Except for Kakdhimu East location where the majority of the respondents (52%) were males, in other locations, the majority respondents were women.

Age Distribution of the respondents: Most of the respondents were above 52 years old, followed by 30-35 (19%), 16% for 24-29years and 36-41 years. The age profiles are similar across all the locations.

Marital Status and Educational Profile of the respondents: Marital Status show that 77% are married, 16% widowed and 6% divorced. The educational Profile of the respondents show that 52% have 0-level education, followed by 26% A-level, 10% certificate.

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Occupation of the respondents: About 51% of respondents are subsistence farmers, 22% are engaged in trade/business and 19% are self-employed in undefined activities. Occupational profile is similar across the locations.

Incomes of the respondents: About 50% of households have monthly income of 5000kshs or below. 22% of respondents have monthly income in the range 6000-11000kshs.

Dwelling types by Households: Most (dwellings in the villages are semi-permanent (iron sheet roof and mud walls) – 82% and the rest are permanent.

Household Economic Vulnerability by the Households: About 62% of respondents are in households that have gone without enough food to eat several times or many times. About 63% of respondents are in households that have gone without enough clean water several times or many times. Water vulnerabilities are similar across the regions. About 67% of respondents are in households that have gone without enough medicines or medical treatment several times or many times. Health vulnerabilities are similar across the regions. About 77% of respondents are in households that have gone without enough fuel to cook several times or many times. Energy vulnerabilities are similar across the regions. About 72% of respondents are in households that have gone without enough cash income several times or many times. Income vulnerabilities are similar across the regions. About 69% of respondents are in households that have gone without enough school expenses several times or many times. School expenses vulnerabilities are similar across the regions. About 7% of the households consider themselves destitute. About 1% of households consider themselves quite well off. About less than 1% of households consider themselves wealthy. About 9% of households consider themselves not so well off.

Access to Services by Households: Access to electricity 29%. Access to health facilities 98%. Access to piped water 13%. Access to roads 93%. Access to educational facilities 99%

The use of geothermal or hotsprings resources by households: Traditional healing (herbalists and spiritual healers) 74%. Livestock 72%, Health 67%, Religious 61%.

Energy Regularly used for various needs: Cooking Biomass 97%, Cooking LPG 8%, Cooking Electricity 1%. Lighting Electricity 22%, Lighting Biomass 5%, Lighting solar 59%, Lighting kerosene 12%.

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3.2 Socio-anthropological aspects and analysis

3.2.1 General Background Information

The Homa Hills geothermal site is in Western Kenya's Homa Bay County. The visible manifestations of the resources on the earth's surface are located in the county's three administrative locations of Kanam B, Kakdhimu East and Kokoth Kataa. Whereas the main geothermal population inhabiting the area around these manifestations are the Luo, with *Dholuo* as their local language, the predominant religions are Christianity and indigenous religious beliefs. Some of the indigenous faiths consider the geothermal manifestations as sacred. This brings in a perspective that needs to be considered in the context of developing a geothermal project. Some of the nearby Catholic churches also use the water as Holy Water for their religious activities. According to Kenya's 2019 census, Homa Bay County has a total population of 1,131,950 persons, out of whom 539,560 are males and 592,367 females. It has 262,036 households with an average of 4.3 people per household and a population density of 359 people per square kilometre (Kenya National Bureau of Statistics, 2019). The total population of Rachuonyo North, the sub-county in which the geothermal resources are located is 178,686 out of which 85,403 are male and 93,273 are female (Homa Bay County, August 2023). The socio-anthropological data collected in the course of fieldwork around the manifestations during the project period regarding the population's food security and livelihoods suggests that most of the population is living below the poverty line. Ojwang' & Oima (2018) report the poverty level in Homa-Bay County as being 77.9% against 52% in Kenya but the Kenya Bureau of Statistics (2023), indicate that the county had an overall headcount poverty rate of 26.6% in 2021 (against the national rate of 38.8%).

3.2.2 Economic Activities

There is diversity in terms of economic activities within Homa Hills with farming, fishing and fish-mongering as the most predominant. Other economic activities include animal husbandry, retail trading, wage/formal employment such as teaching and motorcycle taxi business (called boda-boda). Part of this data collected from the project's field work in Homa Hills is corroborated by Homa Bay County (August 2023) by indicating that, the primary livelihood activities include medium size and small-scale trade, fisheries, and rain-fed small-scale farming; adding that these practices are highly vulnerable to environmental degradation and the effects of climate change. Indeed, geothermal development targeting Direct Use can respond to these situations. Homa Bay County (2012) & Homa Bay County (August 2023) further indicate that 70% of the county's population are in agriculture, 11% in wage employment, 6% in rural self-employment and 9% in urban self-employment.

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Homa Bay County (August 2023) further confirms that, most of these self-employed individuals are in retail trade, cottage industries and value-added agriculture. Discussions with the community in September 2021 indicated that fishermen are having to sail further into the lake to catch fish because of over-fishing. Direct use geothermal development would open a business model around activities such as fishing, fish-farming and crop-farming.

3.2.3 Uses of the Geothermal Resources – Current and Potential

The local Homa Hills population has numerous uses of the geothermal resources located around the land they occupy. As outlined by Onyango (2022), these include spiritual/religious and/or psychological, culinary, social, economic, sanitary/hygienic/medicinal/health-related, touristic/educational, political and meteorological uses. In a December 2021 FGD with some of Homa Hills indigenous religions leaders, Daniel Omondi Lusi, one of the male participants suggested that pumping water from a higher to lower altitude for irrigation purposes; for example, from the hills where water is available would reduce the drought-related crop failure often experienced by the community[2]. This idea relates to a finding of Jacques Varet (of Géo2D) whereby the community explained to him during one of his fieldwork missions that there existed a system of pumping water from the lake, which was however stopped because it was too expensive. Powering lake water pumping is therefore a potential use of geothermal in Homa Hills. A finding from some earlier research work that Géo2D had been part of also indicated that part of Homa Hill's geothermal system could be used for producing mineral water and its derivatives production. These uses (both current and potential) open up perspectives for a business model related to the Homa Hills geothermal resources, including provision of potable water, which was cited as one of the principal needs.

[2] His real name has been provided because he indicated that should be the case when his contribution during the discussion is used. The other participants of the FGD who were also of the same opinion regarding their contribution were: Pamela Anyango Odindo, Pauline Omollo Okelo and George Obonyo.

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3.2.4 Community's Readiness for a Project Based on the GV Concept and Licence Issue

Various interactions with the members of the population indicated that the local community was enthusiastic about the idea of a project based on the Geothermal Village (GV) concept on their territory. Members of the community have established the Homa Hills Geothermal Community-Based Organisation (HHGCBO) as the structure through which geothermal development matters within Homa Hills should be addressed. HHGCBO is associated to the GV project through a third-party agreement with Scientific and Engineering Power Consultants Limited (SEPCO), one of the project partners. Being at a nascent stage, there is need for capacity-building to bring this entity to a point where they can sustainably manage inclusive geothermal initiatives taking place on their land. Although the exploration licence for the resource is in the hands of a private developer, the local population has until presently (May 2024 the time of writing this section) easy access to the resources for their various uses without any problem. However, for HHGCBO to be involved in the project, the licence holder had to give consent, which they willingly did. The licence holder also gave consent for HHGCBO to develop shallow geothermal resources for community use, should that possibility arise after GV. This is an expression of goodwill on their part for the community to benefit from the resources, alongside whatever other development plans the licensee may have for the resources. The indications are therefore that the licensee has the political will to support a GV concept type of project that benefits the local population. This is highly commendable on the part of the licensee and they should be highly appreciated for this gesture. The situation is however a reflection of how the participation of Kenyan geothermal populations in geothermal development processes can end up being very closely tied to licensee issues, owing to the land tenure regime that allows for private land ownership.

3.2.5 Gender-Based Social Dynamics

Data from the project's socio-anthropological field work indicated reports of high incidences of female-headed households within Homa Hills; impact of the population's history with high HIV/AIDS infection, which has over time, resulted in many women being widowed. 4.4% of the women in Homa Bay are widowed (Kenya National Bureau of Statistics (May 2014). This situation has further exacerbated the poverty levels within the population. At both household and community levels, men are generally the ones with economic and decision-making power compared to women. Among other reasons, this situation is tied to the fact that culturally, men are the ones who own land, having inherited it from their fathers and in turn, pass it down to their sons. Kenya's 2010 Constitution however has a

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provision for daughters to inherit land from their fathers and although this is not yet practiced rampantly, during the project's field data collection, discussions revealed that there were families where daughters had inherited land from their fathers. This is likely to mean that in a few years to come, a project built on the GV concept will have women on the discussion table, participating as landowners, therefore as legal stakeholders at the same level as men. A project premised on the GV concept needs to be prepared to handle the related community issues that may result from this kind of major social change. By and large, there are also more men in formal employment compared to women, a situation that augments their economic power; further tilting gender inequality circumstances in favour of men. There is also a general trend of more men having been exposed to formal Western education, compared to women. Early marriage for girls was given as one of the reasons for general lower formal education levels among women. This scenario would be expected to have a negative bearing on the participation of women in geothermal processes, bringing to fore, the importance of a gender perspective in such activities. Homa Bay County represents an unusual pattern that runs counter to worldwide trends of marriage postponement (Agili, Otieno, Angawa & Magego, May, 2023; World Health Organisation, 2011). Early marriage prevalence rate in Homa Bay County stood at 40.7% in 2014 and 38% in 2015 (KDHS, 2014; Mwololo, 2015). As of 2020, Homa Bay County had the highest proportion of women (76%), of childbearing age (20 – 49 years) who were married when they were below the age of 18 years and had begun motherhood (National Council for Population and Development, 2020). One way in which gender inequality can be said to have manifested itself within the Homa Hills population is in the estimate ratio of 3:7 women versus men membership in HHGCBO. In terms of representation within HHGCBO's governance structure, the number of women either just meets Kenya's two-thirds gender rule requirement or slightly falls short of it[3]. Therefore, although the CBO has made good effort and progress in this regard compared to earlier scenarios, there is room for improvement.

3.2.6 Household and Environmental Vulnerabilities

Household vulnerabilities relevant to geothermal include respiratory tract infections due to exposure to firewood and kerosene smoke – still key sources of household energy and

[3] Article 81(b) of the Constitution provides that not more than two-thirds of the members of elective public bodies shall be of the same gender. This two-thirds gender principle recognizes the historical marginalization of women from political and decision-making processes.

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lighting respectively. Water-borne diseases are an example of water-related vulnerabilities in Homa Bay County. A December 2023 International Federation of the Red Cross report corroborates this statement whereby it gives Homa Bay as one of the eight most affected counties out of Kenya's forty-seven counties, due to the El Niño phenomenon flooding and flash floods that was taking place around that time. Compromised sanitation facilities and clean water sources, that increased the risk of water-borne diseases such as cholera were cited (see https://go.ifrc.org/field-reports/16810). Only 2% of the county population have access to piped water (Homa Bay County, August 2023). Deforestation resulting from the use of firewood as an energy source is an environmental vulnerability characterising the population. All these have links and implications for gender roles, because women are the ones that are most exposed to the firewood and kerosene fumes, take care of those who fall sick from such exposure as well as those vulnerable to water-borne diseases and have to walk longer distances in search of firewood. In the case of Homa Hills, data collected from the field indicated that women are having to walk longer distances – and in most cases, have to go up the surrounding hills to collect firewood as the ones near the homesteads have been depleted. During a September 2021 meeting with the community organised by HHGCBO, women gave estimates of 3 to 5 kilometres as the distances they are having to walk up these hills to access firewood. It means women are spending more time on such tasks, leaving them with less time for other productive activities. Direct Use geothermal, as conceived in the GV concept has the possibility to respond to such needs. Over-fishing is also an environmental issue that is reducing amounts of fish available to this community whose economy is largely dependent on fishing.

3.2.7 Access to Basic Services

The incidences of households with electricity seemed highest among the population in Homa Hills compared to the other three populations, with both hydro and solar panels as sources of electricity. The solar panels, however, provide limited and unreliable power supply. Géo2D's experience was homes that needed to or could only use solar power at night for a very short time possible and for minimal use because the power supply could not sustain beyond a certain amount of time and type of use. All the same only 35% of the county population have access to electricity; up to 75% of the population, particularly those living in rural areas still depend on wood fuel for cooking (Homa Bay County, August 2023). The Homa Hills geothermal sites are located in rural areas.

Concerning access to services such as schools and hospitals there are three hundred and forty-six health facilities s (hospitals, health centres and dispensaries/clinics in the county - even though some may not be well equipped - and numerous educational institutions

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from Early Childhood Development and Education centres all the way to a university (Homa Bay County, August 2023). The sites are within reasonable distance to education institutions, and for example, the site in Kanam B location is literary separated from a nearby primary school by a fence. There is a relatively well-equipped health centre more or less midway between the site in Kanam B and Kokoth Kataa locations. Progressively, geothermal can power such facilities.

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3.3 Stakeholder analysis

GV in Homa Hills covers three different geothermal resources, which are situated across the Karachuonyo Sub-County (in Homa Bay County): the Ayombo hot springs, located in the Kokoth Kataa location, North Karachuonyo ward; the Abundu hot springs, located in Kanam B location, West Karachuonyo ward; and the Bala Kakdhimu hot springs, located in Kanam A location, West Karachuonyo ward. Following the dispersed nature of these sources, the 'GV community' is an extended and potentially large one, counting up to 60,000 people. Moreover, the hot springs are situated at the borders of – and are used by people from – multiple locations, thus diffusing the community of current and potentially future users. The next subsection lists some of the key stakeholders within the Homa Hills community, followed by external stakeholders on the local/ regional and national scales.

3.3.1 Stakeholders within the GV community

Type	Name	Profile	Relation with/ role in GV
Social	Homa Hills Geothermal Community-Based Organization (HHGCBO)	Represents Homa Hills communities in developing GV	Most central stakeholder, since developing GV is its central objective. Has necessary but difficult task to assess and streamline the communities' needs and wishes for GV and to set up GV with few own resources and relatively weak power position vis-à-vis external stakeholders.
	Special interest groups	Women (notably widows), youth, disabled, religious	As also described in the anthropological analysis, these groups tend to be disproportionally affected by poverty, unemployment and lack of access to land and social infrastructure among other problems and challenges. Hence they would have much to gain from GV, and their views and inclusion require special attention.
	Other community-based organizations	There exist multiple other CBOs, e.g. the Homa Hills Community Development Organization	CBOs other than HHGCBO can decide to help in the process of designing/ developing GV, or to mobilize their members to become involved.

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Economic	Business associations for fishermen; cotton; horticulture	Represent members/ workers in these key economic sectors, provide them support, training	Have a major interest and can use GV for powering processing plants, drying crops, irrigation purposes and preserving crops/ fish so to increase market prospects. They have few own resources, but can support GV through labor/ services (e.g. security).
	Savings and Internal Lending Community (SILC)/ 'table banking'	Self-managed, self-financed and low-risk form of microfinance, particularly for and by women in the community	There are multiple SILC groups in Homa Hills, allowing participants to finance small expenses or to set up a small business. Could potentially be used in GV, e.g. for establishing household connection for electricity/ water.

3.3.2 External stakeholders: local/regional

Type	Name	Profile	Relation with/ role in GV
Private sector	Capital Power (CP)	Private energy developer, owns the license to search for geothermal in Homa Hills	The community depends on CP for developing GV as long as CP owns the license. CP has several possible uses in mind, including generating electricity and a spa/conference facility. The license obliges CP to consult/ involve the community and it therefore has an interest in supporting GV.
Public authority	Chiefs, Assistant Chiefs and Assistant County Commissioner	Leaders of (sub-)locations and wards, representing the national government	Are part of/ stand closest to the GV community, hence have a major interest. HHGCBO cannot develop GV without consent/ support of these leaders, hence they are crucial stakeholders. Have very few resources and are at the bottom of the leadership hierarchy, with modest powers to influence decision-making processes.
	County Executive Committee (CEC) member	CECs are County government 'ministers' – the CEC members for water, energy and climate change; for health; and for	CEC's buy-in for GV is important. The CEC for water and energy expressed political will for GV, but financial support cannot be guaranteed. County government might assume a bigger role if external funding for GV is secured,

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		tourism are among the most relevant for GV	e.g. for ancillary infrastructure. HHGCBO could opt for GV to be prioritized in the County government's Community Integrated Development Plans.
	Members of the County Assembly (MCA)	Represent wards in the County Assembly; the MCA's for North and West Karachuonyo wards are most relevant for GV	The MCA's for the mentioned wards support GV and the developments it can bring to their wards. MCA's can put political pressure on/ bring GV to the attention of the County government if needed.
Public agency	Homa Bay County Water and Sanitation Company (HOMAWASCO)	Urban (waste)water utility under the County government	Most of Homa Hills is not part of HOMAWASCO's work area, but until a rural water utility is set up, HOMAWASCO can be consulted if GV is to develop water services. Is interested in buying electricity, should GV generate that.
Non-profit	Development organizations/ NGOs	NGOs that were active in Homa Hills include World Vision, Save the Children, Catholic Relief Services	NGOs could play a supportive role in setting up GV, e.g. through grants or in helping HHGCBO administer the project.

3.3.3 External stakeholders: national

Type	Name	Profile	Relation with/ role in GV
Public authority	National Ministry of Energy and Petroleum	Responsible for energy policymaking and oversight	Declares energy resource areas (incl. for geothermal) and issues licenses for geothermal search and extraction. Hence, an essential stakeholder should GV apply for/procure own licenses.
Public agency	Geothermal Development Company (GDC)	Responsible for geothermal resource assessment and for developing geothermal prospects	GDC and KenGen are mainly concerned with bigger geothermal prospects and large-scale power generation from geothermal resources, but have ample experience, knowledge and equipment needed to assess and exploit geothermal prospects. In that capacity, they might be of value in future developments of GV.
	Kenya Electricity Generating Company (KenGen)	Generates power from steam and other resources	

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3.3.4 Stakeholder perceptions & relations shaping GV

Most of the stakeholders listed above were interviewed. They expressed various challenges and needs in Homa Hills, including the lack of basic infrastructures (water, electricity, roads), social problems (e.g. high rates of (youth) unemployment and poverty, gender-based violence) and environmental and climate change-related issues (e.g. drought and heavy rains/ floods, soil erosion, deforestation). GV could respond to some of these, with water and energy voiced as the most urgent/ desired services. Moreover, GV could support some of the key economic activities in the area, such as the processing and preservation of agricultural or fish products. GV can thus substantially contribute to local development.

One prerequisite is creating a community around GV, which is no easy task; the dispersed nature of the three resources over the Homa Hills area means that HHGCBO has a relatively large number and variety of community actors to consider. At the same time, it is to be expected that only a fraction of the community can benefit from GV services – at least in its early development stages. This is because GV will likely start small and expand in stages. Another potential complication is that resources are situated on or near the borders of administrative locations, which can lead (and has in one case already led) to territorial disputes over access to/ rights to benefit from geothermal resources. It is therefore critically important for the HHGCBO to be clear and explicit about what each GV stage is expected to bring, in whose benefit. In other words, the extent to which and how the potential benefits can be distributed among the different social and economic groups in the community is a pertinent one – one that requires broad consultation, discussion and clear communication across the community, and in close engagement with local leaders (notably chiefs).

Regarding external stakeholders, one of the most important relation is that between the community (represented through HHGCBO) and Capital Power (CP). CP currently owns the license to search for geothermal resources and could apply for an extraction license if studies prove geothermal potential. This means that as long as CP owns the license, the community depends on CP for developing GV. CP is willing to cooperate with HHGCBO to make GV possible, specifically by letting the community use the shallowest geothermal resources (up to 500 meters depth). If this pathway is not pursued for one reason or another, the community could try to gain the licenses themselves though an appropriate entity (e.g. a limited company). This way, they can ensure that the resources remain

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accessible to the entire community, while engaging in a process of building GV for collective ends, and based on its own visions and ideas.

Geothermal developments in part play out at the national level, with national entities possessing special decision-making powers or knowledge/ equipment. For the community it could therefore become important to be represented at this level, to be able to respond to challenges or opportunities that might arise. In general, political buy-in at different levels and in different political arenas is or may turn out to be essential. This ought to occur through political stakeholders that are near to the Homa Hills communities (e.g. MCAs, ACCs), but having direct access to some political players/ platforms at the national scale may serve the community well.

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3.4 How to ensure sustainability for the Geothermal Village? Guidelines for potential business and management models

3.4.1 Economic business model

3.4.1.1 Value proposition

In the Homa Hills community, there may be different Geothermal Village (GV) solutions that take into account the three elements of sustainability. We present them below:

a. The GV's first solution is, for the GV, to be linked to the development of larger-scale geothermal energy plant, perhaps promoted by the holder of the license, the Capital Power Ltd. This would allow the community to significantly save on drilling costs and synergies with Capital Power, which has already demonstrated that it is well disposed towards the GV project.

b. The second solution is for the community to opt for active participation in the project, through a fundraising activity aimed at the population. The fundraising activity, moreover, was barely mentioned in the latest data collection of November 2023, and the population proved to be open to possibilities. How much the community can raise and what to do with these funds as a priority is yet to be determined. But the population could also take over the exploration license, becoming a primary player in the territory. This step would allow the community to have ample margin of operation.

c. The third solution, perhaps more in line with classic development cooperation schemes, is the intervention of a third-party financing body, perhaps international, which can finance the works necessary for the GV. After development and a short period of operation with community support, the third party would leave the management of the GV to the community. The international financing body could be: European Commission, European Investment Bank, World Bank, African Development Bank, national cooperation of an EU or non-EU state (e.g. AICS, US AID, etc.). This solution can also be combined with the previous scenarios, both a) and b).

In all three hypotheses, an active role of the community, and in particular of the Community Based Organization (CBO), in the management of the project is assumed. However, it is recognized that the community could create a company or an ad hoc entity capable of managing the GV, perhaps integrating some specialized local skills if not present on site.

The possible GV Scenarios in Homa Hills are resumed in the following table.

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	Investor	Management	Strength	Weakness
A	Capital Power/Community	Community/CBO	Synergies for sharing of costs with a private investor	Need for a balance of interests with another participant in the area
B	Community	Community/CBO	The community really own the project	Possible risk in not reaching the target of foundraising
C	International actor/Community	International actor/Community/CBO	Synergies between community and the international actor(s)	Need for a high commitment from the community to uptake the project

3.4.1.2 Users ("customer") segmentation: community needs and possible beneficiaries

The primary needs of the population, as highlighted by the actors involved, are mainly:

a. Access to electricity in homes and for small production activities. Access must be stable and at a controlled price

b. Access to drinking water

c. Safe and accessible roads at any time of the year, no matter the seasonal weather

d. Reduction of poverty

e. Lack of employment

f. Health and Access to medicines, especially those to be kept in the fridge

g. Education for youth

h. Women opportunities.

The designed GV for the Homa Hills is expected to contribute to a greater or lesser extent to all the needs, except for point c). However, it is true that the roads leading to the GV should at least be refurbished by the authorities. Therefore, an indirect effect on that point is also expected.

3.4.1.3 Role of partners and actors

The primary actor of the GV in Homa Hills is the community. The community has shown considerable interest in participating, both in the phase of using the GV and in the phase of planning and economic sustainability of the work. By community, we mean all the actors:

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citizens, small entrepreneurs, farmers, fishermen, religious and NGO representatives, etc but especially the the CBO present (called Homa Hills Geothermal Community Based Organization – HHGCBO), which has been very participative in the whole process and has a strong mobilization influnce on the community. Furthermore, the other actors to be involved are:

a. Capital power ltd: currently holder of the license, must certainly and necessarily be involved in the next development steps of the GV;

b. Public authorities: the public authorities have all shown themselves to be interested in the GV. All levels of local government that we met have shown considerable openness towards the GV and have repeatedly stated that they would like to facilitate the project and participate in the design part, although not financially.

c. International investors: Homa Hills has already benefited over the years from interventions by foreign institutional and non-governmental actors, especially for campaigns to combat the spread of HIV. These foreign initiatives demonstrate a precedent that could be repeated for the GV, albeit with different actors. Furthermore, one could think of involving some of these actors in the GV project.

3.4.1.4 Activities and resources: what to do and how with energy

The community, through the GV, can use the electricity and hot water and steam, with a cascade use, for:

- domestic use: lights, cooking, etc

- agriculture: pumping water, both from the lake and wells

- fishing: drying/storing fish

- public services: lights in schools, conservation of medicals in dispensaries

- enlarge job opportunities: lights in local markets, processing cotton, etc.

- possibilities to develop local tourism (i.e., spa) through the steam extracted or the hot water, with the last level of the cascade use.

3.4.1.5 Channels

We believe that the methods adopted to involve the actors in the feasibility study in the first phase of the GV are the most suitable also for the following steps. The population responded very well to the requests for focus group discussions and interviews.

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Furthermore, initial training work has already been carried out. Hence, the methods adopted for involving the population could be replicated in subsequent phases. The involvement of the CBO is fundamental and essential. Word of mouth, through the activity of engagement of the CBO, can represent an easy way to reach all the community.

3.4.1.6 Economic sustainability: cost and revenues

The sustainability of the GV was a theme addressed in the interviews and focus groups. The community expressed its support for contributing to long-term economic sustainability. The community expressed willingness to pay, saying it was open to financing the project with fundraising and paying to use the GV services. Some cooperatives and associations could be involved in fundraising: the fishermen's cooperative, table banking, etc. However, the community also said that a way should be found to facilitate those who are not able to pay directly for the GV's services. One possibility could be to lend labor.
The community is also very scared at the idea that the GV could start and then run aground over time, as evidenced by the story of a trauma experienced due to a project wrecked more than twenty years ago by a Norwegian NGO. This project left an indelible memory in the community. The community traces the failure of this project to the lack of human and financial resources which did not allow the community to continue carrying out that project. In addition to resources, training is fundamental for the economic sustainability of the project.

With regard to the other actors, and taking into account the expected configurations of the GV, to facilitate economic sustainability, the interception of private or public funding is recommended. Geothermal exploration activity is probably the most expensive among the activities foreseen in renewable energy resources and it is unthinkable that drilling is paid for only by the community. The other actors involved did not demonstrate an immediate willingness to participate financially. Even the public authorities, although they have demonstrated a willingness to participate in the GV, do not appear to have resources available in the short term.

3.4.2 Environmental life cycle business model

3.4.2.1 Functional Value

The functional value of the GV in the Homa Hills is certainly to provide the community with clean energy from renewable sources, and clean water. This could improve the community's impact on the environment.

3.4.2.2 Supplies and outsourcing

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As with other types of renewable energy solutions, supplies for GV construction and technologies should come from abroad. As regards skills, however, it is believed that some local realities could contribute (e.g. Sepco).

3.4.2.3 Production and materials

As regards materials (e.g. pipes), some of these could be developed on site. Nevertheless, the preliminary project will take into consideration local skills.

3.4.2.4 Distribution, use phase and end of life

The GV provides for the distribution of electrical and thermal energy and produced locally. Electricity, being produced from renewable sources, does not involve emissions into the atmosphere. Regarding the materials used, it is expected to use all recyclable materials, so as to be able to convert them into reusable material at the end of the useful life of the GV. However, with regard to the hot water used, once its calorific value has been exhausted, it is currently assumed that it will be released into nature, after verifying the polluting parameters required by law. This environmental aspect must be monitored and assessed in the initial environmental examination.

3.4.2.5 Environmental impacts and benefits

The most obvious environmental benefits are the use of energy from renewable and non-fossil sources. Currently, the population uses energy from biomass and fossil sources for domestic activities, especially for cooking. The use of local biomass has led numerous areas to be subject to deforestation and consequent land run-off phenomena. Being able to use clean energy would allow a gradual reforestation of areas currently without trees. The environmental impacts remain to be monitored, which will be the subject of an initial environmental examination to be carried out during the project development phase.

3.4.3 Social stakeholder business model

3.4.3.1 Social Value

Beyond the environment, GV in Homa Hills can significantly improve health and quality of life. In fact, the use of clean energy can prevent diseases resulting from the use of fossil fuels and biomass for cooking and promote clean cooking. Furthermore, the supply of clean water is often the responsibility of women and children, who spend many hours going to get supplies from public fountains or the lake. The water in the lake cannot even be said to be safe. Being able to operate wells through the GV would allow women and children to have more time available to work, study, etc. Finally, the training necessary to manage

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the GV represents an increase in the skills of the entire community, which could also see positive effects on other aspects of their lives.

3.4.3.2 Local communities and employees

The local communities of Homa Hills will be involved from the beginning of the GV, as was also done in this first phase. This direct involvement will allow communities to directly influence the design and make the GV respond to their primary needs (electricity, water, etc.). Furthermore, the spirit of the GV is to involve the communities as much as possible in the maintenance and operation of the work. It cannot therefore be ruled out that part of the employees or in any case of those who will carry out some of the GV's work may be selected from within the community. The community has expressed its willingness to provide workers and it seems that there are hidden professionals, such as geologists, engineers, perhaps retired, or perhaps who work on weekends in the larger cities (Kisumu, Nairobi) and who could return to supply their weekend work in the Homa Hills. Some lending-workers may be involved, however, because they cannot afford to contribute monetary resources to the development of the GV.

3.4.3.3 Governance

One of the objectives of the data collection was to investigate whether the community wanted to be involved in the governance of the GV once the plant began operating. The community said it was willing to participate in governance. Their participation in governance, according to the community, could ensure "security" for the geothermal plant. The meaning of security must be understood, as it was clarified within the focus groups, as belonging of the plant to the community. Belonging would ensure possession, therefore the community «owns the project» and will not allow its decay and ruin, ensuring sustainability over time.

3.4.3.4 Societal Culture and Scale of outreach

For further information regarding societal culture involved, please refer to the dedicated chapters. Here we just highlight that the development of the GV will take into consideration the socio-anthropological characteristics of the Homa Hills community, building on these, without altering them. The project is certainly entirely built from the bottom up, and this is demonstrated by the fact that the GV will be developed based on the needs analysis presented in this report. Furthermore, the project has the ambition to last, and a guarantee of duration is inherent in the strong relationships that it will establish from the early stages with the local community and all the other actors involved. This is also evident from the concerns of the community, which has repeatedly reiterated the need for sustainability and security of the project.

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3.4.3.5 End users, social impacts and benefits

The end-users of the GV are the members of the community itself. The social impacts and benefits of the GV in the Homa Hills communities are represented by the achievement, even partial, of the needs that have been collected. The GV will bring an improvement in the quality of life, an increase in the community's possibilities in both economic and health terms, an increase in skills that can then be spent in the job market, producing cascading benefits. Furthermore, we expect that all these benefits will lead, in a virtuous circle, to increasing the medium-term possibilities of creating new GVs or new development possibilities.

3.5 Local skills and capacity building

In terms of capacity-building, Géo2D carried out a Training Needs Assessment (TNA) in July 2022 after leading the process of preparing the necessary document and circulating it for input from GV partners. In November 2023, two-day capacity-building activities were carried out by members of both Geoscience and Social Science teams. The results of the TNA played a part in informing these activities. On its part, Géo2D carried out capacity-building for HHGCBO around the topic of gender. Using everyday speech and way of speaking within the community, discussions to provoke thought and analysis were carried out. At least sixty participants were in attendance. Géo2D also participated in another two-day exercise that was closely linked to the capacity-building activities. These were reflection sessions under a different source of financial support (United Kingdom's Anglia University), led by UNITO but managed by NORCE that mainly targeted the CBO leadership and a few other community members. The result of this has been a chapter in a book (with contributions and input from the GV institutions that participated in the reflection exercise processes) making some pertinent policy recommendations related to community-based geothermal development in Africa's Rift Valley, with EU as a key target audience of the publication. Géo2D's Social Science arm embedded other capacity-building activities within its work in the field. For example, in doing the TNA, I worked with a total of ten community members as Research Assistants whereby relevant basic training, including on how to handle the questionnaires was first provided to them.

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4. Ethiopia – Era Boru

4.1 General intro: a context analysis of the region and the site(s) involved, including demographic data and energy access

In this section, the study has mainly used information from secondary sources by the UoN team. This is because the team was not able to travel to the field.

Demography: In the Afar geothermal region, the density of the population is relatively sparse because of its hot climatic conditions; 69% of the land area has a population density of less than 50 persons per square kilometer. Only 42.3% of the population are literate, 13.6% lower than the country as a whole. Households in the Afar region have relatively larger size than elsewhere.

Livestock: Cattle, shoats and camel are the major livestock holdings. On average, livestock holding per household in the Afar region is 6.8 cattle, 15 goats, nine sheep, and 2.2 camel, far higher than the national averages (3.6 cattle, 3 goats, 2.3 sheep and 0.3 camels).

Services: The population in the Afar region have relatively low access to major services and facilities. They were particularly and relatively poorer in accessing urban centres, safe drinking water, sanitation facilities, and human and veterinary health/medical services.

Economic Vulnerability: The top five important sources of vulnerability in the region were price/inflation, drought, increasing temperature, scarcity of water, and human disease. The top six vulnerable assets in the region were camels, cattle, and shoats, transport and health services, and food.

Energy Sources: Sources of energy for lighting and cooking is an important welfare indicator. The Afar region is relatively well off in terms of energy sources for lighting with about 90% of the population having access to standard sources of lighting including electric meter, solar, or generator. The pastoralists communities often lack access to regular energy supplies, which hinders the use of electronic equipment.

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4.2 Socio-anthropological aspects and analysis

4.2.1 General Background Information

The Era Boru geothermal site is situated in the Northern part of Afar Regional State in North-Eastern Ethiopia, Teru Woreda, Era Boru *Kebele*[4]. The geothermal population living there is the Afar, with Afar language as their local language and Islam as the predominant religion. There are however sources that refer to Afar language as *Afaraf*, which is of Cushitic origin (see for example Berhe & Adaye, 2007). The Joshua Project affirms this statement by giving statistics of 99.1% of Afar population being Muslim. (see Joshua Project, undated). The local population has no religious connotations related to the geothermal resources. The Afar Regional State has a population of 1,812,002, consisting of 991,000 men and 821,002 women. It is a predominantly rural population comprised of 346,000 urban dwellers and 1,466,000 pastoralists (Federal Democratic Republic of Ethiopia Central Statistical Agency, 2017). While a meeting during a November 2023 fieldwork in Teru town organised by AGAP estimated the population of Era Boru as around 5,200 people, another one held at the site of the geothermal resources gave the total population of the local community around the site as about 500 people[5]. The first meeting also gave 87,000 and 20,000 as population estimates of Teru *Woreda* and Teru town respectively.

Discussions held with members of the Era Boru community in November 2023 in a meeting organised by AGAP suggested that most of the population members around the site are

[4] A *Woreda* in Ethiopia is the equivalent of a District. A new *Woreda* called Boyna under which Era Boru would fall was in the process of being created as at November 2023 (the time of the meeting with the Era Boru community), so Era Boru would now be under this new *Woreda* and no longer under Teru, as Teru had been found to be too big for a *Woreda*. Boyna (variously spelt as Boina) is the Afar word for geothermal resources. A *Kebele* is the smallest administrative unit of Ethiopia, contained within a *Woreda*. It is the equivalent of a Ward. Both *Woreda* and *Kebele* are managed by the local government. Ethiopia's administrative structure has the following hierarchy: Central government, Zone, *Woreda* and *Kebele*.

[5] A plausible interpretation of these figures is that the first one refers to a more expansive geographic area covered by the geothermal manifestations, while the second concentrates on a smaller area around where we held the meeting.

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living below the poverty line and can only manage to have two meals a day. This kind of data is backed by statistics such as those provided by Teka, Woldu & Fre (2019), stating that 46.7% (almost half) of Afar households are poor.

4.2.2 Economic Activities

The main occupation of the local population is pastoralism (rearing mainly camel, goats, cows, donkeys) with a few also engaging in regular trading of livestock, livestock products and other commodities mainly at the nearby market, but also in further places such as Teru (about 40 kilometres), Logiya - variously written as Logya (about 80 kilometres) and Yalo (about 120 kilometres) away. They also sell butter and livestock hide. However, due to reduced livestock count occasioned by climate change effects, they are only able to spare very little butter for commercial purposes, although they would like to be able to make and avail more for selling. Women make handcrafts such as mats and necklaces, but until now, they have not been selling them. Being pastoralists, they mainly rear camels, donkeys, cattle, goats and sheep. They are an Indigenous Peoples (IPs) population. They sell livestock, not for luxury, but to meet their basic needs such as food (cereals mainly). During the dry season, the men are forced by circumstances to sell the livestock at throw away price – as low as half what the price would be during wetter seasons. This scenario should inform part of the business model related to the Era Boru population. Although pastoralists, the Era Boru population is quite sedentary, given that by and large, the geothermal resources on the land they inhabit provides them with water all year round. A part of the community however moves during the drier seasons of the year in search of pasture for their livestock. There are also a few community members (primarily men) that were as of November 2023 employed (mainly as casual labourers, drivers, security guards, etc) by the Chinese company in charge of the big road construction project that was taking place in the area. Some migrate to far off places such as Assaita and Samara (variously written as Semera or Semara) to look for work. All these economic activities – traditional and emerging - also unplug potential for a business model that corresponds to the Era Boru context.

4.2.3 Uses of the Geothermal Resources – Current and Potential

The local community mainly uses the geothermal resources around Era Boru for economic purposes revolving around water provision for household and livestock use as well as spas. Other functions of the resources as observed during fieldwork either in Era Boru or other parts of Afar include using the resources for bathing, washing (clothes and household

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items), washing hair, making tea (as the water from the resources has very high temperatures) and as salt lick. Discussions carried out earlier by Géo2D with a renowned Ethiopian geoscientist in the framework of a different but related research also indicated that farming of certain crops that can do well in the Afar climate and altitude would also be an interesting consideration, by using the water from the geothermal resources for irrigation. Discussions with an AGAP official in November 2023 indicated that the CBO also has the ambition of later supplying electricity to the national grid and even selling power to Djibouti. Electricity production is therefore a potential use of the Era Boru resource. Farming for animal fodder using water generated from geothermal (irrigation for pasture growing) also came up as a potential use of the resources. They grill (barbecue) their meat. They indicated that drying is one of the ways they preserve their food. Food drying is a use that can apply in Direct Use of geothermal resources. In addition, these discussions with the community revealed that the Era Boru community gets monthly food aid from the government, which includes about 15 kg of wheat/person/month. However, there is no grinding mill in Era Boru, and so the nearest place they can do this is in Teru, about 40 kilometres away. This scenario presents one of the potential uses of geothermal within the Era Boru population. These uses (both present and potential) likewise provide insights for a business model relevant to the local population on the Era Boru geothermal site. The local population gave potable water as one of their immediate needs.

4.2.4 Community's Readiness for a Project Based on the GV Concept and Licence Issue

Numerous discussions with the members of the population have exhibited community preparedness for a project on their territory built around the Geothermal Village (GV) concept. This is further proved by the existence of a local geothermal entity through which they intend to participate in geothermal development activities on their land. Members of the community have established AGAP as the structure through which geothermal development matters within Afar should be addressed. Several papers relevant to this issue have also been written (Gardo & Varet, 2018; Onyango & Varet 2018; Gardo & Varet, 2020). Like HHGCBO, AGAP being a young enterprise, requires capacity-building activities to acquire skills for sustainable and inclusive community-based geothermal activities. AGAP is associated to the GV project through a third-party agreement with Géo2D, one of the project partners. The land belongs to the clan (local community); in accordance with Ethiopian land tenure regulations and the local population, has easy access to the resources for their use. Article 40.2 Proclamation No. 1/1995 states that all land belongs to the state and is a common property of the Nations, Nationalities and peoples of Ethiopia and shall not be subject to sale or other means of exchange (Federal Negarit Gazeta, of the Federal

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Republic of Ethiopia, 1995). Ethiopia's land law makes the Era Boru population legally the most secure out of the four GV local populations in terms of land ownership, access and rights. AGAP has a trade licence from the Regional State government and engaged the process of obtaining an exploration lease at federal level for geothermal activities in the region. Present during the meeting in Teru was the Head of Teru *Woreda* who also expressed their readiness to facilitate and coordinate activities with the community as necessary. His office welcomed the idea of a GV concept project as it would contribute to the community's economic development and job creation.

4.2.5 Gender-Based Social Dynamics

Regarding women's marital status, the concept of widowhood does not per-se exist in traditional Afar culture because widowed women are married by either a brother or a cousin of the deceased. This reduces the vulnerability of women that lose their husbands to death. Traditionally, men are the ones with both decision-making and economic power. This is for example seen in the fact that there are very few women in AGAP's membership and even fewer in its governance structure. A male official of AGAP observed in a meeting had with two of them in July 2021 that there is need to encourage gender diversity in the composition of AGAP's membership to prevent it from being an extremely male-dominated endeavour. Women have less inheritance rights compared to men, and do not own assets. Berhane-Selassie (1997) confirms this in part in his assertion that Afar women cannot inherit land. Progress related to gender equality and women empowerment in Afar has been particularly slow (UNICEF, April 2022).

Exposure of the local population to formal Western education is generally low with even less girls' than boys' enrolment. Population Reference Bureau (2017) authenticates this in stating that the school enrolment rates in Afar are among the lowest in Ethiopia. The Regional State's Net Enrolment Ratio (NER) for pre-primary education in Afar was the second lowest in the country at 5.8%; with Afar's NER for primary schools, Grades 9 and 10 as well as Grades 11 and 12 (secondary school) at 46%, 6% and 2% respectively as the lowest in the country. The Gender Parity Index (GPI) for Afar primary schools is 0.87 meaning more boys are enrolled (UNICEF, April 2022). Cultural attitude regarding the place of women and girls in the society, Female Genital Mutilation/Cutting (FGM/C) and early marriage are some of the reasons that account for general lower formal education levels among women and girls compared to men. As at 2016, FGM/C and child marriage stood at 91.2% and 67% respectively in Afar (ibid). All these statistics are most likely higher in Era Boru as until very recently, before the road reached this area, it has been a very remote and difficult to access area; cut off from the rest of even the Afar regional state.

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4.2.6 Household and Environmental Vulnerabilities

Firewood is the main source of household energy, with deforestation as an associated environmental vulnerability. The women and girls are having to walk further for firewood (on average one hour), as the nearby ones are depleted and because culturally it is forbidden to fetch firewood from trees before they get to a certain level of maturity, as was revealed in a November 2023 meeting by members of Era Boru community.

Potable water is also a vulnerability for some of the community members, because since a major earthquake in the area in 2005, water from some of the geothermal manifestations is no longer potable (contaminated by fumaroles bearing sulphur[3]). It makes both livestock and human beings sick. Some of the community members were equally having to walk up to one hour or more to access water; as evidenced by a woman who came to fetch water in a geothermal resource near where we held a meeting with some members of the community, who said she had come from about an hour's walk to fetch the water. Indeed, we were informed during the discussions of November 2023 Teru meeting that only about 10% of the population in Teru *Woreda* have access to potable water. A related vulnerability is also drought affecting the vegetation. The November 2023 community meeting revealed that in 2008, the community suffered one of the worst droughts in recent times, whereby many people and livestock died due to famine. After that, there have also been other droughts, although the 2008 remains the severest of those experienced in recent times. Their livestock count has however remained comparatively low as they have never managed to get back to the levels of livestock they had before this 2008 drought. This narration speaks to the scenario of climate change effects that Direct Use geothermal – thus the GV concept - can very well respond to. All these aspects also have implications for gender roles, as women, still being the ones in charge of providing firewood, water as well as taking care of the sick would have to spend more time on the tasks, compromising the time they could spend on other productive roles.

4.2.7 Access to Basic Services

Concerning access to services such as education and health facilities, the nearest school is in Teru, the closest town, which is about 40 kilometres away (roughly 1.5 to 2 hours in a four-wheel drive car), while the nearest hospital is at Zone level 72 kilometres away. *Woreda* has access to electricity. The national electric grid has not yet reached Era Boru.

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4.3 Stakeholder analysis

The prospected GV site in Era Boru is situated some 4,5 – 5 hours' (4x4) drive from Semera, the capital of the Afar regional state, and 1,5 – 2 hours from Teru, the main town of the Woreda (district) of Teru. Era Boru is (or has) no town with a concentration of households like Teru – rather, the Afar live here in families/ clans, dispersed over a larger area. The Era Boru clans comprise some 5200 people. The GV site is a stretch of flat (valley-like) land surrounded by low hills with geothermal resources found at shallow depth. The Afar population uses steam to condense water in traditional so-called *Boyna*. The road leading up to Era Boru is not tarred and accessible only by 4x4, although a Chinese company is currently building a tarred road that will pass through Era Boru, making it far better accessible. This might change the dynamics in the area, but so far, the Afar community in/near Era Boru live a relatively secluded, semi-nomadic, pastoralist life with hardly any access to public services provided by the regional or national governments. The next subsection sketches a picture of the community as well as of the external stakeholders in the region and nationally.

4.3.1 Stakeholders within the GV community

Type	Name	Profile	Relation with/ role in GV
Social	Afar Geothermal Alternative Power (AGAP) / Afar Geothermal Development	Community-based social enterprise – set up, driven by and representing the Afar people in developing a GV in Era Boru. Has some 200 members	Most central stakeholder, with developing GV as one of its central objectives. Apart from a limited fund raised by its members, AGAP has few own resources/ is highly dependent on external actors. There are some members of the regional parliament involved in AGAP and they can help raise the matter at regional political level.

4.3.2 External stakeholders: local/regional

Type	Name	Profile	Relation with/ role in GV
Non-profit	Afar Pastoralist Development Association (APDA)	Set up in the 1990s as a humanitarian organization providing all types of services (e.g. health, education, income generation) to	Highly important stakeholder and the one closest to the Afar people in Era Boru (APDA's director also has a major role in AGAP). Has access to resources (incl.

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		the Afar people across the Afar region – often in mobile form, adapted to the nomadic lifestyle. 850 people work for APDA, in different roles.	links with many funders) and is very well-established/ deeply embedded in Afar society across the region. Given its rationale of self-development by and for the Afar people, coupled with its decades-long experience, it is best positioned to help AGAP and GV develop.
	Development organizations/ NGOs	Many (national and international) NGOs have established a (temporary) field office in Semara and/or elsewhere in the Afar region, not least triggered by the Tigray war	Now the Tigray war has come to an end, NGOs may leave the Afar region again. Those that stay, might be consulted to assess whether there are options to provide support/ resources for setting up GV.
Public authority / agency	Woreda (district) and Kebele (ward) leadership	Era Boru used to be part of the Teru Woreda, but was in the process of being transferred to another Woreda called Boyna	In administrative terms, the Kebele and Woreda leaders stand closest to the Era Boru community; need to be kept informed and provide consent with any GV developments taking place. Have few resources and modest power to influence
	Mines Resource Development and Job Creation Bureau, Afar National Regional State	Responsible for extraction of natural resources/ minerals	Issues licenses for so-called 'Grade II' geothermal resources, for direct-use purposes – which GV must obtain in the next development stage
	Water & Energy Bureau, Afar National Regional State	Responsible for energy and water policy and development for the Afar region	The Bureau's objective is to raise access to electricity (and water), notably through renewable energy sources in rural areas like Era Boru. GV fits this objective, and it is therefore supported by the Bureau, but it has few resources (other than political leverage) to help develop GV
	Samara University, School of Geoscience	Does research on mineral/ natural resource extraction in Afar, funded in part by the Mines Resource Development Bureau of the Afar Regional State	Geoscientists aim to put their knowledge to the service of Afar communities. Are willing to collaborate on GV, if needed/ desired

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4.3.3 External stakeholders: national

Type	Name	Profile	Relation with/ role in GV
Public authority	Federal/ National Ministry of Water and Energy	Responsible for national energy and water policymaking and oversight	The ministry is in the process of developing a strategy and master plan on geothermal development in the country; depending on how GV fits with this strategy/ plan, opportunities might open up for GV support
	Petroleum and Energy Authority (PEA)	State agency that regulates the energy sector	Issues licenses for various stages of geothermal development, including for generating electricity; if GV is to do this and sell electricity to the grid, it needs a license from PEA
Public agency	Addis Ababa University (AAU), School of Earth Sciences	Involved in geothermal energy research and partner in GV	Besides supporting the research required for GV, researchers at the AAU have connections in relevant national entities, such as ministries
Non-profit	Development agencies	There are a couple of development agencies that specifically deal with geothermal development in Ethiopia, e.g. JICA	JICA supports the federal government in geothermal development plans and strategies. The World Bank more generally supports the energy sector development in Ethiopia, including geothermal-related ones.

4.3.4 Stakeholder perceptions & relations shaping GV

The Afar people have adapted to the climatic (i.e. arid and hot) conditions of the Era Boru area, which have always been challenging to a greater or lesser degree. Yet, climate change intensifies these conditions and coupled with a lack of social services provided by the regional or national government, make living conditions evermore challenging, especially during Summer. Despite the innovative (traditional) use of geothermal steam for meeting their and their livestock's water needs, water can become scarce during the hottest months, forcing people to move long distances in search of alternative water sources. Water was therefore indicated as the primary need that GV can respond to. Electricity, secondly, can enable the community to create something like a small market. Here, primary goods and even cattle can be traded, and it enables placing a cell phone

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mast for network connection that is currently lacking and which hampers communication. The road that is being built increases accessibility and prospects for such a small market.

AGAP and APDA are the two local actors who are key in driving GV. APDA has a long history of providing different kinds of development support in the whole of the Afar region and is trusted with and by the Afar people. Many Afar people work (either paid or voluntarily) for APDA. Its management is also closely involved in AGAP and has many connections with national and international actors. Their resources for developing GV are limited though, and they thus depend on other, external stakeholders. Resources of the Kebele and Woreda administrations, and even of the Afar regional State, are also limited and it is agencies at the national or international level that have to chip in if GV is to be realized. A recent event illustrates the possibility of international agencies chipping in; a hot spring not too far from Semara will soon be developed into a spa using funds from the Agence Française de Développement (French development agency AFD). A similar arrangement can be used for setting up GV in Era Boru.

When it comes to administrative processes like licensing, it seems that relatively small-scale geothermal projects aimed at direct use applications, like GV, do not need to go to the federal level anymore, but can deal with the Afar Regional State agencies. Yet, most geothermal knowledge, equipment and development frameworks/plans are available or made at the national scale. The various existing stakeholder relations between AGAP/ APDA and regional and national agencies should therefore be maintained and expanded.

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4.4 How to ensure sustainability for the Geothermal Village? Guidelines for potential business and management models

4.4.1 Economic business model

4.4.1.1 Value proposition

In the Era Boru community, they are two feasible and possible schemes for the Geothermal Village (GV), taking into account the three elements of sustainability. We present them below:

The first solution, perhaps more in line with classic development cooperation schemes and with the current situation in Era Boru, is based on the intervention of a third-party financing body, perhaps international, which can finance the works necessary for the GV. The international financing body could be: European Commission, European Investment Bank, World Bank, African Development Bank, national cooperation of an EU or non-EU state (e.g. AICS, US AID, etc.). We can imagine the contribution in fundraising of APDA.

The GV's second solution is, for the GV, to be linked to the development of larger-scale geothermal energy plant, even not strictly close to the Era Boru area, perhaps promoted by a national provider, such as Ethiopia Electric Power. This would allow the community to benefit from the savings on drilling costs done by EEP. The Corbetti Geothermal Power Station is far from Era Boru, but together with other public statements and plans, gives evidence of the Ethiopian interest in geothermal energy development. In this case, a support from an NGO or another entity is suggested, such as APDA.

In the two hypotheses, an active role of the community in the management of the project is assumed and wished. After development and a short period of operation, in which the community can be included and trained, the third party (in option a) would leave the management of the GV to the community, although we recommend a constant presence and supervision of experts. In fact, the community is less developed and less skilled compared to the Homa Hills' one and, also to the Bugarama's one. Therefore, external experts, maybe provided by international or national actors, are essential. In both the previous hypotheses, the presence of Afar Geothermal Alternative Power (AGAP) Company is fundamental considering their role and networking in all the Afar Region, together with the Afar Pastorialism Development Association (APDA).

The possible GV Scenarios in Era Boru are resumed in the following table.

	Investor	Management	Strength	Weakness
A	International actor	International actor/AGAP/Community /APDA	Freedom from national actor for the	Difficulties in finding the funds from a donor

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			community and AGAP	
B	Electric company	AGAP/Community/APDA	Synergies for sharing of costs with electric company partnership	Difficulties in taking on board national actors

4.4.1.2 Users ("customer") segmentation: community needs and possible beneficiaries

The primary needs of the population, as highlighted by the actors involved, are mainly:

- Access to clean water
- Access to electricity
- Access to health
- Roads
- School
- Reduction of poverty through jobs creation

The designed GV for Era Boru is expected to contribute to the needs, even if depending on the type of scenario and also on the dimension of the plant. For sure, GV can't provide roads or school, but it can provide electricity that may improve health situation (ensuring the possibility to store drugs) and also improve the skills of the community, once trained.

4.4.1.3 Role of partners and actors

The pivotal actor of the GV in Era Boru, in both the scenarios, will be probably the attributed to APDA and AGAP. APDA is very well established in the Afar region and counted, at one point in time, also 800 employees. This NGO has been found by Ismail Ali Gardo, a well-recognized leader in the community. It's impossible to imagine an NGO without the involvement of Mr. Gardo, who is also a promoter of AGAP. APDA can serve as fundraiser, considering its international network of Afar diaspora.

Besides APDA and AGAP, the Afar National Regional State Government (in particular the Water & Energy Bureau) and the Teru Wareda (local government) too. We also believe that the contribution from the Samara University, the School of Geoscience, can partially answer to the need of experts to be included in the training activities for the local community.

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Finally, the AFAR region has benefited in the last decades of the intervention of foreign institutional and non-governmental actors, especially during the civil war and the draught. Those actors can facilitate fundraising, if properly mobilized.

4.4.1.4 Activities and resources: what to do and how with energy

The Era Boru community is already using the steam to extract water, through a condensation process. People and animal are drinking the water probably since centuries. The remaining steam is use as a bath for local people and it should remain like this. Nevertheless, the GV, through with a cascade use, can provide both the electricity and the clean water (if connected to wells). The electricity can answer to the needs for:

- Domestic house
- Wells
- Schools
- Storage
- Develop local activities
- Develop local tourism.

4.4.1.5 Channels

We believe that the involvement of APDA as a key driver to involve the actors in the feasibility study in the first phase of the GV is the most suitable also for the following steps. Mr. Gardo has a recognized leadership in the area, and APDA, through its wide network, can work as a glue to attract community members and other stakeholders. There are not fears but any change in life can be a trauma for people that have developed an ability to live in peace where the any other human being can't stand. Word of mouth, through the activity of engagement of community leader and local representative of APDA, can represent an easy way to reach all the community.

4.4.1.6 Economic sustainability: cost and revenues

While conducting a focus group, the research team had the possibility to understand the living condition of the people in Era Boru. The community members are not used to consumerism, basically because they can't afford. Apart from cows, camels, goats, the just buy few clothes and sandals, which will last until they will break and even more. This premise to say that the sustainability of the GV in Era Boru can't be based on the

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contribution by the users, at least at the beginning and in the short period. Maybe, in the medium period, an enhancement of local wealth can provide monetary resources, but by now, any fundraising activity inside the community it not possible. Therefore, it is fundamental, and in all the scenarios presented, that the GV will anticipate future costs in the phase of production: less maintenance, no pay-per-use, are just two of the challenges which the GV in Era Boru must face.

Hence, to facilitate economic sustainability, in Era Boru more than for other sites, the interception of private or public funding is crucial, both for the drilling phase and for the management of the GV. The public authorities, although they have demonstrated openness to the GV, do not appear to have any resources in the short term to contribute.

4.4.2 Environmental life cycle business model

4.4.2.1 Functional Value

The functional value of the GV in Era Boru is certainly to provide the community with clean energy from renewable sources, clean water for domestic house and for animal farming. Considering the weather condition, clean water can avoid people to have long trip to feed animals.

4.4.2.2 Supplies and outsourcing

All the supplies for GV construction and technologies should come from abroad the Afar region. Some minor skills can be formed with the collaboration of Semera University.

4.4.2.3 Production and materials

Materials (e.g. pipes, cement) have to be developed in Semera (6-7 hours by car). The worksite can be established close to the site, but everything is needed, including water. The good news is that a Chinese company is building a tarmac road that will pass some kilometers close to the Era Boru site.

4.4.2.4 Distribution, use phase and end of life

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Considering that there is not grid connection, and neither a small grid, all the electricity will be consumed in the Era Boru area, and the same will be for the clean water. Regarding the GV plant, it will be designed to be moved in case of end of production of the wells.

4.4.2.5 Environmental impacts and benefits

The most obvious environmental benefits are the use of energy (both electric and thermal) from renewable and non-fossil sources. Currently, the population uses energy from few biomasses (little firewood) they catch around the villages, especially for cooking. The community have declared that, considering the almost desert area where they live, catch green bushes is prohibited. People are allowed to take just dry woods. Being able to use clean energy (even with a common kitchen) would allow a gradual recovery of grass areas.

The environmental impacts of the GV construction remain to be monitored, which will be the subject of an initial environmental examination to be carried out during the project development phase.

4.4.3 Social stakeholder business model

4.4.3.1 Social Value

The most important value of GV in Era Boru is the social value, considering that GV can improve health and quality of life condition of Afar people. In fact, the use of clean energy can prevent diseases resulting from the use of biomass for cooking and promote clean cooking. The clean cooking can also improve the ingredients the community can use, improving a very poor diet. In fact, even if the GV can work a common fridge, people will be allowed to store milk and other vegetables they can buy in Teru. Moreover, the supply of clean water is often the responsibility of women and children, who spend many hours going to get supplies from the boyna (the name of the family-well based on the condensation of steam). Being able to operate wells through the GV would allow women and children to have more time available to do other daily business, including study and improving living condition, etc. Finally, the training necessary to manage the GV represents an increase in the skills of the entire community, which could also see positive effects on other aspects of their lives.

4.4.3.2 Local communities and employees

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The local communities of Era Boru and the neighbourhood areas will be involved from the beginning of the GV, as was also done in this first phase. This direct involvement will allow communities to directly influence the design and make the GV respond to their primary needs (electricity, water, etc.). Furthermore, the spirit of the GV is to involve the communities as much as possible in the maintenance and operation of the work. Hopefully, part of the employees or in any case of those who will carry out part of the work of the GV will be able to be selected within the community. The community has expressed its willingness to provide workers and it seems that there are hidden professionals, such as plumbers and constructors, etc. Some lending-workers may be involved, however, because most of the community cannot afford to contribute monetary resources to the development of the GV. Regarding more skilled employees, we believe that synergies between AGAP and APDA can push the GV forward.

4.4.3.3 Governance

One of the objectives of the data collection was to investigate whether the community wanted to be involved in the governance of the GV once the plant began operating. The community said it was willing to participate in governance, although with a different degree in respect to the Homa Hills community and the Bugarama communities, that for sure are more skilled. We can rely on AGAP and APDA for the governance. This will ensure sustainability to the project.

4.4.3.4 Societal Culture and Scale of outreach

For further information regarding societal culture involved, please refer to the dedicated chapters. Here we just highlight that the development of the GV will take into consideration the socio-anthropological characteristics of the Afar people, that are semi-nomadic and unique in the world considering their history in living in one of the hottest place in the world. The project is certainly entirely built from the bottom up, and this is demonstrated by the fact that the GV will be developed based on the needs analysis presented in this report. Furthermore, the project has the ambition to last, and a guarantee of duration is inherent in the strong relationships that it will establish from the early stages with the local community and all the other actors involved. Finally, considering the very fragile balance between the Era Boru community and their boynas, any GV project have to take care about the possibile consequences on their long-lasting habits.

4.4.3.5 End users, Social impacts and benefits

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The end-users of the GV are the members of the community itself. The social impacts and benefits of the GV in the Era Boru community are represented by the achievement, even partial, of the needs that have been collected. The GV will bring an improvement in the quality of life, an increase in the community's possibilities in both economic and health terms, an increase in skills that can then be spent in the job market, producing cascading benefits. Furthermore, we expect that all these benefits will lead, in a virtuous circle, to increasing the medium-term possibilities of creating new GVs or new development possibilities.

4.5 Local skills and capacity building (AGAP)

AGAP was also supposed to be considered for some capacity-building activities as was done for HHGCBO. However, the plans could not be sustained because of the prolonged political instability in the country (the war between the Tigray and the central government) that made it impossible to do fieldwork there for a good part of the project's term. Given the geographical context of Afar that is different from that of HHGCBO and where transport and communication can be a big challenge, an ideal situation would have been to ride on an event that would bring AGAP's members together such as an Annual General Meeting (AGM), but COVID and a prolonged political instability, disrupted such events. In relation to gender however, several discussions were held with members of the Secretariat to purposefully encourage the inclusion of more women in the CBO and in its leadership structure. As part of enhancing AGAP's financial management skills, EU reporting guidelines (and more specifically LEAP-RE) were also well discussed with members of AGAP's Secretariat in November 2021 during Géo2D's field mission to introduce the GV project to Ethiopia's stakeholders.

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5. Djibouti – Lac Abbé

5.1 General intro: a context analysis of the region and the site(s) involved, including demographic data and energy access

The Lake Abhé Geothermal Field is located in the South-Western region of the Republic of Djibouti, on the border with Ethiopia. The Lake Abhe geothermal system occurs within a rift basin filled with Pliocene-Quaternary volcanic (mainly basalt) and lacustrine sediments.

Socio-economic dimensions of geothermal development: The socio-economic analysis is based on surveys conducted in Lake Abhé area, which is the second most geothermal potential of the country, at the end of May 2022. Located in the southwest of the country, the Lake named Abhe is shared between Djibouti and Ethiopia.

Gender of Respondents*:* A gender parity of 51-49 percent was achieved during the survey with skewed outcomes in Lake Abhé where most the residents had migrated due to closure of schools during the long holidays.

Level of Education: The survey showed that most of the respondents (80%) did not have formal education with only 13% having attained primary education.

Age Distribution of Respondents: Most respondents were above 50 years (28%) old, followed by 48-52 years (19%).

Marital Status: About 92% of the respondents were married, while the rest were mainly widowed (7%).

Dependents in the Household: Most households have 6-7 dependents.

Household Size: Most households are 8-11 in size.

Occupation of Respondents: Most of the respondents (62%) are not engaged in any economic activity. About 14% are employed while 7% are self-employed.

Average Monthly Incomes: On average, the money incomes are below 6500 DJF, households in Lake Abbe and Kouta Bouyya have higher incomes than As Eyla.

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Household Economic Vulnerability: About 60% of the respondents reported that they lacked food to eat just a few times or never. About 57% of the respondents reported that they lacked enough water for home just a few times or never, while 36% indicated that they lacked water always. About 54% of the respondents reported that they lacked medicines or medical treatment just a few times or never, and 34% indicated that they lacked medicines or medical treatment always. About 60% of the respondents reported that they lacked enough cooking fuel for home just a few times or never, while 33% indicated that they lacked fuel many times. About 61% of the respondents reported that they lacked cash income just a few times or never, while 16% indicated that they lacked cash income always. About 73% of the respondents reported that they lacked school expenses just a few times or never, while 14% indicated that they lacked school expenses always.

Livestock Ownership and Livelihoods: Livestock activities predominantly affect livelihoods to a very large extent in Lake Abbe (100%) and Kouta Bouyya (86%). About 27% of the households own cattle while the rest do not. Most of the cattle ownership is around Koutta Bouyya sub-region. About 27% of the households own sheep while the rest do not. Most of the sheep ownership is around Koutta Bouyya sub-region. About 8% of the households own livestock while the rest do not. Most of the camel ownership is around As Eyla sub-region.

Household Access to Services: Most of the services are accessible in As Eyla, followed by Kouta Bouyya while Lake Abbe has the least access. Households generally can access water from dug well (73%), followed by piped water into a well (52%), and public standpipe (42%). Distance to regular water sources is longest for households in Lake Abbe (4km), followed by Koutta Bouyya (8km) and As Eyla (0.8km). Distance to health facilities is longest for households in Lake Abbe (20km), followed by Koutta Bouyya (8.8km) and As Eyla (1km).

Access to Energy Resources for Cooking and Lighting: Households generally use biomass resources for lighting (39%), followed by solar (25%) and Kerosene (7%). A good percentage also uses sport lights (30%). Households generally use biomass resources for cooking (89%), followed by LPG (11%). Good percentage LPG users are from As Eyla (24%).

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Use of Geothermal Resources: The geothermal resources are mainly accessible to households in Lake Abbe (75%). Both As Eyla and Kouta Bouyya sub-region households don't have access to the geothermal resources.

Social and Economic Transformations: The rural communities found close to geothermal resources have specific cultural and livelihoods approaches, such as nomadic pastoralism. The remoteness of these locations implies that socio-economic transformations are likely to be long-term.

Environmental Factors*:* Households generally use biomass resources for cooking (90%) and lighting, putting severe pressure on the few vegetation existing.

5.2 Socio-anthropological aspects and analysis

5.2.1 General Background Information

The Lake Abbe (often referred to and written as Lac Abhé in French[6]) geothermal site and named after the nearby lake is positioned to the West of Djibouti republic near the country's border with Ethiopia, in Dikhil regions of South-West of Djibouti the country.The geothermal population living there is also the Afar, with Afar language as their local language (or *Afaraf*, similar to the Ethiopian context as already stated) and Islam as the principal religion. The Djibouti Afar have been exposed to Islam since the 800s (more than 1,200 years ago). 99.7% of the population confess Islam as their faith (AFRIGO, undated); resulting in the population attaching no religious or spiritual connation to the geothermal manifestations as Islam only allows belief in Allah and in the teachings of the Quran, as per an October 2021 discussion with two male community members. There is some mention of the astounding characteristics of the Lake Abbe site in an ensuing paragraph in this section. Of Djibouti's 1,147,857 estimated population, about 342,000 (one-third) are Afar (see for example AFRIGO, undated; https://en.wikipedia.org/wiki/Afar_people). Dikhil region's population estimate (surface area about 7,200km2) is 111,457 habitants (République de Djibouti, 2021). Feld data from community discussions by ODDEG and Géo2D in October 2021 field visit done by ODDEG and Géo2D with the aim of introducing

[6] Meaning rotten in Afar language (due to the smell). Although an Afar term, the word has a French alphabet letter (é) because that is the way the word was written in French toponymy.

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the project and holding some preliminary discussions with key stakeholders including the local community gave the population estimate around the site as roughly 200 inhabitants[7]. By and large, the population lives dispersed on the nearby surrounding hills and not really by the lakeside, with settlements linked to water points.

The creation of a school in 2021 and the existence of the tourist camp favours the formation of a real village here, which also gives good prospects for a project based on the GV concept. The school is contributing to sedentarisation of the population, as part of the community remains behind to take care of the school children when the rest of the community moves during drought season in search of water and pasture for their livestock. It is also resulting in an increase in population around the site, as observed by the community in 2021, a pattern that was expected to be continuous. For the GV concept, this is a positive trend because a project on site would end up serving more households.

Data from the field data indicates that most of the population members around the Lake Abbe site are living below the poverty line. Dikhil region's unemployment rate is at 39%. 52.9% of the population lives in extreme poverty (Republic of Djibouti, June 2018). They

[7] This figure varies considerably from the 3,000 to 4,000 people figure (mentioned under the Stakeholders' Analysis section) given during a February 2023 discussion in a community meeting with part of GVI's Social Science team (UNITO, SSSA and Géo2D) and some ODDEG staff members near the Lake Abbe site. Several issues persuade us to consider the February 2023 figures as closer to the actual figures (even though probably given on the higher side) than the October 2021 figures. This includes the mere observation of a village stretched out over a nearby hill. The discrepancy may also be linked to the interpretation given to the term "around the site" in terms of geographic space coverage by the October 2021 respondent. This aspect of interpretation ties to an issue raised elsewhere in this document posing the question: Where does a 'GV community' begin and end? In addition, although this meeting was intentionally timed and done towards the end of October (about two months into the greener season), to give time for the return of the population from where they had migrated to during the dry season, not all of them had returned by then; thus a possibility that the answer was given with the estimated figures of the population that was around during the dry season, rather than the figure of the larger population size in mind.

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face strained access to basic social necessities. This aspect will be addressed later in this segment.

5.2.2 Economic Activities

According to the October 2021 discussions with community members, being pastoralists, the main occupation of the local population is herding, with camels, cattle, goats and sheep as the main animals reared. Like their counterpart Ethiopian Afar, they are an Indigenous Peoples (IPs) population. A few members are employed in the nearby tourists' camp facility and in the school. The women also make handcrafts (weaving mats, leather objects, jewellery eg beaded necklaces, etc.), which they sell to the tourists who come to the geothermal site or stay at the nearby tourists' camp. They also make butter which they sell at Dikhil or KoutaBouya (written variously as Kouta Bouya, Kouta Bouyya or Koûta Boûyya). They also make leather rugs or wineskins from the animal hide. However, in recent times, they have been throwing away the livestock hide because they do not have the varieties of trees needed to tan the animal hide (skins) nearby. It would be interesting to for example know if geothermal can be used to tan the animal hide or if the variety of tree required for this purpose can be grown nearby through irrigation from geothermal water. Being a pastoral population, they do not grow vegetables, but some community members have in the past tried growing watermelons without much success – a situation they attribute to high temperatures and soil salinity. This demonstrated desire within the population for some level of agricultural activities should be explored further in the context of a GV project. The women buy all their commodities such as fruits, vegetable and fish from the market. The discussions revealed willingness of the community members to be engaged in greenhouse and/or fish-farming initiatives in the context of a GV project. There are ways in which the economic activities mentioned herein can be aligned to a GV concept project on the ground. They therefore provide a foundation on which a business model for the Lake Abbe site can be based. The report prepared jointly by ODDEG and Géo2D after the October 2021 fieldwork based on discussions with members of the community and what we observed suggested that a GV project could potentially revolve around: the creation of a thermal centre for tourism (spa), a drinking water borehole for the village, school and thermal centre and camp; a hot water borehole for the thermal centre and direct local uses such as bathing, washing and possibly greenhouse and fish-farming downstream as well as deeper geothermal drilling for electricity production by ORC from a medium temperature fluid (120 to 140°C). Ideally, the business model for the Lake Abbe population could consider a combination of the local community's current uses of the geothermal resources discussed in an earlier paragraph, the economic activities discussed herein, identified specific socio-economic needs related to the community's pastoral

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economy and existing gaps in relation to use of derived products such as food (meat, milk, etc), animal hide, handcrafts, etc.

5.2.3 Uses of the Geothermal Resources – Current and Potential

The main uses of the geothermal manifestations by the local community revolve around economic (to especially serve their pasture, livestock and domestic needs), culinary (including cooking), touristic/education (as numerous tourists and researchers have also been to the site) and hygienic needs (including bathing and washing of clothes). Under the economic needs is also the use of the resources such as salt lick (to enhance livestock health) and for deworming of livestock. The community uses geothermal water to irrigate land on which they grow pasture and a plant that the livestock like to graze on. Regarding tourism, the site has notable potential for touristic activities. Besides being in a remarkably pristine state, some of its characteristics include the spectacular and picturesque geothermal manifestations (smoking chimneys, chimneys 'forest" and hot springs) - no doubt a sight to behold. This site has attracted both researchers and tourists (see for example Deville et al., 2023). Indeed, a proposal that was under consideration within the circles of government stakeholders such as ODDEG[8] and Ministry of Tourism in Djibouti during the February 2023 field visit was to follow through the process of getting Lake Abbe area listed as a UNESCO heritage site. This was the result of a proposal first made by Jacques Varet during Géo2D's October 2021 field visit to Djibouti. This proposal by J. Varet was made in light of the huge potential of the site for tourism, and the need to protect it owing to the fragile nature of the environment and ecosystem around it. Meetings ODDEG and Géo2D held with the Préfecture and the President of Dikhil Regional Council in October 2021 indicated that the latter two were supportive of the idea of a policy to promote tourism in the region. Under a GV concept, the idea would be to find ways of incorporating the local population as key stakeholders in such an arrangement alongside other relevant actors (stakeholders) on the ground. The uses and potentials of the site provides opportunities for a business model of the Lake Abbe site.

The February 2023 community meeting indicated that the community had reservations around research being done on the site, citing reasons such as marginalisation and

[8] In full: *L'Office Djiboutien de Développement de l'Energie Géothermique*, which in English translates to The Geothermal Energy Development Office of Djibouti.

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numerous previous research whereby they had spent their time answering researchers' questions, but until the time of the meeting, had nothing to show on the ground as resulting from the research activities. The community was, however, acceptable to research being conducted and them being part of such studies if there were clear indications that the research would directly benefit them. Discussions with community members in October 2021 had also exhibited acceptance of a project that could address their priority needs relevant to geothermal development. These responses from the community members need to be considered as an indication of research-related community fatigue, that should not be overlooked in future activities on the site. It underlines the relevance of the GV approach in geothermal development matters. A future project built around the GV concept should, working closely with ODDEG (who have also expressed interest in a project with this approach), and the local community, be designed to address these issues that were raised by the community.

5.2.4 Community's Readiness for a Project Based on the GV Concept and Licence Issue

There is no established local geothermal entity existing within the Lake Abbe population, but through the remarks of an older male during the February 2023 community meeting – the local population indicated a preference for handling community-based geothermal development matters through their traditional governance structure rather than a registered legal entity. The various discussions from the October 2021 field stay with community members and State Representatives revealed the hierarchy of this governance structure as being Sultan (at the helm and leading the different *Okal)*, Okal (Regional Chiefs leading the different *Makaban*) and *Makaban* (Clan leader – the equivalent of Village Chief) who also deals with inter-clan issues; and that in the event of a GV project, the Prefect and the Regional Council as central and decentralised government representatives would have to be informed and they would be the ones to direct Géo2D and ODDEG to the relevant *Okal* or *Makaban*. From the GV concept perspective, the idea would definitely be to involve the local population (through its representatives) in such processes from as early as possible, including at the point of being directed to the concerned *Okal* or *Makaban*.

The traditional governance structure suggested during the February 2023 meeting as the vehicle through which a GV project would be carried out heavily leans towards being gerontocrantic. The Afar people administer themselves through their traditional

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administrative systems of unwritten rules of procedure known as *Madaa*[9] and *Adaa*[10], which handle all economic, social and political issues at the local level, including water rationing during mild and average drought, general economic utilization, management and protection of resources (such as water and grazing land). All these have a direct relation to Direct Use of geothermal resources as articulated in the GV concept. Below the *Makaban* is the *Kedo Haboti* (clan elders); then the *Kedo Aba* (sub-clan chiefs) and *Bura Haba* (household head). Although most of those elected as elders are aged men, a respected, young man of integrity may also be elected. *Woger Habaa* (Committees) may also be assigned decision-making roles when appropriate. Women are excluded from giving any such services (Talachew & Habtewold, 2008).

Therefore, although Afar traditional culture has dynamism and norms to manage natural resources, including geothermal, similar assertions having been made by other authors (see for example Kebebew, Tsegaye and Synnevåg, November 2001); it seems to omit the voice of women in decision-making processes. Culture-sensitive mechanisms for involving women and to some extend younger men (because they at least play a part in discussions, even if marginally as observed during the February 2023 community meeting) will be explored in the event of a GV-concept project, to bring on board the voices of all segments of the population.

Additionally, it would be essential to include some individuals with necessary exposure to formal Western education in the governance of the local structure that would take charge of managing a project under the GV concept among the Lake Abbe population, even if it

[9] The *Madaa* (Afar's traditional legal system) is considered as a base for other administrative systems and therefore their constitution; consequently, the highest decision-making body of all the clans. For example, wildlife is protected by the Act of the *Madaa*. This traditional system is still widely used among the Afar even in solving disputes/conflict. About 90-95% of the Afar people use traditional system to resolve cases that arises between them (Talachew and Habtewold, 2008).

[10] *Adaa* (a system within Afar's pastoral and agro-pastoral production system that has been in use since time immemorial but does not have any structure) is a cultural mechanism that applies rules and regulations within Afar culture in accordance with *Madaa* rules and regulations for example in resource management, conflict management and external relations.

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would be based on the community's traditional governance systems. Integrating the relevant government representatives (the office of the Préfecture and Dikhil Regional Council) in the governance structure to facilitate required government administrative processes would also be worth considering. These aspects would be discussed in more detail with the local community in the event of such a project. The October 2021 interactions with the community revealed the existence of a collective local arrangement whereby the men of the village come together to make the trenches near the shores of the lake as part of a system of irrigation management. Therefore, there already exists a traditional structure and a collective practice related to natural resources management which a GV concept project can tap into.

All land in Djibouti, including the ones with natural resources belong to the state (IGAD, undated). The licence of land with geothermal resources in Djibouti is issued to ODDEG (Djibouti's public entity supporting geothermal energy development in the country, that is housed under the Presidency or Office of the President and that is a partner in this LEAP-RE GV project). The local population has until presently (May 2024 the time of writing this section) easy access to the resources for their various uses without any problem.

5.2.5 Gender-Based Social Dynamics

Given that the culture and lifestyle of the local population on the Lake Abbe site is very similar to the one of Northern Ethiopia Afar, it is understood that the concept of widowhood does not per-se exist in traditional Afar culture because widowed women are remarried by a close male relative of the deceased, thus reducing the vulnerability levels of women whose husbands die.[11] Traditionally, older men are the ones with both decision-making

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[11] Tadesse & Yonas Adaye (2007) confirm the cultural proximity of the Afar living at the boarders in Ethiopia, Djibouti and even Eritrea (at times also referred to as the "Afar Triangle" even in social terms – see for example Nicol & Otulana, 2014)[11] when they state that though the Afar are divided by the borders of the three countries, they maintain close physical contact, strong sentiments of kinship, and an inclusive Afar identity. A November 2023 discussion with members of the Era Boru community for example also revealed that there is cross-border movement of the Afar between Eritrea, Ethiopia and Djibouti including as markets for their products.

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and economic power within this population. The February 2023 discussions suggested that being male and from the older generation was a key factor for leadership and participation in decisions within the community. The status of women is lower than that of men and is variously evidenced.[12] A project on site needs to be alive to such issues to come up with appropriate ways of promoting inclusivity.

Exposure of the local population to formal Western education is generally low. While Knoema (2002) gives Dikhil's adult illiteracy rate as 64%, Republic of Djibouti (June 2018) indicates that literacy levels in the region for people aged 15 and over stands at 26%. A nearby newly established school located within the vicinity of the site (that as at October 2021 had pupils only up to lower primary school) is likely to progressively change this situation. There were fifteen girls and thirty-three boys of the age bracket of six to ten years enrolled in the school; with the majority being between seven and eight years as at October 2021; an indication of the gender imbalance in this regard which in turn is most likely to translate to fewer women participating in geothermal processes.

5.2.6 Household and Environmental Vulnerabilities

Potable water is a key vulnerability for the community members around Lake Abbe, as the water from the Lake is yellow and has a very salty taste. Like the October 2021 discussions held with some community members, participants of the February 2023 community meeting, gave potable water as their principal need, saying the lake water causes them to faint, have stomach aches and even diarrhoea. They also gave each of the three of us GV's LEAP-RE Social Sciences researchers (UNITO, SSSA and Géo2D) a bottle containing this yellow water challenging the team to go and show it to the rest of the world, as a demonstration of their poor living conditions.

Throughout the lake area, grazing land is communal. The dispersion of families does not depend on land or pasture but is linked to the lack of water (rare water points with low flow rates). Coupled with the already existing presence of a newly established school, a project that provides water such as one based on the GV concept would most likely

[12] For example, by the presence of just one woman who nonetheless never spoke) in the February 2023 community meeting, thanks to her being in charge of the cooking in the tourists' camp next to where the meeting was held. Géo2D had however already used other methods while in Lake Abbe in October 2021 to get the perspectives of women included in its GV project data collection process.

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therefore reduce the dispersion of families and facilitate easier sharing of project's resources within a certain radius. Although not one of its objectives, a project based on the GV concept would, just like the school, most likely encourage sedantarisation of the local population; as it would increase access to both potable water and pasture for livestock that cause the population to migrate during the dry season.

Women and girls must walk about one hour away to access potable water. Boys also take part in this role. The negative health effects of drinking the lake water adds pressure to women's and girls' time as culturally, they are the ones charged with care-giving within their households. Electricity also features highly during the October 2021 discussions with some members of the community, saying without electricity, they could not even charge their phones; hampering their communication possibilities. They had however indicated that electricity was also an important need because without electricity, they could not even charge their phones; a situation that greatly hampered their communication possibilities. The priority of an initial GV concept project should therefore revolve around potable water provision. Depending on circumstances, it could also involve immediate related activities such as irrigation for pasture; perspectives which still provide possibilities for a business model related to the site. A project built around the GV concept would also imply a need for enhanced communication. Electricity provision should therefore also be a priority, even if not the immediate one. It would also serve the school and potentially, the medical facility that was built in the vicinity of the site several years ago but has never been used.

Reducing levels of the lake was also mentioned as an observed environmental change during discussions with members of the community in October 2021. Djibouti is considered highly vulnerable to climate change and is experiencing adverse impacts from increased temperatures, changing rainfall distribution, increased aridity, reduced precipitation, changes in sea levels and extreme weather events resulting in droughts and flash floods (United National Environment Programme, January 2024; World Bank Group, 2021). Diversification to the use of renewable energy sources such as geothermal are encouraged to reduce these kinds of climate effects (Moussa & Bruel, 2010). Interestingly, from the perspective of the community, the lowering lake levels has increased pasture land , contributing to the area being a migration zone, as more Afar population members come to the area to use the land freed up by the drop in the levels of the lake as pastoral land. Whereas for boys and men this would most likely translate to less time spent in search of pasture, it may mean more time spent in search of water for the livestock as the lake water is not potable. It would most likely also mean an increase in the livestock population as they have more pasture readily available to feed on; which would in turn lead to more

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demand for potable water for livestock. For the women and girls, it means more people from this segment of the population spending time in search of potable water corresponding to the increase of population. This whole scenario strengthens the case for a GV concept project as it would serve a bigger population and address more needs. It also has implications for a business model of the site.

5.2.7 Access to Basic Services

Regarding access to services such as schools and hospitals there is a newly established primary school just about five minutes' walk away from the lake. Very close to the school, there is also an empty room, built around 2017 by the government, which was meant to be a medical facility, but which has never operated as such because it is yet to be staffed and equipped. The nearest place the local community therefore accesses medical services is in KoutaBouya, at least thirty-five minutes away by car, where there is a dispensary. They carry such patients on their back. The electric grid is 60km away from Lake Abbe. Access to telephone network is at least one hour's walk away on top of a hill. In October 2021, we had to drive for about 25 minutes from the tourists' camp to take someone who needed to make a call from the top of the hill where he could access telephone communication network. Apart from potable water, whereas discussions from the October 2021 community interactions highlighted telecommunication access as another priority, the February 2023 discussions gave medical facilities as a pressing concern. A GV concept project can play a part in responding to all these demands. For telephone network, the appropriate approach would probably be for ODDEG and the community to work closely with relevant government Ministries to extend telephone network access to the area and for the GV project to incorporate a component for electricity provision that would facilitate charging of phones. The electricity could also serve the medical facility, therefore provide some reason to get it up and running. A sedentarised and increased population around the site that a GV concept would most likely contribute to could additionally be good reason to have an operational medical facility.

Firewood is the main source of household energy, with deforestation as an associated environmental vulnerability. During the October 2021 and February 2023 Lake Abbe field visits, one could hardly sight any trees or shrubs within the proximity/environs of the site that could be cut for firewood. A discussion during a meeting with members of KoutaBouya community indicated that they go to the mountains to pick dried wood for firewood and that their practices are very similar to those of the population at Lake Abbe. It so implies that the Lake Abbe population also goes to the mountains to get dried firewood for

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household use. It means that deforestation is spreading even further, in an environment that is by nature already desertic. A GV concept project could attend to the lighting and cooking needs requirements in this context, so that the need to use firewood for energy diminishes. This aspect also lays the grounds for a business model targeting the site.

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5.3 Stakeholder analysis

Notwithstanding the country's small size, the Afar community at Lac Abhé is situated in a remote part of Djibouti that is not easily or quickly accessible. It is the community furthest removed from the regional capital Dikhil on the RN6 non-tarred road to Lac Abhé; and the further one moves from Dikhil, the less social infrastructure or facilities there are – or so we observed during our fieldwork trip in February 2023. It is thus also relatively distant from 'external' stakeholders that are relevant to GV, although this is indeed relative; considering Djibouti's small size and population, combined with a centralized governance system, even the most remote communities are still firmly linked to actors/ subject to decision-making processes at national and regional scales. With some 1000 people, the Lac Abhé community is relatively small and compact – although the size changes during the seasons because of nomadic lifestyles. What follows is a simple composition of actors within the community, and external stakeholders of relevance to GV.

5.3.1 Stakeholders within the GV community

Type	Name	Profile	Relation with/ role in GV
Social	*Makaban/* traditional leadership	Village chief under the *Madaa* and *Adaa* Afar traditional administrative systems (see earlier section on socio-anthropological data)	In the absence of a Community-Based organization for GV, the village's leadership headed by the chief is an important actor group within the community for matters related to GV. Of all social infrastructure that is missing, the community is especially in need of potable water. Other services, such as a health facility, cellphone network and electricity are also very much desired. The community (leadership) thus has a high stake in GV, but it has grown suspicious of external development pledges that do not materialize (see also below). The community has abundant knowledge on the lands/ environments they inhabit, which should be used; yet they rely on external resources to help develop GV.

5.3.2 External stakeholders: local/ regional

Type	Name	Profile	Relation with/ role in GV
Private sector	Campement Touristique Lac Abhé	The only tourist camp next to Lac Abhé and its community is owned by a resident from Djibouti city, and employs a small	Lac Abhé and this tourist camp is often included in travel itineraries of tourists (and their guides) and hence, makes up an important source of income for (some in) the community. Basic services such as

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		number of people from the community. Solar panels offer some electricity.	water and (more) electricity means an upgrade of the camp's facilities, which in turn allows for further development of the camp.
Public authority	Prefecture de Dikhil and Sous-Prefecture d'As Eyla	The leader and one of the sub-leaders of/ within the Dikhil regional administration	Tourism and geothermal development in Lac Abhé feature highly in the Prefecture's regional development program, next to the provision of social services like water. GV has support of, but still needs formal permission from, this administration if it is to develop further. The Prefecture's resources to help develop GV are very limited, as is its power position to forge decision-making on a higher (national) scale.

5.3.3 External stakeholders: national

Type	Name	Profile	Relation with/ role in GV
Public authority/ agency	Djiboutian Office for Geothermal Energy Development (ODDEG)	Public agency for geothermal exploration, investigation and early-stage development	ODDEG is formal partner in GV; the GV project in Lac Abhé is one of 24 geothermal sites in Djibouti that ODDEG seeks to develop, and the only one to be developed in cooperation with partners in LEAP-RE. Considering its mandate to lead all geothermal development trajectories in the country, ODDEG is the single most important national stakeholder in/for GV. Its own resources to develop geothermal sites such as GV are limited, and it is therefore highly dependent on external funding. ODDEG falls directly under the President's office in the government system and thus has a considerable power position.
	National Ministries	Ministries of particular concern to GV are the one for Energy and Natural Resources; for Infrastructure and Equipment; for	The mentioned ministries are responsible for policymaking and development of energy resources (incl. geothermal), upgrading of roads, the extension of telephone/ ICT network connections across the country and tourism – all aspects

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		Communication; for trade and tourism	that were considered important in developing GV.
	Electricité de Djibouti (EDD)	Public electricity utility, falls under the ministry of Energy and Natural Resources	EDD has a monopoly in transmission and distribution of electricity and as such, ought to be consulted/involved if GV is to generate electricity from geothermal. As monopolist, and given its size as State-Owned Enterprise, it is among the most powerful entities in the energy sector and has had access to major amounts of resources, not least borrowed money.
	The Djiboutian Social Development Agency (ADDS)	Public entity responsible for poverty reduction in line with national development objectives	Has a rural electrification program running, mostly based on solar – yet given the small-scale and remote/ rural nature of the GV site at Lac Abhé, this program within ADDS might be as - or even more - appropriate to engage with than (the much bigger) EDD, should GV generate power from geothermal.
	Directorate of Hydrology in the Ministry of Agriculture, Water, Fisheries and Livestock	Responsible for water and sanitation services in rural and suburban areas	Works with/ its water (infrastructure) investments are funded by different development agencies, notably UNICEF. The directorate provides training to community members in self-managing a water point, once constructed. If GV is to supply water at some stage, the directorate and a partner/ UNICEF might be a suitable candidate for providing support. The directorate already asked the government to finance a reverse osmosis plant to desalinize Lac Abhé water; yet it is unlikely to be realized (soon). Is willing to cooperate and provide all necessary information (if required), but has far less access to resources than its urban equivalent (ONEAD) is.
	National Tourism office of Djibouti, Ministry of Tourism	Public agency responsible for marketing Djibouti as tourism destination and for driving tourism development	The office had/ has plans to upgrade the tourist camp at Lac Abhé (i.e. improve and expand current facilities) and the development of a thermal/ wellness centre using geothermal water. This plan is so far evolving slowly or has

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			even paused, due to a lack of resources, among other factors. The office is eager to become involved in GV, should it be developed.
	Centre de Etudes et de Recherche de Djibouti (CERD)	Public scientific and technological research institute	Has been involved in geothermal energy development programs in Djibouti and thus has experts who / possesses knowledge and data on geothermal that can be mobilized in a next stage of GV.

5.3.4 Stakeholder perceptions & relations shaping GV

As mentioned, there is a lack and low level of services available to the Lac Abhé community. In our Focus Group Discussion with members of this community, we were told that government and development agencies have made promises in the past to deliver social infrastructure, but few of these have materialized. As a result, community members said they have grown weary of more such pledges, including the prospect of GV. Surely, they welcome such an initiative that could cater for some of their most desired needs, notably potable water, but have very low expectations as to whether they will ever be realized. Seriously engaging the community would therefore start simple, by (some) GV researchers/ participants making another visit showing them what has been done and discussing what are possible next steps – giving a signal that even though actual developments are uncertain and depending on various factors (not least funding), GV intentions are serious. Such interaction needs to be regularized and intensified once GV is developed further.

There is a complex history behind the relations between the Afar and national authorities/agencies in Djibouti, but these relations are nonetheless of importance if GV is to be developed. Given that many developments, including geothermal and rural water and electricity, fall under the mandate of national state agencies, the two need to engage closely and regularly. A community-based entity – similar to the CBOs in Ethiopia and Kenya – might be helpful in this regard and also more generally, in the broader GV project if that is to enter a next development (demonstration) stage. Surely, the regional authorities (the (sub-)prefecture) need to be involved in this process, as their consent is essential for developments like GV. At the same time, not much support should be expected from the (sub-)prefecture as their budgets and resources are very limited; they stress the need for the Lac Abhé community to be self-reliant, to be able to self-manage a prospective GV plant – or alternatively be supported by external entities. Such self-management of

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infrastructure is not new; there are examples of other services that are quite successfully managed by the community in the region, such as a water system in Kouta Bouyya, not far from Lac Abhé. This requires training of community members in the functioning and maintenance of the plant and more important still, their close involvement in designing it according to their needs, capacities, context and wishes.

Finally, it is imperative to carefully consider the socio-environmental impact of any advanced development at Lac Abhé – a seemingly trivial, but fundamental point we were reminded of by a tourist guide we met at Lac Abhé. Any advanced development infrastructure, not least for tourists, will likely change the dynamics in the area, with potential positive and negative aspects. Those aspects, that come down to weighing the needs of the community with potentially undesired impacts on the environment, will have to be discussed at length with the community, making sure they not just understand, but guide any development steps that will be taken. This means for instance considering the community's extensive knowledge and use of the geothermal resources as equally relevant to the design and implementation of GV as 'modern' scientific assessments and activities – and hence, attempt to integrate indigenous and scientific knowledge.

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5.4 How to ensure sustainability for the Geothermal Village? Guidelines for potential business and management models

5.4.1 Economic business model

5.4.1.1 Value proposition

The GV possibilities in the Lac Abhé community are quite similar to the one possible for the Era Boru community. Considering the three elements of sustainability, there are two possible schemes. We present them below:

a) The first solution, for the GV, to be linked to the development of larger-scale geothermal energy plant, perhaps promoted by a national provider, under the supervision of the ODDEG agency. This would allow the community to benefit from the savings on drilling costs done. In fact, ODDEG is already investigating the area of Lac Assal, where the first explorative well has been drilled. In this solution, is highly recommend developing GV not just as a minor spillover of the larger plant, but as a part of a unique project, in order to carry forward the double interest together, without any prejudice for the ones of the community.

b) The GV's second solution is perhaps more in line with classic development cooperation schemes and with the current situation in Lac Abhé, is based on the intervention of a third-party financing body, perhaps international, which can finance the works necessary for the GV. The international financing body could be: European Commission, European Investment Bank, World Bank, African Development Bank, national cooperation of an EU or non-EU state (e.g. AICS, US AID, etc.).

In the two hypotheses, an active role of the community in the management of the project is assumed and wished. After development and a short period of operation, in which the community can be included and trained, the third party (in option b) would leave the management of the GV to the community, although we recommend a constant presence and supervision of experts. In fact, the community is less developed and less skilled compared to the Homa Hills' one and, also to the Bugarama's one. Therefore, external experts, maybe provided by international or national actors, are essential. In both the previous hypotheses, we highlight that the presence of a Community Based Organization, an NGO or association that can represent the community of Afar (as AGAP in Era Boru) would be fundamental. Nevertheless, the community seemed not to be convinced about this opportunity, especially if comes from the national government. In fact, Afar people are quite reluctant to initiatives coming from Djibouti City.

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The possible GV Scenarios in Lac Abhé are resumed in the following table.

	Investor	Management	Strength	Weakness
A	Electric company	International NGO/Community /CBO	Synergies for sharing of costs with electric company partnership	Possible unbalance between national and local interest considering the lack of a representation of community's interests
B	International actor/donor	International donor/Communit y/CBO	International expertise and know-how	Difficulties in finding the funds from a donor and need for a local leading actor

5.4.1.2 Users ("customer") segmentation: community needs and possible beneficiaries

The primary needs of the population, as highlighted by the actors involved, are mainly:

- Access to clean water
- Access to electricity
- Access to health
- Roads and phone connection
- Reduction of poverty through jobs creation

The designed GV for Lac Abhé is expected to contribute to the aforementioned needs, even if depending on the type of scenario and also on the dimension of the plant. GV can't plenty of jobs, but it can provide electricity that may improve health and wealth situation (ensuring the possibility to store drugs) and also improve the skills of the community, once trained.

5.4.1.3 Role of partners and actors

The pivotal actor of the GV in Lac Abhé, in both the scenarios, will be probably the CBO/NGO/association, if its foundation will success. Otherwise, it will be the Makaban (Village chief) that can take the lead from the community-side. As anticipated, from the four communities visited in Kenya, Ethiopia, Rwanda and Djibouti, the one in Lac Abhé was the more reluctant in participating in the project. The community complained about unsuccessful previous contacts and broken promises. This may be related also to the fact that the national government is formed mostly by another ethnic group and this fact didn't facilitate the interaction when the research team was there (see socio-anthropological part). There is a serious risk that this situation may cause a weak commitment in

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collaborating. The local community of As-Eyla, although quite far (approximately 30km from Lac Abhé), has demonstrated interest in the GV project.
The other main actor for the GV in Lac Abhé is ODDEG, which is directly connected to the President of the Republic of Djibouti. ODDEG has the license to to research exploration in Djibouti and is the only actor that can access to the geothermal field, apart from the community.
Besides the Lac Abhé community, ODDEG and As-Eyla, we met the Dikhil prefecture and the sous-prefect from As-Eyla that seemed to be positive about GV. We also believe that the contribution from the national agencies and institutions as Ministry of Hydrology, the Minsty of Energy and National Resources, the ministry of Tourism, the CERD, and the ADDS can bring to the project an added value. Finally, the Campement Touristique Lac Abhé should be evaluated as private partner, considering is the only place with electricity (PV-standalone) in the area. Hence, it should benefit from the GV and also contribute to it.

5.4.1.4 Activities and resources: what to do and how with energy

The Lac Abhé community is already using the geothermal hot water, through a system of canals which low the temperature water, to irrigate desert areas and make the grass to grow. Animal farming is hence facilitated from decades.
Apart from such direct use, the must not be changed by the new project, the GV, through a cascade use, can provide both the electricity and the clean water (if connected to wells). The electricity can answer to the needs for:

- Domestic house and public spaces (i.e., common kitchen)
- Wells
- School
- Water and food storage
- Develop local activities connected to farming
- Develop local tourism.

5.4.1.5 Channels

We believe that the involvement of the Makaban, if the CBO will not be established, is fundamental to mobilize the community and for the GV to really be accepted and welcomed. As exposed in details in the chapter on socio-anthropological dynamics and on the stakeholders, there difficulties in engaging with the local community, often linked to enthic and political previous troubles. Nevertheless, throughout the word of mouth, and considering the lack of mobile phone connection, we believe that we can rich the majority

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of the community. For instance, the people involved in the focus group discussion were already present with a little notice in the hour after dawn.

5.4.1.6 Economic sustainability: cost and revenues

While conducting a focus group discussion and interviews, the research team had the possibility to understand the living condition of the people Lac Abhé. This living condition are very similar to the one's experienced in Era Boru. The community members are not used to consumerism, basically because they can't afford. Apart from trading farming animals (camels and goats), the just buy traditional clothes and sandals. This premise, as per the Era Boru site, means that the the sustainability of the GV in Lac Abhé can't stand on the monetary contribution by the users, at least at the beginning and in the short period. Maybe, in the medium period, an enhancement of local wealth can provide monetary resources, but until by, any fundraising activity inside the community it not possible. Therefore, it is fundamental, and in all the scenarios presented, that the GV will anticipate future costs in the phase of production: less maintenance, no pay-per-use, are just two of the challenges which the GV in Lac Abhé has to face.
Therefore, to facilitate economic sustainability, the interception of private or public funding in Lac Abhé is crucial, both for the drilling phase and for the management of the GV. The public authorities, apart from ODDEG in the geothermal exploration (although minority), have demonstrated openness to the GV, but they do not appear to have any resources in the short term.

5.4.2 Environmental life cycle business model

5.4.2.1 Functional Value

The functional value of the GV in Lac Abhé is certainly to provide the community with clean energy from renewable sources, and clean water for domestic house and for animal farming. Considering the weather condition (Lac Abhé is in the middle of the desert), clean water can avoid people to have long trip to feed animals and also to have diseases.

5.4.2.2 Supplies and outsourcing

All the supplies for GV construction and technologies should come from abroad the Region. Some minor skills can be formed with the collaboration of the CERD, the ADDS, and the touristic camp.

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5.4.2.3 Production and materials

Materials (e.g. pipes, cement) have to be developed in Djibouti (7-8 hours by car). The worksite can be established close to the site, but everything is needed, including water. The road to the site is basically almost inexistent.

5.4.2.4 Distribution, use phase and end of life

Considering that there is not grid connection, and neither a small grid, all the electricity will be consumed in the Lac Abhé area, maybe involving the As-Eyla community. The same will be for the clean water. Regarding the GV plant, it will be designed to be moved in case of end of production of the wells.

5.4.2.5 Environmental impacts and benefits

The most obvious environmental benefits are the use of energy (both electric and thermal) from renewable and non-fossil source. Currently, the population uses energy from few biomasses (little firewoods) they catch around the villages, especially for cooking. Being able to use clean energy (even with a common kitchen) would allow a gradual recovery of grass areas.

The environmental impacts of the GV construction remain to be monitored, which will be the subject of an initial environmental examination to be carried out during the project development phase.

5.4.3 Social stakeholder business model

5.4.3.1 Social Value

As per Era Boru, the most important value of GV in Lac Abhé is probably the social value, considering that GV can improve health and quality of life condition of Afar people. GV can bring clean water and clean cooking. The community, during the focus group, complained a lot about the quality of water they drink, that is coming directly from the lake, and is dirty and salty. Then, the use of clean energy can prevent diseases resulting from the use of biomass for cooking and promote clean cooking. The clean cooking can also improve the ingredients the community can use, improving a very poor diet. In fact, even if the GV can work a common fridge, people will be allowed to store milk and other vegetables they import from Djibouti City. Moreover, the supply of clean water is often the responsibility of

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women and children, who spend many hours going to get supplies from the hot spring. Being able to operate wells through the GV would allow women and children to have more time available to do other daily business, including study and improving living condition, etc. Finally, the training necessary to manage the GV represents an increase in the skills of the entire community, which could also see positive effects on other aspects of their lives.

5.4.3.2 Local communities and employees

Starting from the premise stated before on the possible difficulties in engaging and involving the community on the GV project, the aim of GV is to involve the local communities of Lac Abhé as much as possible, from the beginning of the project and in its future. This direct involvement would allow communities to directly influence the design and make the GV respond to their primary needs (electricity, water, etc.). Furthermore, the spirit of the GV is to involve the communities as much as possible in the maintenance and operation of the work. Hopefully, part of the employees or in any case of those who will carry out part of the work of the GV will be able to be selected within the community. We believe that most of the contributors will be lending-workers, because the majority of the community cannot afford to contribute monetary resources to the development of the GV.

5.4.3.3 Governance

One of the objectives of the data collection was to investigate whether the community wanted to be involved in the governance of the GV once the plant began operating. Unfortunately, we can state that the community expressed their availability to be involved in the governance. This is a high risk for the GV, because it may affect the economic sustainability to the project.

5.4.3.4 Societal Culture and Scale of outreach

For further information regarding societal culture involved, please refer to the dedicated chapters. Here we just highlight that the development of the GV will take into consideration the socio-anthropological characteristics of the Afar people, that are semi-nomadic and unique in the world considering their history in living in one of the hottest place in the world. The project is certainly entirely built from the bottom up, and this is demonstrated by the fact that the GV will be developed on the basis of the needs analysis presented in this report. Furthermore, the project has the ambition to last, and a guarantee of duration is inherent in the strong relationships that it will establish from the early stages with the

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local community and all the other actors involved. Finally, considering the very fragile balance between the Lac Abhé community and the use of hot water to irrigate desert areas, any GV project has to take care about the possibile consequences on their long-lasting habits.

5.4.3.5 End users, Social impacts and benefits

The end-users of the GV are the members of the community itself. The social impacts and benefits of the GV in the Lac Abhé community are represented by the achievement, even partial, of the needs that have been collected. The GV will bring an improvement in the quality of life, an increase in the community's possibilities in both economic and health terms, an increase in skills that can then be spent in the job market, producing cascading benefits. Furthermore, we expect that all these benefits will lead, in a virtuous circle, to increasing the medium-term possibilities of creating new GVs or new development possibilities.

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6. Rwanda – Bugarama

6.1 General intro: a context analysis of the region and the site(s) involved, including demographic data and energy access

The Bugarama geothermal prospect is located in the southern province of Rwanda. The geothermal manifestations in this area are hot and warm springs and travertine deposits, which is being mined as feedstock for a nearby cement factory. Bugarama site is located in Nyakabuye Sector, Rusizi District, Western Province of Rwanda. Data in Bugarama was collected through a site visit in June 2022. For more information on the location, see figure 4 and 5. Overall, about 50% of household respondents were females and 50% were males.

The Bugarama region is the warmest in Rwanda and also the site of the country's first cement and rice production. The Bugarama area has a tropical climate that is characterized by an average temperature of 24°C and a dry season from June to September. Total annual rainfall is about 1,050 mm. There are two rainy seasons: a short-wet season from October to November and the main rainy season from mid-March to end May.

The area around the geothermal site is has a rich and varied species composition including cultivated mixed crops widely distributed in the study area and some relic and several ruderal species. Several vulnerable and indigenous plant species of the area are gradually disappearing due to severe land use pressure and over-use by local people. Flora observed during site visits includes but is not limited to: Banana, Cassava, Coffee, Sorghum, Rice (Big space), Bamboo, Grevelia, Eucalyptus, Avocados, Flowers, some papaya, Ordinary beans, Climbing beans, Peas, Soybeans, Irish potatoes, sweet potatoes, Taro, and Yam. Natural forest in the area consists of the Cyamudongo forest, which is a continuation of the Nyungwe Forest. This is located about 20 km from Bugarama Hot Spring Lake. Rice production dominates the Bugarama marshland and mixed agricultural characterizes the rest of land.

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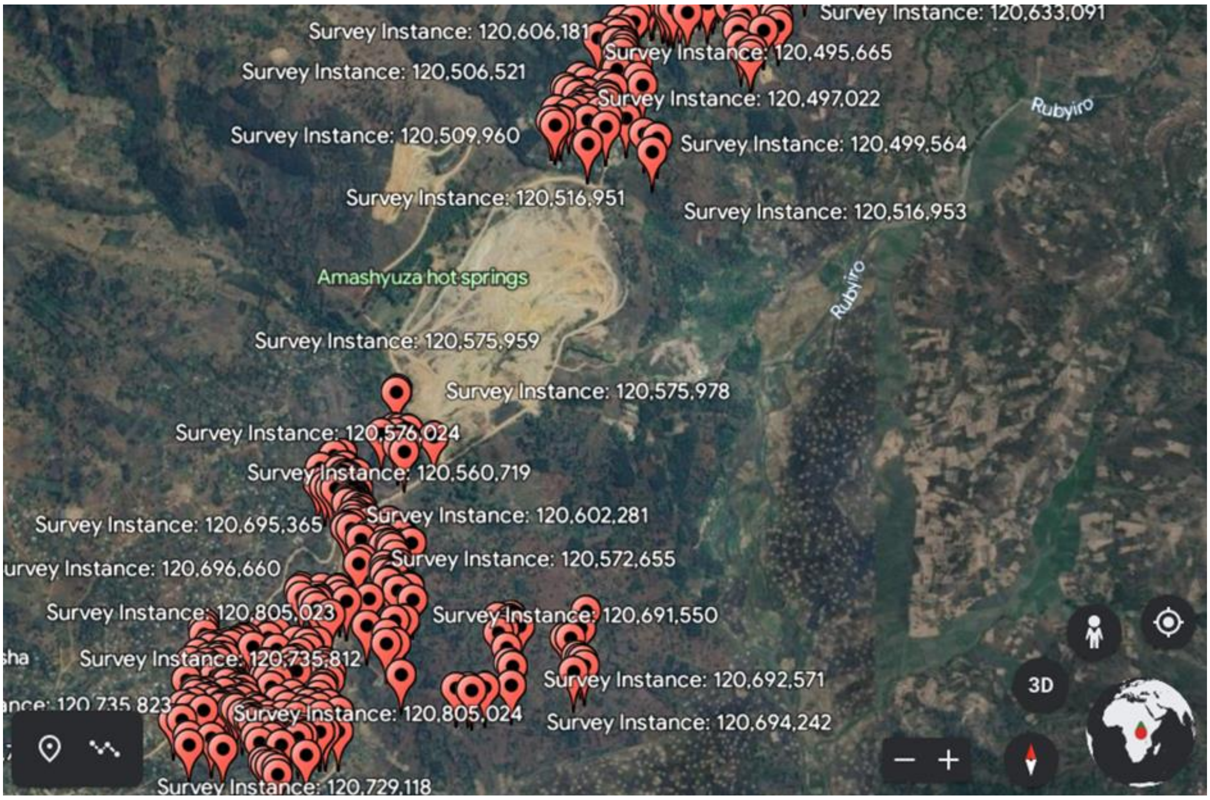

Figure 4. Data collection in Bugarama around the Amashyuza hot spring.

Figure 5. Data collection in Bugarama, satellite overview.

Overall, the Bugarama area ecosystem is linked closely with human settlements and human activities. The area has rivers whose sources are hot springs or water springs that

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run all the year. When the site was surveyed, water from the rivers was almost all being diverted to agricultural irrigation canals, and downstream from the canal dam the river was dry. However, as the downstream still maintains nature, once the water flow comes back a recovery of the river ecosystem can be expected.

CIMERWA has installed a water treatment plant in the village of Nkangabashi that draws water from the Njambwe River. The water is treated and then supplied to the cement plant and nearby community. The water treatment plant treats 2,500 m3 of water per day out of which 1,200 m3/ day are supplied to the Plant. CIMERWA supplies the balance of the water to six villages (Kabarore, Ramiro, Rubeho, Nyenyeri, Murabyo and Busasamana) and to a primary school. This meets the requirement of around 6,000 local villagers through Company-owned pipelines. Rivers from surrounding hills supply water to the Bugarama wetland, which is used for rice production. Downstream water from the hot springs is used by APC Mashyuza and COCOCHAUMA, two small factories producing lime in Bugarama. Water from natural sources is the primary source for all domestic activities.

Population

The national census of 2012 shows that Rusizi is the most populated area in Western Province with 404,712 people (194,310 male and 201,402 female), while Nyabihu District is the least populated, with 295,580 inhabitants. The Rusizi District average annual growth rate is 2.0 and the District density of population is 422 people per square meter.

Industry

Rusizi District hosts agro-processing industries for rice, tea, fruit, honey and cement production. These industries are not fully used because they operate at less than 25% of their production capacity. This is a great opportunity for rice cultivators and there is a strong need for encouraging all mechanisms which can help to increase the agro-production capacity. The major economic activities in the study area include those related to agriculture, apiculture, and handicrafts. The study area has 11 agricultural-based cooperatives of which 8 are involved in rice production in the Bugarama Marshland, 2 are involved in maize production and 1 in honey production. Some local people are employed by CIMERWA, the Health Centers, primary schools, financial institutions like COGEBANK and Micro financing organizations, NGOs (like PREPAF, CARITAS, and Global Fund), etc. Commercial activities such as kiosks and small-scale trade centre also characterize the study area.

Agriculture

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Agriculture is the chief occupation in the area and is the main source of income. The dominant crops in the study area are rice, maize, cassava, beans, sorghum, banana, and mangoes. The dominant farming system is mixed crops . A major part of the geothermal area comprises of mixed agriculture and settlements. Another part is covered by artificial forest plantations and rice cultivation as a result of crop intensification programs. The Bugarama Marshland consists of monocrop agriculture (Rice) that is owned by cooperatives. Within our area of interest, we found 8 cooperatives involved in rice production. The main livestock in the area include pigs, goats, sheep, cattle and hens.

Socio-economic dimensions of geothermal development: Geothermal initiatives would bring much-needed job creation opportunities and also support greater electrification in the zone.

Age Distribution of the respondents: Most of the respondents were above 52 years old (29%), followed by 30-35 (19%), 16% for 24-29 years and 36-41 years. The age profiles are similar across all the study locations.

Marital Status and Educational Profile of the respondents: Marital Status show that 77% are married. Educational Profile of the respondents show that 62% have primary level education.

Occupation of the respondents: Majority of the of respondents 56% are subsistance farmers, while 19% are commercial farmers. Occupational profile is similar across the study locations.

Incomes of the respondents: About 80% of households have a basic monthly income of 41,000rwf or below, while 12% of respondents have monthly income in the range 41,000-91,000rwf.

Dwelling types by Households: Most (dwellings in the villages are permanent (iron sheet roof and brick walls) – 63% and the rest are semi-permanent.

Economic Vulnerability Status of the Households: About 56% of respondents are in households that have gone without enough food to eat several times or many times. Food vulnerabilities are similar across the regions. About 55% of respondents are in households

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that have gone without enough clean water several times or many times. Water vulnerabilities are similar across the regions. About 37% of respondents are in households that have gone without enough medicines or medical treatment several times or many times. Health vulnerabilities are similar across the regions. About 42% of respondents are in households that have gone without enough fuel to cook several times or many times. Energy vulnerabilities are similar across the regions. About 60% of respondents are in households that have gone without enough cash income several times or many times. Income vulnerabilities are similar across the regions. About 39% of respondents are in households that have gone without enough school expenses several times or many times. School expenses vulnerabilities are similar across the regions. About 10% of the households consider themselves destitute. About 7% of households consider themselves quite well off. About 2% of households consider themselves wealthy. About 25% of households consider themselves not so well off. About 56% of households consider themselves poor.

Access to Services by Households: Access to electricity 66%, Access to health facilities 99%, Access to piped water 52%, Access to roads 95%, Access to educational facilities 89%.

The use of geothermal or hotsprings resources by households: About 69% use geothermal resources. About 69% use geothermal resources. Traditional healing accounts for 3%, Livestock 25%, Health 92%, Religious 58% and Agriculture 66%.

Energy Regularly used for various needs: Cooking Biomass 98%, Cooking LPG 2%, Cooking Electricity 1%, Lighting Electricity 64%, Lighting Biomass 5%, Lighting solar 59%, Lighting, kerosene 12%.

6.2 Socio-anthropological aspects and analysis

6.2.1 General background information

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The Mashyuza geothermal site is located in Western province, Rusizi district, Nyakabuye Sector, Mashyuza Cell in Muganda Village Southwest of Rwanda.[13] According to City Population (undated) population census as at August 2022 gave population estimate and density of Nyakabuye Sector as given as 33,200 (15,739 males and 17,461 females) and 884.5/km² respectively. The population inhabiting the area around these manifestations is Rwandese with *Kinyarwanda* as their local language[14]. The predominant religion of the inhabitants is Christianity and indigenous religious beliefs. The majority of Rwandans, about 65%, are Roman Catholic, with another 9% Protestant. Only about 1% of the population is Muslim. About a fourth of Rwandans are adherents of indigenous beliefs. However, these numbers and divisions are not clear cut. Many Rwandans practice both their traditional religion and Christianity at the same time (Taylor, 1995). In regard to indigenous religious beliefs, there are implications for geothermal development which will be explained a bit more under the part on uses. 73.5% and 26.5% of Rwanda's Western province where the Mashyuza site is situated live in urban and rural areas respectively. This population comprises of an estimated 540,103 households; out of which 65,867 and 474,236 are urban and rural based respectively. 26.5% and 30.3% of the province's households living in urban and rural areas respectively are female headed (Republic of Rwanda, 2014). On one hand, according to Republic of Rwanda (2019), while Western Province's average poverty levels stand at 48.4%, those of Rusizi district are lower with 20.5% identified as poor and 24.5% as extreme poor. On the other hand, National Institute

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[13] Rwanda is currently composed of two layers of government (central and local) and of six administrative entities: These structures, which were reorganised under the 2005 reform, are complementary. The country is divided into four Provinces and the City of Kigali which are also further divided into 30 districts. The districts are further divided into 416 Sectors. The sectors are further divided into 2148 cells and lastly, these cells are divided into 14837 villages (Republic of Rwanda, See:https://www.gov.rw/government/administrative-structure#:~:text=The%20Cell%20is%20an%20entity,°%20A%20Development%20Consultative %20Committee). Consulted on 05 June 2024. The four Sectors surrounding the Mashyuza geothermal site are: Nyakabuye to the East, Muganza to the West, Gitambi to the Norht and Gikundamyura to the South.

[14] After the 1994 Rwanda genocide, the people of Rwanda no longer identify themselves according to any ethnic or cultural groups, but are all supposed to consider themselves and to be considered as Rwandese.

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of Statistics of Rwanda (2017), states that the poverty headcount index of Nyakabuye Sector is given as 35.35. These figures are close to those given by Director of Social Affairs who we had a meeting within Kigali during this fieldwork period who talked of estimates of about 30% of the population living in the environs of the Mashyuza geothermal site as living below the poverty line. Participants in a discussion with community members in Mashesha Cell of Gitambi Sector near the cement factory and Mashyuza geothermal site during the October 2023 fieldwork gave 3% and 5% as estimate figures of youth and women's employment.

6.2.2 Economic Activities

There is diversity in terms of economic activities in the environs of the Mashyuza geothermal site. These include livestock husbandry and crop farming. Fruits (bananas, oranges, mangoes, lemon, avocado), vegetables (including tomatoes, onions), cereals (including rice, soya beans, maize and beans) and other crops such cassava as are among the main crops (see also for example: National Institute of Statistics of Rwanda & Republic of Rwanda, 2023). Coffee growing is also an economic activity. There is also rearing of goats, cows, pigs, and chicken as was articulated by the Nyakabuye Sector Executive Secretary during the meeting organised by EDCL (who were also in attendance) that we had with him. Some of these also formed part of the observations made during the fieldwork. Small-scale trading of household items and wage/formal employment (including in a nearby cement factory) are other economic activities. Possible applications of Direct Use geothermal in relation to some of the economic activities listed above include preservation of the crops through drying as already outlined in a preceding paragraph under the sub-topic on *Uses of the Geothermal Resources – Current and Potential.*

6.2.3 Uses of the Geothermal Resources – Current and Potential

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The local population around the Mashyuza geothermal resource has various uses of the geothermal resource[15]. Observations made by Géo2D as well as the discussions held with various community members during an October 2023 field visit either at the site or its environs indicated uses such as bathing and medicinal. Closely tied to bathing, is recreation/leisure as a use, as seen for example in the use of the site by young boys who come together to the site and combine bathing with play.

Medicinal purposes given included: drinking the water to deal with loss of appetite, using the water for relaxing muscles and veins (including back pains) as well as for the stomach in both livestock and human beings because of the natural salt it contains. The grass around the geothermal site is good for livestock health. Indeed, on one of the days, while Géo2D was at the site, there was a member of the local community massaging the feet of some of the visitors to the site using the warm water from the resource for a small tip depending on what the person receiving the services wanted to pay. There was also a man who came to fetch the water with a five litres plastic container (jerrican) and when asked what he was going to do with it, he said it was to drink it for a stomach ailment he had. A man who had brought his goats to graze and drink the water on these grounds explained that the grass is good for the health of the animals and the water helps to deworm them.

Energy Development Corporation Limited (EDCL) also identified the site as having good potential for touristic attraction; a point that was also given by the Nyakabuye Sector Executive Secretary during a meeting with him that was organised and also attended by EDCL in the course of the October 2023 fieldwork. These views were in line with those expressed in a June 2022 report prepared by Géo2D's Jacques Varet and Peter Omenda (of SEPCO) after the fieldwork for site selection done jointly with EDCL and SEPCO in May 2022 in which the District authorities had indicated that they considered rehabilitation and modern development of the thermal and bathing site as a priority; as per their development

[15] Géo2D was informed by an Energy Development Corporation Limited (EDCL) member of staff that the word *Mashyuza* is derived from the *Kinyarwanda* word *Amashyuza* which refers to any water coming from the ground. *Mashyuza* also refers to a river. *Arashushe* is also a related word which means "boiling" in reference to the warm water of the Mashyuza site. Amashyuza therefore generally makes reference to features such as hot water, hot pond, steaming grounds and hot springs, all of which are associated with geothermal resources. Google Translate gives *ashyushye* as *Kinyarwanda* word for "hot".

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plan. The report had indicated that the Mashyuza thermal waters attracts the population in the surrounding area, and also potentially tourists coming from other parts of the country including Kigali (Rwanda's capital city) or from neighboring countries. The report thus talked of bathing, spa, thermal station(s) as areas of interest under a GV concept project.

Other potential uses will be discussed in an ensuing paragraph under economic activities. These uses provide leads for a business model targeting the Mashyuza geothermal site. The October 2023 field visit in Mashyuza revealed that there is a place (not too far away from this manifestation) that seems to be part of the rift system associated with the Mashyuza geothermal site, where there is a kind of a water-fall[16] and cave-like structures that people consider sacred and so serves spiritual/religious and/or psychological needs[17]. Some of the people come from far away[18]. During a visit to the place by Géo2D, there were people praying around the place as well as inside the water as they allowed the water to flow through their body (which Géo2D was told by someone else who had come to pray at the site was symbolic of being washed/cleansed by the water in a spiritual sense). Some people also pray inside the cave-like structures. There were also pieces of papers with written prayer petitions left behind stuck on spaces of the walls of the caves. Discussions with some community members indicated that from a spiritual perspective, some of the community members consider this place as a gift from God. We may not share in some of the indigenous religious beliefs associated with such sites, but we should appreciate that they are sources of hope for the people that do. These perspectives should therefore be

[16] Another EDCL member of staff told Géo2D that water first appeared and started to flow at this place around the same time that the levels of the water at the Mashyuza site manifestation drastically dropped.

[17] People come to read the Bible, sing and pray there, all which Géo2D was able to observe while at this place. Some even come there on long prayer retreats, spending more than a day there. While there, Géo2D saw a young woman sleeping in one of the cave-like structures. She had light beddings – including a pillow. Beside her was a small bag with what seemed to be her belongings – an indication that she may have come there for more than one day.

[18] Géo2D spoke to a young man who indicated that he frequently comes for prayer retreats at this place. He spends about three hours travelling by public transport to get to the place.

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borne in mind in a GV concept project to ensure that development activities can co-exist with these kinds of indigenous practices, and to avert conflict with the local community.

Some of the potential uses identified by EDCL and confirmed by discussions with the community done by Géo2D and SSSA during their fieldwork in October 2023 include using geothermal to dry rice to reduce time spent as well as drying costs and the post-harvest loss farmers incur at the moment because of the methods they use to dry the produce; which includes drying under the sun[19]. A member of staff at one of the rice factories in Bugarama informed us in a meeting we had with him during the October 2023 fieldwork that electricity is the most expensive cost in rice production, so if geothermal can provide a cheaper solution, it would be a welcome idea. He added that one of the biggest challenges the farmers face is providing rice that is dry enough, which ultimately affects the quality and quantity of the rice. The December rice harvest season is the most affected as the rains makes it difficult to dry the rain in the sun as is traditionally done in other seasons. A drying system that takes into consideration retention of both the quality and quantity of harvest would therefore be ideal. Geothermal Direct Use has this possibility.

The EDCL member of staff with whom Géo2D held discussions indicated that in the case of rice, both the farmers and the factories where the rice is taken by the cooperatives had expressed interest in a geothermal-based rice drying facility. As articulated by the Director of Social Affairs during a meeting with him organised by EDCL (also in attendance), agro-(food) production, fruits processing, food preservation and tea drying are other possibilities for geothermal Direct Use in Mashyuza, supported by the fact that there are many hectares of land surrounding the areas that can be used for farming; that Rusizi District is thinking of an initiative around processing of fruits; that the local community have no means for preserving food and that tea factories use firewood to dry their produce. These remarks also tally with some of EDCL's earlier findings recommending preservation and storage facilities for the fruit farmers around the geothermal site, because they end up selling their fruits cheaply before they get spoilt and also because they have no storage facility. Coffee washing and drying also came up during our discussion with the cooperative members as

[19] He added that in most cases, the farmers must be physically present watching over their rice as it dries under the sun, otherwise it gets stolen. He indicated that in most cases it is the men that must provide this kind of security. This has a direct effect on the time of the men (or in some cases, women) that must handle this gender role.

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a potential use of geothermal resources, because it is currently dried in the sun. Bottled sparkling mineral water and derived products; rice drying devices in partnership with the rice plantations and processing factories; fruits and vegetable drying devices made available for the surrounding producers, fish-farming (pond fish) and drying in the Rusizi River basin were also potential areas mentioned in the June 2022 report prepared by J.Varet and P. Omenda.

Taking into consideration some of the local population's key economic activities articulated socio-economic needs during the October 2023 fieldwork and strong attachment to using the resource for bathing as observed during the field visit and also articulated by the community, a spa is another potential way to develop the Mashyuza resource, besides food drying. In a September 2023 email discussion with a section of the GV project team J. Varet suggested that in view of CIMERWA's activities, the GV concept should also consider a post-mining economy. The CIMERWA member of staff indicated during the October 2023 virtual discussion with Géo2D that going by the pace they have been going, it will take about another twelve years (effective November 2023 when we talked) for the resource to be exhausted. To his suggestion, J. Varet added that a project should therefore be built around a circular development economy whereby after completion of the cement extraction, the quarries would be rehabilitated, the landscape naturalised and the GV concept's cascade approach to geothermal development applied. As one of the ways to share the resource between the cement factory and the local community, J. Varet proposed that part of the land could be used to develop both a public and a private spa among other applications. Going by observation and the discussions held with the local community as well as government representatives, this suggestion is plausible. NORCE, the EU Engineering partner in the GV project have since confirmed that a spa modelled around Iceland's famous "Blue Lagoon" spa would fit where Mashyuza quarry activities are presently taking place and still leave a lot of room for a hot-spring resort, agricultural drying, limestone drying and other applications. They will prepare 3D/oblige figures for this. Further discussions however need to be held with CIMERWA, as a follow-up to the discussions initiated in October 2023 to define their role in such an arrangement and concretise an agreement with them. The background to the discussions with CIMERWA go back to the fieldwork done by Chris Buscher (of University of Torino) in June 2023 whereby the issue of the disappearance of the water first came up during his engagements with community members. One of his recommendations was that SSSA and Géo2D should try to have a meeting with CIMERWA during their October 2023 fieldwork as his attempts to do so during his visit in June had not been successful; a recommendation that was taken on board as part of the fieldwork. This scenario confirms the importance of the GV concept's multi-disciplinary approach to geothermal development.

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Potential uses of the geothermal resource by the CIMERWA cement factory were also proposed in the report. These included using the geothermal heat for limestone extraction and pre-heating as well as drying in the first stage of the cement production process for fossil fuel savings (with mitigation of GHG emission). The October 2023 virtual meeting discussion with the cement factory employee confirmed these potential uses. The employee explained that during the rainy season, they have challenges with drying the wet material that is excavated, and so geothermal could be a solution. He added that they excavate about 50,000 tonnes of limestone per month. Rutagarama (2014) gives industrial uses as one of the potential ways in which Rwanda's geothermal resources can be utilised. The aspect of economic activities tied to that of potential uses of the Mashyuza geothermal resource opens up perspectives for a business model that could incorporate both present and post-mining scenarios in relation to the cement factory.

During the October 2023 discussion with the employee of CIMERWA - the cement factory in question – he stated that the organisation is looking for ways of improving their activities. He indicated that he would inform the relevant person(s) within the organisation - his supervisors - about our discussion, for further consideration. There was therefore willingness on the part of the factory for further discussions on how this could happen. A GV concept project that takes into consideration some possible needs of the factory, but also permits activities targeting the community to take place - in other words, sharing of the resource between the cement factory and the local community - is one of the things Géo2D mentioned during the meeting and so a good place to pick up the conversation from, once all the data (geoscience, engineering and social science) for the site will have been compiled, so that we would be engaging them with data that can be used to present a case for the site. EDCL should be at the centre of these discussions and therefore, ideally drive the process.

6.2.4 Community's Readiness for a Project Based on the GV Concept and Licence Issue

Although there is no community-based entity specific to geothermal that exists among the local population around the Mashyuza site, members of the community have organised themselves into farmers' cooperatives (for example for coffee and rice); an arrangement that presents opportunities for structures that can form the basis for a GV concept project. A discussion with a member of EDCL during the October 2023 fieldwork indicated that geothermal activities in Mashyuza premised on the GV concept should be community-

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owned with technical support from institutions like Rwanda Energy Group (REG; i.e. mother Company of EDCL), Ministry of Local Government (MINALOC) and Rwanda Cooperative Agency (RCA)[20]. Of course, EDCL would also be part of such a project.

Géo2D was informed by the EDCL staff that gender inclusion is taken care of in Rwanda's legal framework therefore, inclusion of women and youth in these cooperatives is guaranteed. Rwanda's Gender policy stipulates that there should be at least 30% representation of women in decision-making organs (Republic of Rwanda, February 2021). Although overall, there seemed to be more men in attendance, a big cooperative meeting that took place near where we (Géo2D and SSSA) had a discussion with some of the cooperative members during the October 2023 fieldwork had a considerable number of women in attendance. Out of an approximate one hundred attendees, maybe about thirty-five to forty-five were women.[21] In a different discussion Géo2D had with a male member of staff of the cooperative, he indicated that the Chairperson's position is rotated between a male and a female at the end of each office bearer's term in office. The idea of a project based on the GV concept was well received by the cooperative representatives. After presenting the background information related to the GV concept and indicating that it implies a small power plant, the eight attendees (five women and three men) agreed in unison that it was a good idea. Indications from the earlier discussion with the EDCL staff member were that cooperative members they had met and talked to during their socio-economic data collection had stated that they were ready and willing to pay a fee for crop drying services of a geothermal facility.

[20] There are two sister companies under REG: EDCL – which generates electricity and Energy Utility Corporation Limited (EUCL) – which sells electricity to the consumer. The MINALOC ensures the coordination of good governance and high-quality territorial administration programs that promote economic, social and political development throughout the nation. The EDCL staff was of the view that MINALOC should be involved at District and Sector levels as they would facilitate certain processes related to implementation of energy-related projects at local level. RCA oversees all cooperatives in Rwanda and ensures activities within these cooperatives run well.

[21] Five women and two men from the cooperative participated in the meeting. A third man joined briefly towards the end.

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The various government officials we met in the course of the October 2023 fieldwork also welcomed the idea of a project premised on the GV concept citing its potential to improve the economic activities and to create jobs as some of the reasons.

Initially, the land was owned by the local community, but when CIMERWA cement factory excavation activities started; the investor expropriated the land from the local community to be able to use the land. The licence for the land around the Mashyuza geothermal site is therefore in the hands of CIMERWA cement factory, but the population, has until presently (May 2024 the time of writing this section) easy access to the resource for their various uses without any problem. The EDCL staff member explained to Géo2D that expropriation takes place in the case of public projects, so the land is now in the hands of CIMERWA. However, there is a portion of the land that the company allows the community to use, including for farming. In Rwanda, the local community may own the top soil and/or have permission to use it for purposes such as farming, but anything below 100 metres belongs to the government.

According to the community, the land around the hot springs is in the hands of CIMERWA and although the factory does not prevent them from farming around the area (whereby they generally grow crops like beans, cassava and fruits), you could plant but they may come up and say they need the land before you harvest and so clear off all your crops before you harvest. Although until now the local community still has the permission to access the resource, the cement factory's activities and their negative impact on the resource (to be discussed in an ensuing paragragh), coupled with the fact of the land having been expropriated from the community bring in a measure of vulnerability related to the population's access to the resource. A proper agreement that protects the community's interests would therefore need to be reached with CIMERWA in the event of a GV project to take care of power relations between them and the community. In a virtual meeting discussion Geo2D had with an employee of the cement factory during the October 2023 field stay in Rwanda he confirmed that the Mashyuza hot spring waters is inside the company's quarry. This aspect of expropriation makes the cement factory a stakeholder in issues related to any geothermal development that may take place on the Mashyuza site.

In the case of Rwanda, need for capacity-building was also identified. The EDCL staff indicated that if for example a geothermal facility for drying farm produce is installed, maintenance of equipment to ensure the machinery is in good condition would be required. For this, he proposed the need to work with the relevant institutions and ministries for

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example the Ministry of Education, etc to ensure the locals are well trained to handle the facilities and their infrastructures. EDCL would also be an important institution to provide relevant technical skills and expertise related to such projects, including the aspect of sustainability. The staff also talked of the need to build strong institutions that can manage such projects well and ensure community ownership of the initiatives. Relevant capacity-building would also be required for the local structure or entity that would eventually take up the role of managing a GV project in the Djibouti case.

6.2.5 Gender-Based Social Dynamics

Reports of incidences of female-headed households owing to the country's 1994 genocide were given during the field data collection. 26.5% and 30.3% of Rwanda's Western province households living in urban and rural areas respectively are female headed (Republic of Rwanda, 2014). The EDCL member of staff indicated that about 20% of Rwanda's population is comprised of widows and about 10% are single mothers. In one of the Focus Group Discussions (FGDs) we held about a kilometre from the site, the two women who partially attended it out of a total of about twelve participants (therefore ten men in attendance) were both widows. Female-headed households are more likely to live in poverty and experience higher rates of unemployment than those headed by males (UNDP Rwanda, December 2018). The EDCL staff indicated that Rwanda's current cabinet has a nearly 50-50 of men: women ratio and that the women are doing a good job – at times even performing better than men. Although gender equality rules are inscribed in Rwanda's constitution, like in most other parts of Africa, at household level, men are generally the ones with decision-making and economic power. In the October 2023 discussion in Mashesha Cell, which happened to majorly have male participants[22], composed of men In addressing the unequal power relations between men and women (UNDP Rwanda, December 2018) states that whereas women's literacy rates are lower than men's (65% as compared to 72%6); a fact that further constrains women and girl's already limited opportunities in terms of accessing resources, creating and managing small businesses and participating in decision-making processes. Women are paid less than men in comparable employment and with Rwanda's gender pay being at 27%, it is higher than

[22] There was a total of twelve participants (ten men and two women), but one woman attended part of the meeting and left. The other spent part of the time attending to other tasks such as serving drinks.

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the global average of 23%[23]. Rusizi District's literacy rate is given as 72.7% (Republic of Rwanda, 2019). The stated gender dynamics should be expected to have an impact on the participation of women in geothermal processes such as those envisioned in the GV concept.

6.2.6 Household and Environmental Vulnerabilities

Respiratory tract infections due to exposure to firewood and kerosene smoke are household vulnerabilities relevant to geothermal. So is smoke from the cement factory's activities. Kerosene lamps are the main source of energy for lighting outside Kigali city. Whereas 29.1% and 36.9% of Western province's urban and rural populations respectively use kerosene for lighting, 88.6 % of the province's population uses firewood for cooking (Republic of Rwanda, 2014). Participants of the October 2023 discussion with community members in Mashesha Cell also stated that firewood is their main source of household energy and that it is principally women and girls who go out in search of it. During the meeting with the Nyakabuye Sector Executive Secretary, he also indicated that many people use charcoal for cooking. Similar to the other populations, deforestation resulting from use of firewood as an energy source is therefore an environmental vulnerability. The implication is a vicious cycle in which women and girls get more exposed to poisonous fumes from unclean energy sources, spend time and resources getting treatment and/or taking care of others affected by such exposure and that women and girls spend more time on The Director of Social Affairs stated during the meeting that their target as government is to reduce the use of such traditional sources of energy in line with the Sustainable Development Goals (SDGs), adding that women are the most impacted by energy poverty and take care of energy-related household chores. Water-borne diseases are an example of water-related vulnerabilities in Rusizi district. 27% of West province's population has no access to improved sources of water and depend on sources such as unprotected springs/wells, rivers, lakes/streams/ponds/surface water (Republic of Rwanda, 2014). Participants of the October 2023 community discussion in Mashesha Cell also indicated that they have to walk about 500 metres to access drinking water. This is still a need that a project premised on the GV concept can respond to. A GV concept project can therefore attend to the gaps related to both the energy and potable water deficiencies faced by the local community around the Mashyuza geothermal site.

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[23] This indicates that women who are working in Rwanda earn an average of 27% (73 cents per dollar) less than their male counterparts (UNDP Rwanda, December 2018).

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In the case of the Mashyuza geothermal manifestation, the activities of a nearby cement factory have also been blamed by the local population for recent drastic decrease in the levels of the water resources (which the population uses very much for bathing – in other words as a spa) as well as emissions of some poisonous gas at some stage in time; that were even said to have resulted in the death of at least two people at the site. These reports talked of fluctuations of the water levels at the site and a reduced surface area occupied by the waters, in the recent past (since around 2020) with the water having practically all disappeared at some stage. A meeting with a Ministry government official in Kigali during the October 2023 fieldwork indicated that an emergency Committee even had to be set up to look into this matter.

There was however a sense of helplessness on the part of the local community regarding the fact that CIMERWA had faced no consequences in relation to the negative impact of their activities. The community also expressed deep displeasure regarding what they considered the negative impact of the quarry activities on the Mashyuza hot spring that they use as a spa. One of the issues that emerged from the meeting with members of the community that we had about a kilometre from the site was cracks on the walls of houses occasioned by the cement factory's activities[24]. There is therefore conflict between CIMERWA, and the local population related to the cement factory's activities, but the uneven power dynamics between the two parties is what causes the sense of helplessness on the part of the community. CIMERWA, however, carries out Corporate Social Responsibility (CSR) activities as a way of giving back to the community. Although using CSR to try to damage-control the kind of environmental issues that have resulted from CIMERWA's activities should not be the norm, in this case as the damage has already been

[24] The discussions during the October 2023 virtual meeting with the employee of CIMERWA indicated that there were plans by the government to relocate the community members living within a radius of 300 metres from the quarry activities because of the vibrations. A team had even gone to the ground to assess the situation and see how many houses would need to be relocated. The feasibility of such an exercise will depend on the budget available. Although the community members likely to be affected had expressed a preference for being given money so that they can move themselves, the government has said that it has to build houses for the members to be affected so that they will be given houses instead of money.

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caused, a GV project can tap into this aspect as an opportunity for a community-based initiative with financial support from CIMERWA forming part of the sources of funds.

6.2.7 Access to Basic Services

Concerning access to services such as education institutions and medical facilities, there is a school and health centre that is mainly associated with CIMERWA factory within an approximate distance of fifteen minutes from the geothermal manifestation. Start here There is also good telephone network around the site. However, although only about 4% of Western province have access to household electricity, the national electric grid passes close to the Mashyuza geothermal site.

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6.3 Stakeholder analysis

The Mashyuza hot springs are situated in the Nyakabuye sector, in the Rusizi District in Southwest Rwanda. According to the sector's Executive Secretary, the sector has a population of 32,300 people and is subdivided into six (administrative) cells and 49 villages. The hot springs are situated in the cell that is also called Mashyuza. With six villages that, according to the village leaders, count nearly 3000 people, this cell represents the 'community' in the narrow sense that GV focuses on. But considering the hot springs are used by people from, and are under administrative control of, the entire sector, this is indeed the broader community that GV targets. The tables below list a selection of key stakeholders within and beyond the community, i.e. at the local/regional and national levels.

6.3.1 Stakeholders within the GV community

Type	Name	Profile	Relation with/ role in GV
Social	Mashyuza cell executive secretary and village coordinator	The cell executive secretary is appointed by the district, village coordinators are elected by village inhabitants. These are the leaders who stand closest to the people living near the Mashyuza hot springs	Given the various issues in their community, ranging from a lack of jobs, infrastructure and basic/ social services, they have much to gain from GV. Involving the broader community and special groups (see below) through these leaders is important.
	Women, youth	Women and youth are organized and represented in special interest groups	Women and youth bear extra burdens of issues in the community, e.g. higher unemployment rates, heavier workloads or missed opportunities due to lack of access to water and electricity. They have much to gain from GV, especially if it supplies these basic services and opens up (job) opportunities (e.g. through tourism).
Economic	Farmers	Most people in the community rely on small-scale farming, producing crops for their own use and/or for sale (e.g. vegetables, fruits, coffee beans). Farmers	Farmers would have much to gain from crop drying facilities, but also from ancillary infrastructure that a project like GV could trigger – especially better roads, which provide better access to markets. Other

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		are organized in a community group	than labor power and knowledge, they have few if any resources to contribute to help develop GV.

6.3.2 External stakeholders: local/ regional

Type	Name	Profile	Relation with/ role in GV
Private sector	Cimerwa cement factory	Biggest cement plant/ producer in Rwanda (capacity of 600,000 tons/year). Owned 99.94% by National Cement Holdings (Devki Group) since February 2024. Rest shares owned by Government of Rwanda	Key stakeholder affecting GV, given [1] the impact of its limestone mining on the community and [2] its ownership of land around the hot springs, rendering community activities dependent on Cimerwa. Could also enable GV through their Corporate Social Responsibility (CSR) program. In any case, crucial to involve in GV’s early stages – not least because of its powerful position and impactful role (see also below).
	Rice cooperatives	Farmers are obliged to join and sell their rice to a rice cooperative, which in turn sells to a rice factory. There are 4 rice cooperatives in the broader Bugarama valley. The government decides what type of rice and how much of it ought to be produced annually	Rice cooperatives and factories are above all interested in better and quicker ways of drying rice, which is currently being done using the sun. That would be their major interest in GV. Cooperatives have very few financial resources, but the workers are willing to provide an in-kind contribution. The cooperative form, moreover, could act as example of how the GV (its management) could be structured. The Catholic Church-owned factories are contributing to community projects, tend to have more resources, which might be interesting for GV.
	Rice factories	There are 5 rice factories in the area, 3 of which are owned by the Catholic Church. They buy rice from the 4 cooperatives and process it for the market	
	Coffee washing stations	Grade and wash coffee beans until parchment. They buy coffee beans from farmers, some of whom are organized in a	Stations might be interested in electricity and a drying facility, although current (basic) drying methods (sun + cover against rain) are sufficient for the

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		coffee cooperative or associations	quantity of coffee processed by the stations.
Public authori ty	Nyakabuye sector administratio n	Administrative entity for the sector (one level below the district), led by an Executive Secretary (ES). The Mashyuza cell and villages fall under the Nyakabuye Sector	The sector ES and its administration is a crucial stakeholder for GV, given its thorough insight into the communities' dynamics as well as its hierarchal relationship with the district (and higher) governments. The ES welcomes GV, provided the community's involvement is guaranteed. Its material and political resources to forge developments is modest, however.
	Rusizi district government	The highest public authority at district level, led by a committee of one mayor and several vice-mayors. Like all public entities, it works on the basis of a comprehensive annual development plan *(Imihigo)* in various socio-economic/ environmental sectors	GV could play a role in/ contribute to some sectors & 'transformation pillars' listed in the district's *Imihigo*, including agriculture, energy, water and sanitation, and private sector development and youth employment. The Joint Action Development Forum, which mediates between different sectors, projects and partners in the district, may prove useful in mobilizing district support.

6.3.3 External stakeholders: national

Type	Name	Profile	Relation with/ role in GV
Public authority	Ministry of Infrastructure (MININFRA)	Responsible for energy policymaking and oversight	Determines objectives for geothermal development, among other, for REG to follow up/ meet. Given the centralized governance structure in Rwanda, GV needs buy-in from MININFRA.
Public agency	Rwanda Energy Group (REG) – EDCL	National state-owned energy/ electricity company; the Energy Development Corporation Ltd (EDCL) is a REG subsidiary, responsible for	As partner in GV, EDCL has a major interest and stake in the project. GV's focus on geothermal direct-use is of particular interest to EDCL, since high enthalpy

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		exploring and developing new energy projects	resources for large-scale electricity generation have not yet been found in Rwanda. As state agency, EDCL/ REG has and can exert influence to make GV possible, perhaps even organize resources required to set up GV.
	Rwanda Utilities Regulatory Authority (RURA)	Regulates different sectors, including energy and water	Becomes involved if and when GV starts supplying electricity and/or water services.
	Rwanda Development Board (RDB)	Helps developers and investors set up business/ projects in Rwanda. Includes a 'one-stop center' where developers can go to for business support (e.g. for dealing with administrative issues, licenses)	RDB was once involved in conversations about tourism development of the Mashyuza hot springs, in the form of a high-end lodge, but this has not been followed up. RDB can support GV in its development stage, e.g. by liaising between different public/ private entities.
	Rwanda Environment Management Authority (REMA)	REMA is responsible for environmental impact assessments	In a next stage, GV likely requires the execution of an environmental impact assessment, for which REMA is the authorized public agency.
	Water and Sanitation Corporation (WASAC)	Responsible for delivering water and sanitation services across the country	Should GV supply water services or if it considers bottling water, WASAC needs to be consulted.
Private sector	Energy Private Operators (EPD)	EPD is a professional association aimed at supporting and increasing private sector participation in all types and stages of (renewable) energy developments in Rwanda. It has some 150 private companies as member, both domestic and international.	EPD engages in advocacy, capacity building, trade missions and business development and facilitates access to financial services. Its own resources are limited. If GV is to engage private companies, support of EPD might be worthwhile.

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6.3.4 Stakeholder perceptions & relations shaping GV

There are different stakeholder relations of importance to GV. Because of Rwanda's centralized governance structure, i.e. the large involvement of national state agencies in structuring developments at subnational scales, the GV communities' relations with authorities and public agencies are of great importance. But arguably the most stringent and decisive relation affecting GV is that between the community and the cement factory Cimerwa. Cimerwa's mining activities have a major impact on the community living near or even further away from the limestone quarry. That started with the expropriation of people from their land decades ago, an impactful event that people feel might happen again in the future if there is need for more land for mining. The mining activities are said to cause cracks in houses, health issues and noise, leading to despair – the more so because community members have shared their concerns with authorities at different levels, to no avail. On the other hand, some community members expressed the desirability of having a major factory like Cimerwa in their area, despite the negative effects.

That Cimerwa is among the most impactful players in relation to GV is well illustrated by a major event in August 2020, when the pond/ hot springs dried up overnight. Before that, many had long used the hot springs for bathing, watering cattle and for religious and medical purposes – with the hot springs believed to have divine powers and a capacity to heal. The hot springs were also well-known in the wider environment and attracted quite a number of visitors from further away, even from neighbouring countries. This has changed significantly with the disappearance of the pond's water. Water returned into the pond, but not (nearly) to the same degree as before. This prevented visitors from coming any longer. Moreover, occasional concentrations of gas (hydrogen sulphide) caused uproar and refrained local people from using the pond, especially when two people were said to have died after inhaling it near the pond. In short, the hot springs are still used for the abovementioned purposes, but not nearly to the same degree or by as many people as before this event.

The event caused a lot of commotion, first and foremost in the community, but also nationally in the media and other outlets. Community members were quick to point at the limestone quarry as the main cause. The factory uses dynamite for blasting the limestone, which the community related to the pond water's disappearance – not least because of small earthquakes or tremors that they relate to the blasting. An official investigation into the matter concluded that this blasting or earthquakes were not so much the cause, but rather 'acidic water and chemical compounds found in rainwater and underground water' (KT Press 2021). Considering this investigation been undertaken by the national Rwanda

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Mines, Petroleum and Gas Board, and given the national importance attached to cement as a commodity generally and this cement factory specifically, it deserves recommendation to re-investigate this matter and to test this conclusion by independent experts – experts that have no relations to the government or stakes in Cimerwa. However one interprets this event, it illustrates how Cimerwa is a crucial actor mediating the relation between the community and the pond/ hot springs as the source for GV. Apart from the possibility that mining may render activities such as tourism less attractive, it is related to changes in the geology of the area, which may affect the geological potential and feasibility for GV.

The current (new) owner of Cimerwa has pledged to increase operational efficiency and annual production of cement, which will increase rather than reduce the factory's pressure on the natural environment and the communities. This continuation and intensification of the factory's activities thus needs to be factored in when further developing GV, as it might constrain GV activities. On the other hand, as also alluded to, Cimerwa might want to support GV through its CSR program. Either way, some type of formal relation or cooperation needs to be established between the community and Cimerwa, through which factors constraining and/or enabling GV can be discussed and tackled. Such an arrangement should account for the fact that the power relationship between the two is highly uneven, with Cimerwa having major political leeway and many (more) resources to achieve its objectives.

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6.4 How to ensure sustainability for the Geothermal Village? Guidelines for potential business and management models

6.5.1 Economic business model

6.4.1.1 Value proposition

In the Bugarama community, there may be different Geothermal Village (GV) solutions that consider the three elements of sustainability. We present them below:

a. The GV's first solution is, for the GV, to be linked to the development of larger-scale geothermal energy plant, perhaps promoted by EDCL. This would allow the community to benefit from the savings on drilling costs done by EDCL, which has already demonstrated interest in exploring the geothermal resource (the geothermal pool hot spring is called "amashyuza" or "mashyuza", in Kinyarwanda language by the local people).

b. The second solution is for the community to opt for active participation in the project, through a joint venture between Cimerwa industry (the cement factory) and the rice cooperative(s). In fact, Cimerwa, which is operating a quarry close to the amashyuza, is interested testing a drying station for the clay. Cimerwa can benefit from a pilot installation of a drying station that can serve also the rice cooperatives, interested in drying rice. In minority way, also the coffee cooperative can join the consortium.

c. The third solution, perhaps more in line with classic development cooperation schemes, is the intervention of a third-party financing body, perhaps international, which can finance the works necessary for the GV. After development and a short period of operation with community support, the third party would leave the management of the GV to the community. The international financing body could be: European Commission, European Investment Bank, World Bank, African Development Bank, national cooperation of an EU or non-EU state (e.g. AICS, US AID, etc.). This solution can also be combined with the previous scenarios, both a) and b).

In all three hypotheses, an active role of the community in the management of the project is assumed. However, the community is less developed and less skilled compared to the Homa Hills' one. Therefore, external experts, maybe provided by EDCL, are essential.

The possible GV Scenarios in Bugarama are resumed in the following table.

	Investor	Management	Strength	Weakness
A	EDCL/Community	Community	Synergies for sharing of costs with EDCL partnership	Need for a balance of interests with national interest of EDCL

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B	Cimerwa, Rice cooperatives	Community	Cimerwa provide material and project managers to build the GV	The plant will follow the Cimerwa ideas more than community's ones
C	International actor/Community	International actor/Community	Synergies between community and the international actor(s)	Need for an high commitment from the community to uptake the project

6.4.1.2 Users ("customer") segmentation: community needs and possible beneficiaries

The primary needs of the population, as highlighted by the actors involved, are mainly:

- Access to clean water
- Access to "social affairs": infrastructure (safe and accessible roads), public electricity, sanitization, in homes and for small production activities. Access must be stable and at a controlled price
- Health (no hospital) and Access to medicines, especially those to be kept in the fridge
- Reduction of poverty through jobs creation - the community met in Idaga village put job creation for young and women has the priority above all
- Education for youth
- Women opportunities.

The designed GV for the Bugarama valley is expected to contribute to the needs, even if depending on the type of scenario and also on the dimension of the plant. Regarding infrastructure, the community believes that the investor will build roads to develop the project.

Moreover, the rice cooperative (and, also the coffee cooperative) really need a drying machine or a drying station for the rice. In fact, drying the rice outdoor and in open air is not convenient, due to seasonal rains that can affect the quality of the rice. Nevertheless, the rice machine seems to be very expensive for the local economy (around 25k euros from a Chinese supplier - a quotation received from the rice cooperative).

6.4.1.3 Role of partners and actors

The pivotal actor of the GV in Nyakabuye, in both the scenarios, will be probably the Koimunya rice cooperative, established close to the amashyuza hot spring. This rice cooperative is one of the four existing in the valley. This role must be exercise together

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with the Idaga village members (Mashyuza cell, Kitambi sector). The community also believe that they should be involved in the project because they know how the geothermal pool has been formed. Moreover, they want to control the operation of Cimerwa, because they have caused problems to people and to the amashyuza. Apart from the local community (which is not part of the rice and the coffee cooperative), the other actors to be involved are:

a. EDCL: currently participating in the project, has a team dedicated to geothermal exploration. EDCL is under REG (Rwanda energy group), so has the fully support from the national government;

b. Rusizi District government and other local public authorities (e.g., Nyakabuye, Muganza, Kitambi, and Bugarama sectors; Mashyuza cell): the public authorities have all shown themselves to be interested in the GV. All levels of local government that we met have shown considerable openness towards the GV and have repeatedly stated that they would like to facilitate the project and participate in the design part, although not financially.

c. National public authorities, such as the Rwanda Development Board (RDB) or Mininfra: they are both interested in the project, even if at the same time they recognize the full authority of EDCL. RDB can accelerate authorizations and other processes for investors they judge they have priority.

c. International investors: the Bugarama area has already benefited over last decades from interventions by foreign institutional and non-governmental actors, especially during and after the genocide. These foreign initiatives demonstrate a precedent that could be repeated for the GV, albeit with different actors.

Activities and resources: what to do and how with energy

The community, through the GV, can use the electricity and hot water and steam, with a cascade use, for:

- generate electricity for domestic house
- drying rice and coffee
- agriculture: storing fruits
- public services (so called "social affairs"): lights in schools, conservation of medicals in dispensaries
- enlarge job opportunities: lights in local markets, etc.
- possibilities to develop local tourism (i.e., spa) through the steam extracted or the hot water, with the last level of the cascade use.

As two opposite sides of the configuration, the GV-option 1 provides for the distribution of electrical energy and produced locally. GV-option 2 just use the hot water for priorly

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heating and drying harvest and limestone. Of course, option 1 and 2 a presented separated but can be combined.

6.4.1.4 Channels

SSSA believes that the methods adopted to involve the actors in the feasibility study in the first phase of the GV are the most suitable also for the following steps. The population responded very well to the requests for focus group discussions and interviews. The community and the local authorities also suggested the mobilization is a key for the future of the project. Mobilization can front the fears of not achieving the targets and land expropriation. Hence, the methods adopted for involving the population could be replicated in subsequent phases. Nevertheless, a collective actor that can manage the relations is lacking. The possible establishment of a CBO and its involvement can give added value to the future steps of the GV. Word of mouth, through the activity of engagement of the local actors (rice and coffee cooperatives) and local representative of national ones (EDCL), can represent an easy way to reach all the community. Cimerwa must be officially contacted in their headquarters, in particularly the Corporate Social Responsibility department, in Kigali or elsewhere.

6.4.1.5 Economic sustainability: cost and revenues

“The poverty is a challenge, but if they see the benefit maybe they can pay.” This quote comes from a public officer met and explains very well the situation in the Bugarama valley, especially around the amashyuza in Nyakabuye. The sustainability of the GV is fundamental, and in all the scenarios presented, we believe that the community can’t afford the expenses as alone, due to the low-income situations. Nevertheless, the benefit has to be evident for them: the possibility to dry rice and coffee and to save money and keep the value of the harvest can be the key to involve the local actor in the GV. Moreover, if Cimerwa and ECDL perceive the possibility to find their way to exploit the geothermal resource, synergies on the investment are evident. Furthermore, the Bugarama rice company, that will benefit form the higher quality of the rice, can be involved, starting from the entrepreneur and owner, who is foreigner.

As in Homa Hills, the community also said that a way should be found to facilitate those who are not able to pay directly for the GV's services. One possibility could be to lend labor. In the Idaga village, plumbers, electrician and constructors are present.

Finally, to facilitate economic sustainability, as for other sites, the interception of private or public funding is recommended. Geothermal exploration activity is probably the most expensive among the activities foreseen in renewable energy resources and it is unthinkable that drilling is paid for only by the community. The public authorities, although

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they have demonstrated a willingness to participate in the GV, do not appear to want to put resources in the short term.

6.4.2 Environmental life cycle business model

6.4.2.1 Functional Value

The functional value of the GV in the Bugarama valley is certainly to provide the community with clean energy from renewable sources, clean water and drying station for the harvest. This could improve the community's impact on the environment (also reducing deforestation).

6.4.2.2 Supplies and outsourcing

As with other types of renewable energy solutions, supplies for GV construction and technologies should come from abroad. But if the project will be developed according to the first two scenarios, the internal skills can be provided by EDCL and Cimerwa.

6.4.2.3 Production and materials

As regards materials (e.g. pipes, cement), some of these could be developed on site, through Cimerwa and other local companies. The preliminary project will take into consideration local skills.

6.4.2.4 Distribution, use phase and end of life

The technical project has still to be developed, so we have to assume two different configurations of GV in Nyakabuye. The GV-option 1 which provides for the distribution of electrical energy and produced locally. Electricity, being produced from renewable sources, does not involve emissions into the atmosphere. Regarding the materials used, it is expected to use all recyclable materials, so as to be able to convert them into reusable material at the end of the useful life of the GV. Considering, instead, GV-option 2, which just use the hot water for priorly heating and drying harvest and limestone, once its calorific value has been exhausted, it is currently assumed that it will be released into nature, after verifying the polluting parameters required by law. This environmental aspect must be monitored and assessed in the initial environmental examination.

6.4.2.5 Environmental impacts and benefits

The most obvious environmental benefits are the use of energy (both electric and thermal, considering the two opposite options available) from renewable and non-fossil sources. Currently, the population uses energy from biomass and fossil sources for domestic

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activities, especially for cooking. The use of local biomass has led numerous areas to be subject to deforestation and consequent land run-off phenomena, as happening in the Homa Hills in Kenya. Being able to use clean energy would allow a gradual reforestation of areas currently without trees. The environmental impacts remain to be monitored, which will be the subject of an initial environmental examination to be carried out during the project development phase.

6.4.3 Social stakeholder business model

6.4.3.1 Social Value

Beyond the environment, GV in Nyakabuye can significantly improve health and quality of life. In fact, the use of clean energy can prevent diseases resulting from the use of fossil fuels and biomass for cooking, and promote clean cooking. Moreover, the drying station can improve the quality of rice and coffee sold, and this will improve the wealth of the community. Furthermore, the supply of clean water is often the responsibility of women and children, who spend many hours going to get supplies from public fountains. Being able to operate wells through the GV would allow women and children to have more time available to work, study, etc. Finally, the training necessary to manage the GV represents an increase in the skills of the entire community, which could also see positive effects on other aspects of their lives.

6.4.3.2 Local communities and employees

The local communities of Nyakabuye and the neighbourhood areas will be involved from the beginning of the GV, as was also done in this first phase. This direct involvement will allow communities to directly influence the design and make the GV respond to their primary needs (electricity, water, drying, etc.). Furthermore, the spirit of the GV is to involve the communities as much as possible in the maintenance and operation of the work. Hopefully, part of the employees or in any case of those who will carry out part of the work of the GV will be able to be selected within the community. The community has expressed its willingness to provide workers and it seems that there are hidden professionals, such as plumbers, electricians, constructors, etc. Maybe, who work on weekends in the larger cities (Rusizi, Kigali) could return to supply their weekend work in the Nyakabuye. Some lending-workers may be involved, however, because they cannot afford to contribute monetary resources to the development of the GV.

Two main concerns by the community need to be highlighted here:

- about the possible damage to the amashyuza hot spring of the GV;

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- about the "giant" Cimerwa factory and its impact on the area, including the amashyuza hot spring. The quarry is very close to the hot spring area, and the blasting activity are terrible and impressive in terms of noise pollution and micro-earthquakes.

6.4.3.3 Governance

One of the objectives of the data collection was to investigate whether the community wanted to be involved in the governance of the GV once the plant began operating. The community said it was willing to participate in governance, although with a different degree in respect to the Homa Hills community, that seemed to be more skilled. In any case, the community wants to be part of the project because they know since the beginning the amashyuza. This will ensure sustainability and protection to the project.

6.4.3.4 Societal Culture and Scale of outreach

For further information regarding the societal culture involved, please refer to the dedicated chapters. Here we just highlight that the development of the GV will take into consideration the socio-anthropological characteristics of the Bugarama valley communities, building on these, without altering them. The project is certainly entirely built from the bottom up, and this is demonstrated by the fact that the GV will be developed based on the needs analysis presented in this report. Furthermore, the project has the ambition to last, and a guarantee of duration is inherent in the strong relationships that it will establish from the early stages with the local community and all the other actors involved.

6.4.3.5 End users, social impacts and benefits

The end-users of the GV are the members of the community itself. The social impacts and benefits of the GV in the Bugarama communities are represented by the achievement, even partial, of the needs that have been collected. The GV will bring an improvement in the quality of life, an increase in the community's possibilities in both economic and health terms, an increase in skills that can then be spent in the job market, producing cascading benefits. Furthermore, we expect that all these benefits will lead, in a virtuous circle, to increasing the medium-term possibilities of creating new GVs or new development possibilities.

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7. Conclusions and future guidelines

Action 1- A context analysis of the sites

Diverse findings were observed in our context analysis. In Kenya, most of the household respondents were above 52 years old, followed by 30-35 (19%), 16% for 24-29 years and 36-41 years. The age profiles are similar across all the locations covered. In Djibouti, *mos*t respondents were also above 50 years (28%) old, followed by 48-52 years (19%). In Rwanda, most of the respondents were above 52 years old (29%), followed by 30-35 (19%), 16% for 24-29years and 36-41 years. The age profiles are equally similar across all the study locations within Bugarama. In Kenya, marital status show that 77% are married, 16% widowed and 6% divorced. For Djibouti, educational profile of the respondents show that 52% have 0-level education, followed by 26% A-level, 10% certificate; in Djibouti, about 92% of the respondents were married, while the rest were mainly widowed (7%). In Rwanda, the marital status show that 77% are married. Educational Profile of the respondents show that 62% have primary level education.

In Kenya, about 51% of respondents are subsistence farmers, 22% are engaged in trade/business and 19% are self-employed in undefined activities. In Djibouti, most of the respondents (62%) are not engaged in any economic activity. About 14% are employed while 7% are self-employed. In Rwanda, majority of the of respondents 56% are subsistence farmers, 19% are commercial farmers. Occupational profile is similar across the study locations. In Kenya, about 50% of households have monthly income of 5000kshs or below. 22% of respondents have monthly income in the range 6000-11000kshs. In Djibouti, *o*n average, the money incomes are below 6500 DJF, households in Lake Abbe and Kouta Bouyya have higher incomes than As Eyla. For Rwanda, about 80% of households have a basic monthly income of 41,000rwf or below. 12% of respondents have monthly income in the range 41,000-91,000rwf.

For Kenya Homa Hills, about 62% of respondents are in households that have gone without enough food to eat several times or many times. Food vulnerabilities are similar across the study locations. About 63% of respondents are in households that have gone without enough clean water several times or many times. Water vulnerabilities are similar across the regions. For Djibouiti about 60% of the respondents reported that they lacked food to eat just a few times or never. About 57% of the respondents reported that they lacked enough water for home just a few times or never. 36% indicated that they lacked water always. In Rwanda - Bugarama, about 56% of respondents are in households that have gone without enough food to eat several times or many times. Food vulnerabilities are similar across the regions. About 55% of respondents are in households that have gone

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without enough clean water several times or many times. Water vulnerabilities are similar across the regions.

In Homa hills, access to electricity 29%. Access to health facilities 98%. Access to piped water 13%. Access to roads 93%. Access to educational facilities 99%. In Djibouti, households generally can access water from dug well (73%), followed by piped water into a well (52%), and public standpipe (42%). Distance to regular water sources is longest for households in Lake Abbe (4km), followed by Koutta Bouyya (0.8km) and As Eyla (0.8km). Distance to health facilities is longest for households in Lake Abbe (20km), followed by Koutta Bouyya (8.8km) and As Eyla (1km). In Bugarama, access to electricity is 66%, access to health facilities 99%, access to piped water 52%, access to roads 95%, while access to educational facilities 89%.

Energy regularly used for various needs varied across the countries. In Homa hills, cooking Biomass 97%, Cooking LPG 8%, Cooking Electricity 1%. Lighting Electricity 22%, Lighting Biomass 5%, Lighting solar 59%, Lighting kerosene 12%. *In Djibouti, Households* generally use biomass resources for lighting (39%), followed by solar (25%) and Kerosene (7%). A good percentage also uses sport lights (30%). Households generally use biomass resources for cooking (89%), followed by LPG (11%). Good percentage LPG users are from As Eyla (24%). For Bugarama, cooking mainly relied on biomass 98%, cooking using LPG was 2%, cooking using electricity was 1%, lighting electricity was 64%, lighting using biomass was 5%, lighting solar 59%, lighting using kerosene was 12%. In Homa hills, use geothermal resources by households was mainly traditional healing 74%, Livestock use 72%, Health 67%, religious use 61%. In Djibouti, the geothermal resources are mainly accessible to households in Lake Abbe (75%). Both As Eyla and Kouta Bouyya sub-region households have no access to the geothermal resources. There is no recorded large-scale direct use of geothermal resources in Djibouti, except trapping of steam for water production from steam condensation. In Bugarama, about 69% use geothermal resources, mainly for traditional healing 3 %, Livestock 25%, Health 92%, Religious 58% and Agriculture 66%. In Djibouti, the practice of nomadic pastoralism has severe environmental impacts on the ecology of the village settlements. Households generally use biomass resources for cooking (90%) and lighting, putting severe pressure on the vegetation.

Action 2 – Socio anthropological analysis and dynamics

The GV concept is designed in such a way that its new development activities should co-exist with the local community's way of life and/or build onto already existing uses of the geothermal features. The idea is that the concept should become part and parcel of the local community's way of life. Thus, as an example, beliefs of a given population that considers the sites as sacred places should be accommodated within the development activities of a project premised on the GV concept. The populations' uses of the geothermal

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resources, their economic activities as well as the potential uses informed by given gaps or socio-economic needs are some of the key issues that should inform the business models specific to each site. The social dynamics and issues within the populations targeted by GV indicate that women and girls are more disadvantaged and have lower status compared to men and boys owing to gender disparity; a situation that can have a negative bearing on their participation levels in a GV concept project. These situations of gender inequality are manifested in other areas such as education levels as well as economic and decision-making power. Coupled with the fact that Direct Use geothermal development on which the GV concept is based has a close relation with gender roles, this scenario of gender relations presents a case for the inclusion of a gender component in GV and GV concept initiatives. In our discussion, the EDCL staff underscored the importance of ensuring buy-in from the community of the initiatives as a way of promoting ownership on community's part and thus sustainability, adding that the social aspect can pose a big challenge if not well considered from the very beginning. He was also of the view that GV initiatives should be community-owned with technical support from relevant institutions such as REG, MINALOC, etc and technical people from district and sector level to ensure proper implementation of the projects. Climate change effects have various negative effects on gender roles for both men and women. Household and environmental vulnerabilities have implications for gender roles, with women and girls as most impacted. Aspects of geothermal Direct Use can mitigate some of the climate change effects, especially those related to energy and water access. GV's multi-disciplinary approach enabled the Social Aspects and Dynamics sub-task work to feed into and to be informed by several other sub-tasks notably the sub-tasks related to business models, stakeholders' analysis within the Social Sciences Task; the Tasks on Geology and Engineering as well as the cross-cutting Task on Capacity-building. As an example, the Business Models as a sub-task is of interest and has a direct link to the Social Aspects and Dynamics because of its direct relation to gender roles, gender relations and poverty reduction (which directly relates to the more disadvantaged economic status of women compared to men). As for the Capacity-building sub-task, its potential to change situations by enhancing community members knowledge as well as contribute to attitude change for example regarding gender relations justify the Social Aspects and Dynamics sub-task's interest in it. Other activities that Géo2D was heavily involved in during the GV project included taking up at least eight invitations or opportunities within EU circles and beyond to share information and experiences related to GV's activities as a way of promoting Renewable Energy (RE) projects with local populations as central players/stakeholders and gender as a central issue – both aimed at enhancing consent, sustainability and ownership of RE projects.

Action 3 – Stakeholder analysis

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Of all four cases, the Homa Hills GV site in Kenya constitutes the largest site in terms of geothermal resources (3) and size of the community. Hence, there are various internal (community) and external stakeholders of concern to GV, but of major importance is the relation between the CBO representing the Homa Hills community and the private developer owning the geothermal license. Developing GV in part depends on the latter's cooperation. The CBO would do well to assess its preferred and possible development options for GV in relation to/ together with the private developer and make a GV vision or development plan for the foreseeable future based on that.

The Mashyuza GV site in Rwanda is, like the one in Kenya, a populated area, with many and different types of stakeholders already or potentially involved. Again, different stakeholder relations are of concern to GV, but one that requires special attention is that between the community and the cement factory Cimerwa – considering the latter's impact and potential influence on GV's prospects. This in turn necessitates the involvement of local and (sub) national authorities that should help bring about a social arrangement that ensures a coexistence of GV with Cimerwa's activities and plans. Setting up an entity that represents the community in this process, similar to the CBO in Homa Hills, is recommendable.

Quite different from the Kenya and Rwanda GV cases are the GV sites in Ethiopia and Djibouti. The latter two are situated in more remote areas than the former two, with (much) smaller communities that have (even) less social infrastructure and services available. They are both inhabited by clans of the Afar ethnic group, an Indigenous Peoples (IPs) group with own traditions and (pastoralist) lifestyle – according to which the design of GV should be adapted. In the Era Boru GV site in Ethiopia, a community-based social enterprise is in place to make sure the GV will be developed in line with their ideals and wishes and to interact with relevant external stakeholders. Such an entity is not (yet) present in the Lac Abhé community in Djibouti but could be beneficial in their interactions with external stakeholders – not least national state agencies that will likely play a major role if GV is to be established. Both require funding from external (international) stakeholders to take the next step in GV's development, although this is to a greater or lesser extent required for all four GV sites.

Action 4 - Geothermal Village similar experiences

Our analysis is built on both desk research on grey literature and on scientific literature, through a systematic literature review. The first main result is that GV doesn't exist yet, not even Africa has similar experiences in geothermal energy. Therefore, we had to look at similar experiences in RE. Regarding energy sources, first, GV can merge solar and

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geothermal energy sources, considering solar abundance and easiness to storage. Subsequently, GV can adopt a circular economy approach by investigating the inclusion of biofuel power plants fuelled by the community for a more lasting model. Then, involving communities is essential for GV, which can benefit from existing initiatives and engage local communities in ownership, administration, and skill-building to highlight the broader effects beyond just energy provision, such as enhanced education and gender parity. Moreover, GV requires a proficient workforce and can develop this through collaborating with established organizations (e.g., CBOs) to instruct locals for project execution and maintenance. In terms of financial sustainability, GV can explore innovative financing options, move beyond traditional donors, contemplate micro-credit or diaspora investments, and devise a strategy to help communities sustain the project post-initial assistance. By integrating these insights, GV has the potential to evolve into a more sustainable and impactful model for delivering renewable energy to off-grid African communities.

Action 5 - Business Model Archetypes for GV in the four sites

The experiences we collected through our field work in Homa Hills (Kenya), Era Boru (Ethiopia), Lac Abhé (Djibouti), and Bugarama (Rwanda) design economic and social business models aiming to ensure project sustainability and community ownership. Our analysis for the GV potential business models led to replicable models for empowering communities across East Africa with clean energy and improved livelihoods.

Economic Sustainability: Tailored Solutions for Diverse Needs

Each GV site adopts a flexible economic model catering to its specific needs and resources. In Djibouti and Ethiopia, partnerships with establishing energy companies or international financing bodies offer a path to economic viability, acknowledging the community's limited financial resources. In contrast, Kenya and Rwanda explores multiple approaches, considering partnerships with existing industries, joint ventures, international financing. In Kenya, the community fund-raising as a starting point, is more than a possibility.

Community at the Heart: A Shared Vision for Prosperity

The success of each GV hinges on active community involvement. From contributing to fundraising efforts in Kenya to governing alongside local authorities in Ethiopia and Rwanda, communities are empowered to shape their own futures. The social business model prioritizes not just clean energy access, but also improved healthcare, education, and job creation.

Environmental Stewardship: A Commitment to a Greener Future

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The GV environmental business model embraces clean energy sources and promotes responsible resource management. This not only combats climate change and land degradation, such as in Kenya, but also fosters a healthier environment for future generations. Additionally, in all the communities, the GV aim to reduce respiratory issues associated with traditional biomass burning, leading to a healthier population.

Building a Sustainable Future, Together

The GV project transcends mere infrastructure development. It fosters a collaborative spirit, where diverse stakeholders – communities, NGOs, government entities, and international partners – work together towards a shared vision. Through skills development, local leadership, and ongoing community engagement, the GVs empower communities to become active participants in their own development. The potential social and economic benefits extend far beyond the project sites, offering a blueprint for a sustainable and equitable future across East Africa.

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