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Challenges Faced in Progressing Geothermal Development in SIDS - Case Study on The Union of Comoros

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ABSTRACT

Small Island Developing States (SIDS), represented by some 50 countries around the world, face significant development challenges including energy delivery based on costly fossil fuels, limited natural resources, susceptibility to the effects of climate change and a dependence on international aid for much of their funding. The Union of Comoros, one of the poorest countries in Africa, faces these challenges and more. The main island of Grande Comore is reliant on imported diesel fuel for its electricity generation - fuel alone currently accounts for 75% of electricity generation costs. With high fuel costs and poor electricity infrastructure, the state-owned utility is unable to meet electricity demand or provide a reliable and cost-effective supply.

A number of studies have been undertaken to consider energy options for Grande Comore and, while solar PV is part of the near-term potential mix, geothermal is shown to offer a resilient and cost beneficial solution for the future baseload supply of electricity. It has been estimated that a 10MW geothermal power plant could save Comoros US$30 million in fuel costs each year. However, the costs for a modest geothermal development are significantly higher than comparable developments because of the island's remoteness, difficult terrain and current lack of infrastructure.

The early exploration phase of the program has been funded by donors, with support from the Geothermal Risk Mitigation Fund (GRMF) and executed on behalf of the Government of the Union of Comoros by the United Nations Development Programme. Given the fiscal weakness of the Comorian economy and the limited institutional capacity within the national government, it is unlikely that a viable private sector participation could be established for what is recognised will be an expensive next stage of development. The paper reviews progress to date, documenting the technical success of exploration and efforts to secure funding from various sources. It considers the existing options and what may be the most realistic path to follow to ensure that the potential for geothermal can be firmly established as a key contribution to Grande Comore's energy future.

1. INTRODUCTION

Small Island Developing States (SIDS) are a group of small island countries that tend to share similar sustainable development challenges, including small but growing populations, limited resources, remoteness, susceptibility to natural disasters, vulnerability to external shocks, excessive dependence on international trade, and fragile environments. Their growth and development is also held back by high communication, energy and transportation costs, irregular international transport volumes, disproportionately expensive public administration and infrastructure due to their small size, and little to no opportunity to create economies of scale.

The SIDS were first recognized as a distinct group of developing countries at the United Nations Conference on Environment and Development in June 1992. SIDS' unique and particular vulnerabilities are highlighted in "The Future We Want", adopted at The United Nations Conference on Sustainable Development (also known as Rio+20) that took place in Rio de Janeiro in 2012. SIDS continue to address those structural and external challenges to achieve their sustainable development goals.

"Making Development Co-operation Work for Small Island Developing States" is a report published by OECD (2018) and focuses on the 35 SIDS that are currently eligible for official development assistance (ODA). The report rightly points out that economic growth, human development and vulnerability indicators that point to specific challenges facing SIDS, and suggest that new development solutions and approaches that are needed. The Comoros, which feature in this report, provides some useful statistics on where development assistance comes from, volumes and key socio-economic and environmental vulnerabilities (data from 2012-2015). A snapshot is shown in Figure 1.

This paper will discuss the Comoros geothermal project and the challenges it has faced in order to utilise its geothermal resources for electricity generation, not least of all of challenge of financing such a project in a country which faces the all struggles of SIDS.

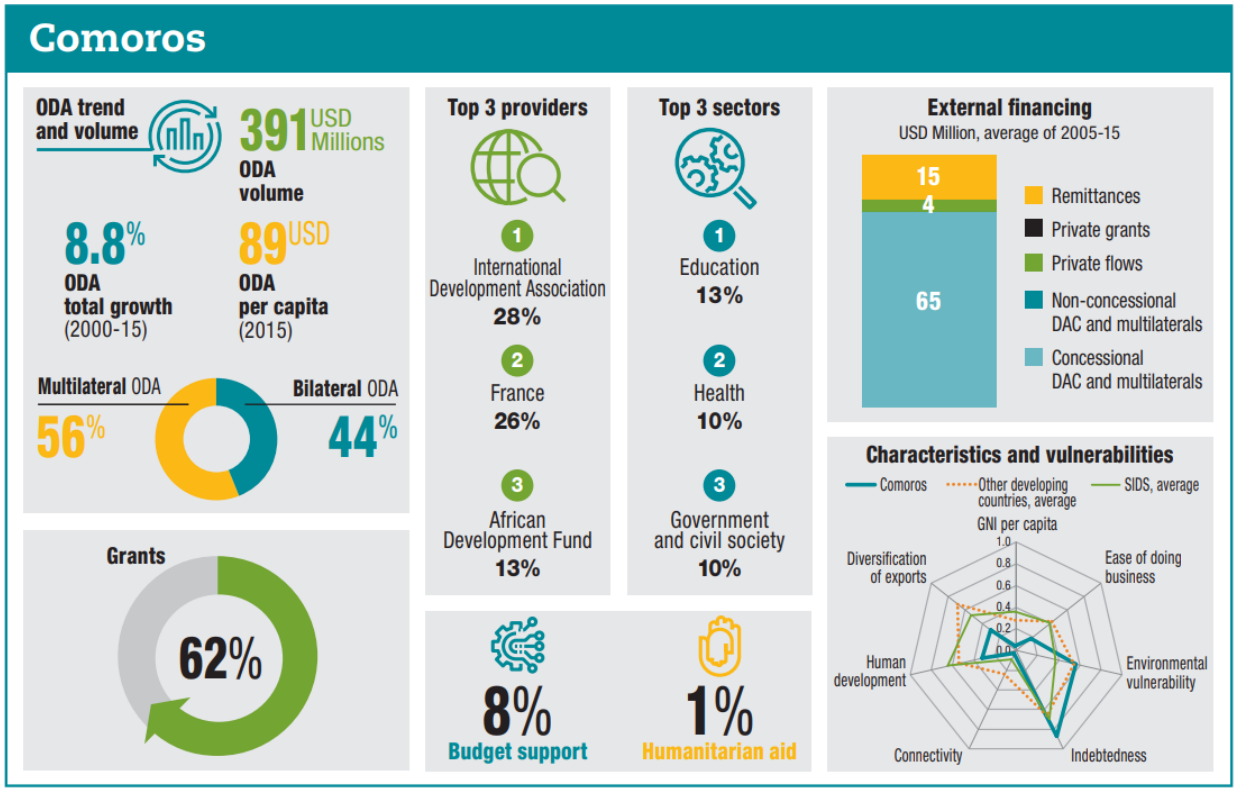

Figure 1: Key statistics on the financing for development landscape and key socio-economic and environmental vulnerability. All figures in the snapshot refer to 2012-15 data (From OECD Report Making Development Co-operation Work for Small Island Developing States, 2018[1])

2. BACKGROUND

The Union of Comoros is a sovereign island nation which lies in the northern part of the Mozambique Channel, between Africa and Madagascar in the Indian Ocean (Figure 2). It consists of three main islands, Grande Comore (Ngazidja) on which the Project is located, Moheli (Mwali) and Anjouan (Nzwani). The total population of the three islands is estimated at 840,000[2]. The country is one of the world's poorest. The economy is dominated by agriculture which contributes to 40% of GDP, employs 80% of the work force and provides most of the exports. 20% of GDP comes from remittances. According to the last household survey conducted in 2014, almost 18% of the population lives under the international poverty line set at US$1.9 (~820 KMF/day) per capita per day[3]. Grande Comore is the largest and most populous of the Comoros Islands with a population of around 400,000. The capital of the island (and national capital) is Moroni, which has a population of 55,000 people.

The island of Grande Comore is approximately about 65 km long and 22 km wide with a total land area of around 1,025 km^2. The island is built from two shield volcanos, with the largest being Mt. Karthala located at the southern end and rising up to 2,361 m above sea level. The volcano is active having erupted more than 20 times since the 19th century, the most recent of which were in April 2005 and May 2006.

As with many other island nations, the primary source of electricity production is from diesel generation, which exposes the country's economy to uncertainty in regard to the cost and supply of diesel imports. Electricity supply is only available intermittently in most of Grande Comore. Users located in Moroni and its immediate surroundings get unreliable electricity supply for most of the day. For the rest of the island, electricity is typically supplied for only a few hours a week and sometimes not at all.

[1] "For the spidegrams, data and indexes were re-scaled through min-max normalisation to obtain values between 0 and 1, where 1 reflects the best position/situation. For variables that are generally associated with preferable development outcomes (e.g. GNI per capita, human development, ease of doing business, diversification of exports, and connectivity) a higher value is associated with better performance, while for indebtedness and environmental vulnerability best performers are countries with the lowest debt over GNI and the lowest EVI score. Therefore, a country that in the spiedegram displays indebtedness below the average line is a country that is performing worse than others in this area, i.e. has a higher debt-to-GNI ration than the average SIDS. Data for the spidegrams are from 2015 (or last year available, but not older than 2012)."

[2] http://worldpopulationreview.com/countries/comoros-population/

[3] https://www.worldbank.org/en/country/comoros/overview

An extensive programme of geoscientific surface exploration of the Karthala geothermal field on Grande Comore suggests that there is potential for a resource that could meet the baseload electricity demand of the island (Jacobs 2015). Cost analyses of the project, through to commissioning, and parallel evaluations of alternative renewable energy options, demonstrate that, despite the magnitude of investment required for a geothermal facility, geothermal could offer a cost effective, long term solution to deliver a secure and reliable source of electricity for Grande Comore (Jacobs 2015b). Comorians are keen to have sustainable, renewable energy development in their country using indigenous resources, and geothermal energy would be a key option.

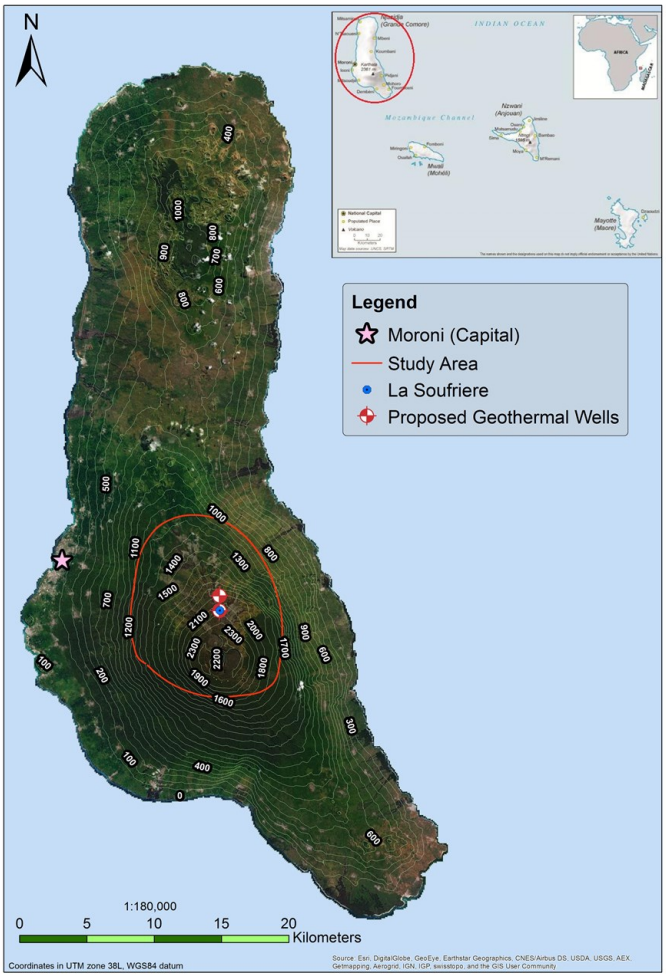

Figure 2 Grande Comore island (Ngazidja) and location of main Study Area. There are 3 proposed geothermal wells at La Soufriere, near the summit.

3. GEOSCIENCE POTENTIAL AND ASSOCIATED STUDIES UNDERTAKEN TO DATE

Surface studies completed in November 2014 indicated that an exploitable geothermal resource exists on Mt Karthala. A further detailed surface exploration programme was undertaken and completed in 2015 in a collaboration amongst the Governments of Comoros and New Zealand, UNDP and the Geothermal Risk Mitigation Fund (GRMF) of the African Union.

These studies have suggested the presence of a resource with likely power generation potential of at least 40 MWe, with indications of a possibly larger resource (Jacobs 2015a) (Figure 3). Exploration drilling, with three full size deep wells, is now planned to confirm the resource capacity. Subject to the success of the drilling activities, these exploration wells could contribute to the production and reinjection capacity for the proposed power development 10MWe.

In an effort to estimate infrastructure requirements more precisely, a detailed assessment with site-visit was carried out in late 2016 which evaluated the port facilities, existing roading and access to the proposed site, and reviewed options for the water supply for drilling. The availability of construction materials, machinery and contractors in-country were also assessed.

From this assessment, the most feasible and practical access routes were determined, including the necessary civil works required to bring the roads up to a standard suitable to transport the drilling rig, ancillary equipment and materials to the site. This included detailing the remedial work that would be required on existing roads and infrastructure. In conjunction with this assessment, a water supply study was undertaken to assess various options for supplying the drilling operations with sufficient flow and quantity of water to complete the exploration drilling program safely.

Additionally, a renewable energy options study (Jacobs 2017a) was undertaken to consider the renewable energy resources on the island -geothermal, wind, solar and biomass - and assess the expected energy production, capital and operating costs of these

options, based on similar projects undertaken on remote islands around the world. The renewable projects were sized based on the limited information that is available for the 20 kV Grande Comore electricity grid i.e. peak demand of around 12 MW, annual electricity demand potential of 65,000 MWh to 80,000 MWh by 2020, total available diesel generation capacity of 11 MW and network feeder capacities of 5 MVA.

To maintain the geothermal project momentum, the Environmental and Social Impact Assessment (ESIA) for exploration drilling is was recently completed. This assessment will not only meet national Comoros standards and regulations but also International Finance Corporation (IFC) environmental and social performance standards.

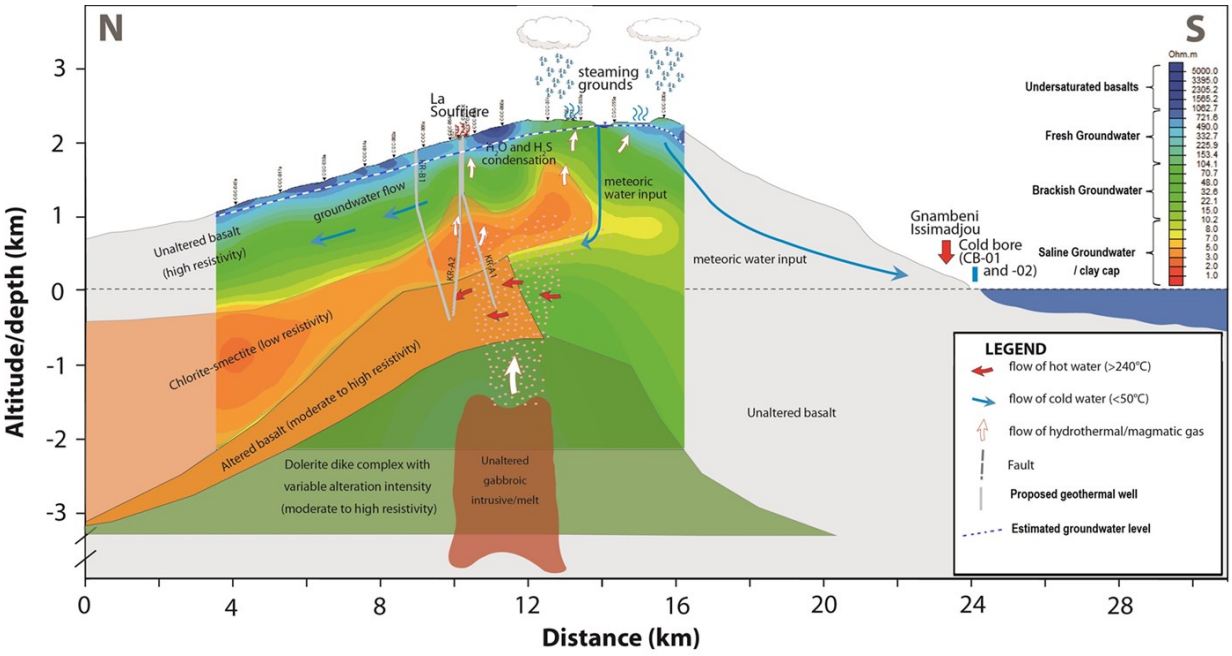

Figure 3 Schematic conceptual model showing known thermal activity, potential groundwater occurrence, and proposed geothermal exploration wells. The colours in this figure stem from a 3D MT resistivity model highlighting zones of different resistivity. Adapted from Jacobs (2015).

4. RENEWABLE ENERGY OPTIONS

A levelised cost of energy (LCOE) study of renewable energy resources on the island of Grande Comore was developed in 2016 as part of an overarching study into the feasibility of geothermal power at Karthala (Jacobs 2017a)

There are a multitude of complex and interrelated issues impacting the Comoros electricity sector and wider economy. These include the total reliance on expensive imported diesel to generate electricity, the degraded state of the electricity network and generation facilities, a high level of electrical and commercial losses, and poor governance within the electricity sector, all of which are manifested in the a low level of electricity access for the population.

For solar to produce the same amount of baseload annual energy as a 10 MW geothermal plant would require around 34 MW of solar arrays on 50 ha of land (or roof area), supported by energy storage capacity in the order of 25 MW / 100 MWh. The latter would cost in the order of $100-200m and, depending on the storage technology used, would need to be replaced every 8-10 years.

A grid connected solar farm of 2 to 5MW could provide a near term option (subject to finance and Government support) to begin reducing imported diesel without the need for energy storage or spinning reserve.

As to other RE resources, there may be some potential for biomass but a lot more work is required to determine availability, size and cost of potential biomass resources. Given the limited availability of land for agriculture and high demand for food, any biomass options are likely to be small in capacity. Based on the limited wind data available, wind is unlikely to be a suitable option for Grande Comore in the next 10 years.

A synthetic daily network load profile for Grande Comore was developed with annual summary electricity data provided by MA-MWE, applying a typical tropical island weekday / weekend load profile curve, allowing for future load growth. Scenarios were run to show the impacts of different levels of solar and geothermal on reducing diesel generation and imported diesel. The combination of a 10 MW baseload geothermal plant and up to 5 MW of solar during the daytime achieved the highest estimated reduction in diesel (20.6 million litres per annum) and was able to meet 95% of the modelled annual electricity demand of 77 GWh. See Figure 4.

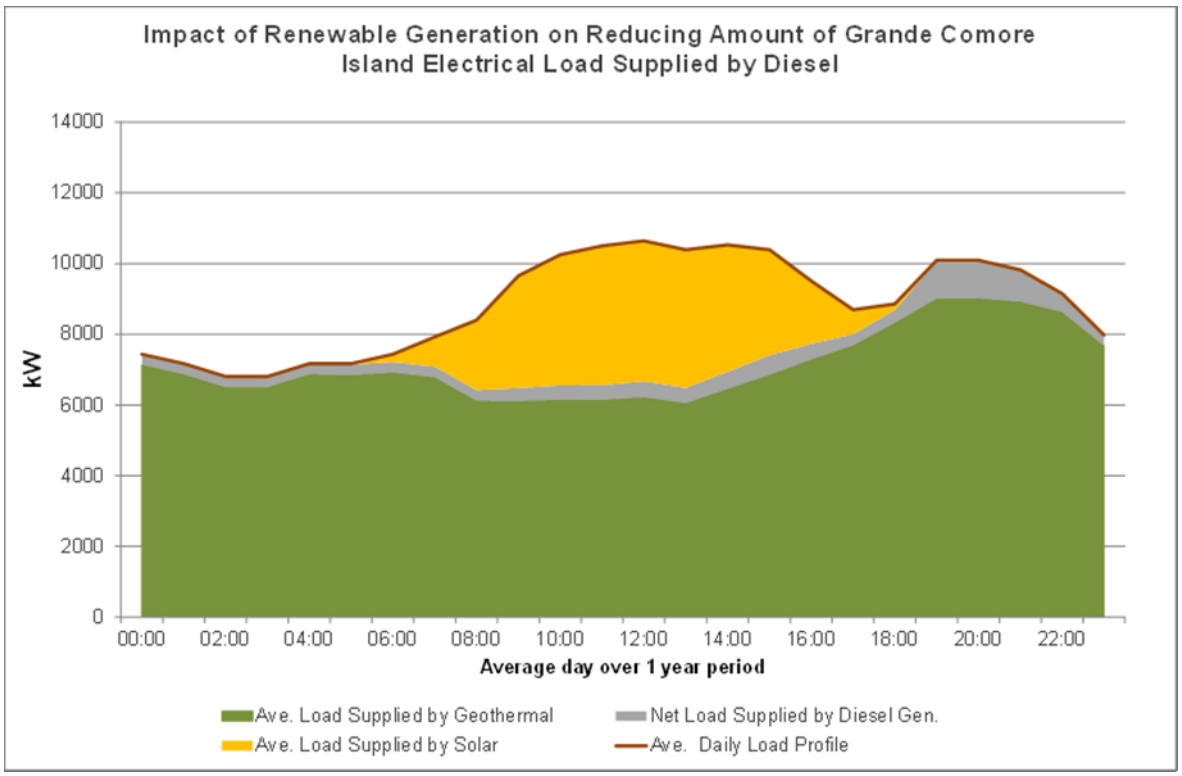

Figure 4: Impact of 5 MW Solar Farm and 10 MW Geothermal Plant on future Grande Comore Diesel Generation

4. PROPOSED DEVELOPMENT APPROACH

The current peak demand on Grande Comore is around 10MW and the installed diesel generating capacity is around 17 MW, although only 11 MW is available. This suggests that generation capacity is adequate. However, the condition of the generation equipment is relatively poor requiring extraordinary maintenance and/or rehabilitation. Still, the main constraining factor to normal service provision is the high cost of the imported petroleum products used for the existing power generators. From the data provided by MA-MWE the average amount of diesel required to generate 1 MWh of electricity is 280 litres. In 2014, this amounted to 10,960,000 litres of diesel consumed. Based on the limited data that is available and given the reported frequency of power cuts, the unmet electricity demand could be in the order of 25,000 MWh per annum, giving a total latent electricity demand of around 65,000 MWh on Grande Comore. If electricity demand does increase by around 5% per annum as suggested (Houmadi 2014) then total electricity demand for Grande Comore could be as high as 83,000 MWh by 2020.

Given this, an appropriate size for a power development on Grande Comore would be in the order of 10MW.

The end user electricity tariffs on Grande Comore are US$0.33 per kWh. The true costs of generation are not published; however, indications are that the true cost of diesel generation in the Comoros islands in 2014 was $US0.71/kWh (excluding distribution costs). Based on a 10 MW geothermal power plant, the Levelised Cost of Electricity (LCOE) is around $US 0.24/kWh. The fact that the true (unsubsidised) cost of generation in the Comoros islands is around 3 times this levelised cost and around 2/3rds of the current subsidised cost, and that the market is continuing to grow at around 5% per year, indicates that there is a clear market for the electricity which could be produced from a geothermal power project developed at Karthala.

Diesel fuel makes up almost 75% of generation costs, the construction of a geothermal plant of even 10MW in capacity could save some US$20 million in fuel costs per year. The total costs from exploration to power plant development are estimated to be in the order of US$125 million, which would be off set after six years by fuel savings alone.

In terms of implementing the project, it appears the institutional environment and fiscal weakness of the economy on Grande Comore would not be conducive to private investment in the project, even though this may be possible under the electricity code. The small size of the project would likely deter those organisations with the capacity and experience to execute it successfully; it is also unlikely that the Government of Comoros could offer to guarantee payments, either under a power purchase agreement or any form of loan arrangement. As such, this plan envisages the project being grant funded by donors and executed on behalf of the Government of the Union of Comoros by the United Nations Development Programme, with support from an internationally experienced and capable geothermal project management company.

5. INFRASTRUCTURE ND DOWNSTREAM COMMUNITY BENEFITS

The target area for exploration and development ranges in elevation from about 1700 m to 2300 m above sea level with scarcity of water at these elevations. Therefore, infrastructure requirements will be more challenging than in other geothermal developments underway in East Africa and will require significant investment.

From the detailed infrastructure assessment (Jacobs 2017c), existing road improvements, a new 10 km road, well pads, waste water sumps, and additional fuel storage, were estimated to cost US$10m. However, there are anticipated benefits for the community and the economy generally beyond the geothermal development, these include:

- Improved access for local farmers to existing plantations and improving their ability to transport their food to market
- 4 WD Access to Mt Karthala for tourism, and subsequent spin-offs for communities (employment, goods and services etc)

Concurrent with the road access assessment, a water supply study was undertaken to assess various options for supplying the drilling operations with sufficient flow and quantity of water to complete the exploration drilling program safely (Jacobs 2016 & 2017b). Although the island receives a high level of precipitation in the wet season (reportedly some 2000mm per annum), the porous nature of the basalt rocks means there is very limited surface water (eg. rivers, streams) but potentially many 'hidden' groundwater aquifers. All options for water supply were assessed including groundwater abstraction, surface catchment and seawater abstraction.

The most viable option for water supply was inland groundwater abstraction from bores down to 350 m depth. The modelling estimated five water bores to be drilled and highlighted 3 potential groundwater exploration areas where potentially high yielding wells could be drilled, to the north of the Karthala summit, at an elevation range of 1,300 – 1,450 m. The cost estimate is some US$13 m which includes drilling five boreholes, downhole pumps, water supply pipes and booster pumps, and excavation and construction of reservoir at drill site. As with the new road access, a reliable water source for communities at higher elevations close to the project will significantly improve their lives and economic outcomes.

If a secure supply of water is identified it may be that this could in future be reticulated for distribution to Moroni and surrounding areas. This could mean that consideration should be made for MA-MWE to provide some cost-sharing for proving inland groundwater resource if the ultimate plan is to turn these proposed bores into water source for the local communities.

6. PRELIMINARY COST ESTIMATES AND FUNDING STREAMS

The figures that follow are conservative and will require refinement as more information is gathered but they are intended to provide guidance as to what order of magnitude of investment may be required, based on the engagement of external specialists and service providers.

At this stage costs up to the exploratory drilling phase are considered appropriate estimates. Provision has been made for drilling up to three exploration wells; it is assumed that these are full production scale wells and that one or more could be used for production or reinjection purposes within the final plant operation. The gross cost of development will be clarified as drilling exploration results are obtained and the location for any production drilling and power plant development is confirmed. These figures have been used in the preliminary economic analysis.

Funding is required in two tranches, the first for the exploration drilling and the second to support the development of a 10MW greenfield geothermal power project once the resource is proven.

Of these requirements for funding the first tranche involving exploration drilling, an application to the GRMF was made in July 2015, followed by a change in eligibility for third well (Oct 2017) meant that at total US$10,870,124 had been approved for exploration drilling. The Global Environmental Facility (GEF) have also approved a contribution of US$6 mil in Jan 2018.

The balance of funding (in the order of US$36.2 million to achieve the budget of US$53.1 million) is being sought from donor sources.

Table 1 Cost estimate for exploration drilling phase only:

Group	**$US000's**
Environmental social and Health Impact Assessment (ESHIA) *Completed, funded by NZAid and UNDP*	
Bankable Feasibility Study *To be completed after exploration drilling*	600
Infrastructure (for exploration) *Share cost with funding agency not aligned with energy projects*	23,000
Exploration Wells (x3)	26,100
Engineering, Contract Prep, PM & Site Supervision	3,400
Total (including 10% estimating margin)	**53,100**
Approved GRMF Dec 2015 then subsequently increased Oct 2017	10,870
Global Environmental Facility (GEF)	6,000
Co-funding sought	**36,230**

Table 2 Cost estimate for full 10MW power plant project:

Group	$US000's
Permits, Land, PPA, ESIA (updated for power development	1,100
Bankable Feasibility Studies & Related	1,100
Infrastructure (for exploration and development)	26,800
Exploration Wells (x3)	26,100
Development Wells (x3)	25,600
Steam Field	5,500
Power Plant (of 2 x 5MW)	29,600
Transmission Interconnection	2,800
FEED, Contract Prep, PM & Site Supervision	7,800
Total (including 10% estimating margin)	**126,400**

A number of specific approaches for funding support have been made over several years. The backing of the GRMF lent credibility to these requests and the Fund provided valuable introductions to a number of potential sources of finance. Given the close association between Comoros and the Gulf States, several regional governments and agencies were contacted. As with any small economy, the dependence on bilateral funding for any development of significant national infrastructure within Comoros is clear. This dependence generates its own tensions as prioritisation of support becomes a challenge. For example, the expenditure for near term needs to replace diesel storage facilities was comparable to almost 50% of the geothermal project budget; timing was however crucial as existing generation had to be maintained.

It is understood that a further donor meeting is planned to attempt to secure the necessary funds to proceed. This will require bold support from key donors to commit to the longer term, potentially sustainable geothermal development against what might offer quicker solutions through PV in particular. The Karthala project has been well structured and executed to date and the long term benefits of geothermal substantiated so supporters should be confident that the investment is in the long term interests of Comoros in achieving a sensible level of energy security using indigenous resources.

7. CONCLUSIONS

With support from the African Union Commission, through the Geothermal Risk Mitigation Facility (GRMF), the UNDP and the New Zealand government, a comprehensive surface exploration programme has been completed on the Karthala geothermal project in Comoros. Based on the positive indications from the surface exploration, the GRMF has offered support of 40% towards the cost of exploration drilling for three full size deep wells and a GEF grant is also available, covering some 32% of anticipated expenditure of the exploration phase.

In addition to the committed funding, the project is seeking US$36.2 million to establish project infrastructure, for access and water supply, and to undertake the drilling work that is essential to confirm the presence of an exploitable resource. Even costed on a conservative basis for cost of capital, geothermal offers a least cost option for generation; grant-based funding clearly enhances this benefit. Estimates suggest that displacing diesel generation would provide an annual saving of some US$20 million per annum.

A number of other donors in the region have been approached, mostly bilateral agencies, but with lukewarm interest in the project. International development agencies need to co-operate and work closer together to provide support to vulnerable SIDS such as Comoros and enable them to access the concessional loans through innovate and collaborative pathways.

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