Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

The Role of Geothermal Power Within the Energy Mix in the Union of Comoros

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Keywords: Geothermal, energy mix, energy security.

ABSTRACT

Comoros is a country with a high reliance on petroleum products. The electricity is mainly generated from fossil fuels (83.3%) and the remaining part consists of hydroelectricity (16.7%). In the aim to end this fossil fuel reliance, a program for the development and supply or renewable energy resources is being implemented. This will enable a reliable and stable electricity supply to be provided to the consumers. The electrification in Comoros is very poor, with a very intermittent connection and daily power outages for the consumers. The main objective is to improve the energy security of the country by implementing renewable energies within the energetic mix, hence mitigating the reliance on fossil fuel products.

It is necessary to know which one of the renewable energies (e.g. geothermal, biomass, wind, solar photovoltaic, hydroelectricity, hydraulic etc.) will be the primary energy replacing thermal power. Solar photovoltaic and wind energies are both intermittent power sources. Their integration within a large-scale electrical system can cause complications in terms of the network stability.

Concerning geothermal power, geophysical and geochemical studies have highlighted the existence of a high potential resource, which was estimated to be more than 40 MW to the northeast of Mt Karthala. Considering the current energy demand of 15 MW, the geothermal development project aims to generate 10 MW in the first instance and then to progressively increase the capacity to 40 MW until 2030.

To implement a stable electricity generated from renewable energy for Grande Comore, none of these energies should be adopted alone, excluding the others. It is always useful having diverse options of energy supply. The energy mix is still the ideal solution. A combination of solar photovoltaic and geothermal energies will significantly reduce the energetic reliance on diesel generation, especially on Grande Comore.

Geothermal is still the best long-term energy option and has an important role in mitigating the diesel importation. Geothermal power represents a strategic emergent industrial sector for Comoros and it has a strong potential in increasing the renewable energy part with the energy mix.

1. INTRODUCTION

Comoros remains today a country that depends heavily on imported petroleum products. Added to the problems related to thermal power plants, the country continues to suffer from energy instability. As a result, the development of renewable energies remains the appropriate solution that the authorities advocate. This will help to know which one is likely to be considered as the base energy that can replace diesel energy.

Comoros, particularly in Grande Comore, has a high potential for geothermal energy estimated at 40 MW. For this, a geothermal development program is set up. The objective is to introduce an average of 75% of geothermal energy into the electricity grid by 2030.

Knowing that Grande Comore has essentially geothermal and solar as the main sources of renewable energy, this document will give comparative details on these two forms of energy that can be exploited and will clearly determine the place of geothermal energy in the energy mix in Union of the Comoros.

2. ELECTRICITY SUPPLY AND DEMAND

Electricity supply is only available for about 6 hours per day in most of Grande Comore, with about 20 hours per day in Moroni and 5 hours per day in rural areas (SREP 2014). In 2013, the capital Moroni was reported as having six hours per week of programmed power cuts with increasingly frequent non-programmed cuts (African Energy, 2013). Due to the high cost of imported diesel the production cost of electricity is 256 KMF/kWh (US 55 c/kWh) whereas end-customer tariffs are set by the State at 132 KMF/kWh (US 28.5 c/kWh), based on an ideal reference cost of 84 KMF/kWh (US 18c/kWh). Therefore significant State subsidisation of the power companies is required with the support of the Government and international grants and loans (AfDB 2016).

3. RENEWABLE ENERGY RESOURCES

3.1. Geothermal

Geophysical, geochemical and geological studies have been undertaken to evaluate the geothermal potential in the Karthala zone (Jacobs 2015). These studies show that the majority of the thermal features are directly related to the caldera of Karthala volcano, with an exploitable geothermal system immediately beneath the caldera. However, the solfatara (La Soufriere) on the upper

northern flanks of the volcano within a rift has both gas chemistry and the resistivity pattern of a potential resource at depth. It may be analogous to the successfully developed resource at Puna, Hawaii.

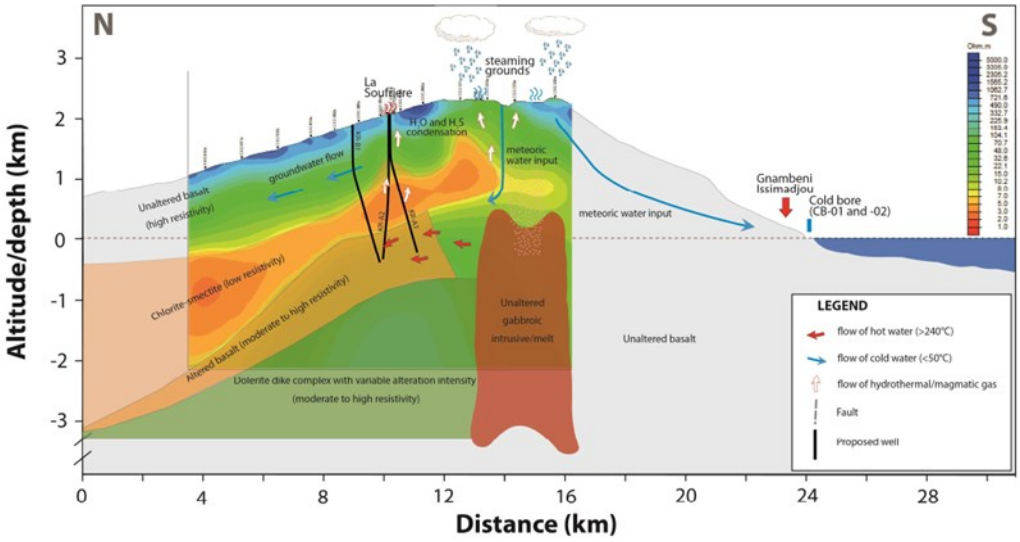

Figure 1: Schematic conceptual model along the rift hosting known thermal activity, and proposed exploration wells.

The results from these studies show that geothermal potential exists and is estimated at 40MW northeast of the caldera. The inferred size of this resource area, located at 800 m asl (Figure 2), is 4.2 km^2 and it exhibits low resistivities which are expected to occur over a mature high temperature geothermal system.

Based on gas geothermometry results, Jacobs assumed an average reservoir temperature of 280°C and the reservoir thickness was modelled with a triangular probability distribution between 500 m and 1300 m with a most likely value of 1000 m. A Monte Carlo analysis was run with 10,000 iterations, which gave a median (P50) value of 38.9 MWe, a 10th percentile value of 18.1 MW and 90th percentile value of 64.9 MW. These values give sufficient confidence for an initial development size of 10 MWe.

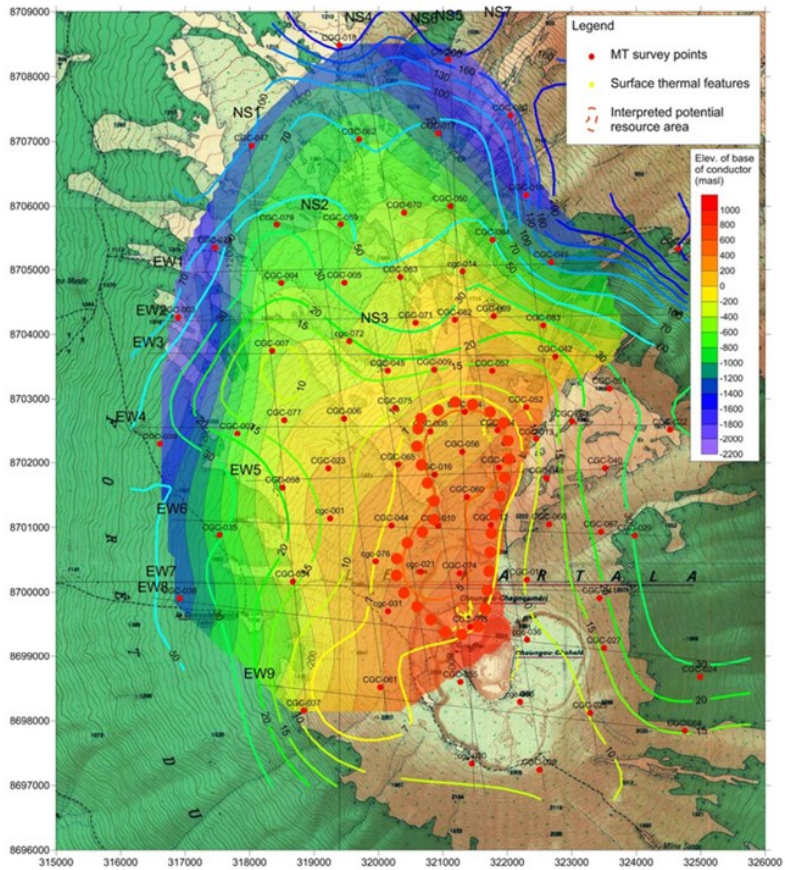

Figure 2: Interpreted potential 4 km^2 geothermal resource area (in red) shown with filled contours of the elevation of the base.

3.2. Solar

Comoros have significant sunshine all year round with an average annual solar insolation on a horizontal surface of 6.14 kWh/m^2/day, based on 22 years of data captured by NASA[1]. On a fixed surface facing north at an 11 degree tilt[2], the annual average solar insolation figure is 6.28 kWh/m^2/day[3]. Figure 3 shows the daily averages by month for these two orientations with the minimum and maximum range for the 22 years indicated for the horizontal insolation data. The greatest variances in solar radiation figures occur in the months of December to April (rainy season or kashkazi) compared to the cool, dry season (kusi) from May to November, reflecting the greater variability of cloud cover caused by monsoons during kashkazi.

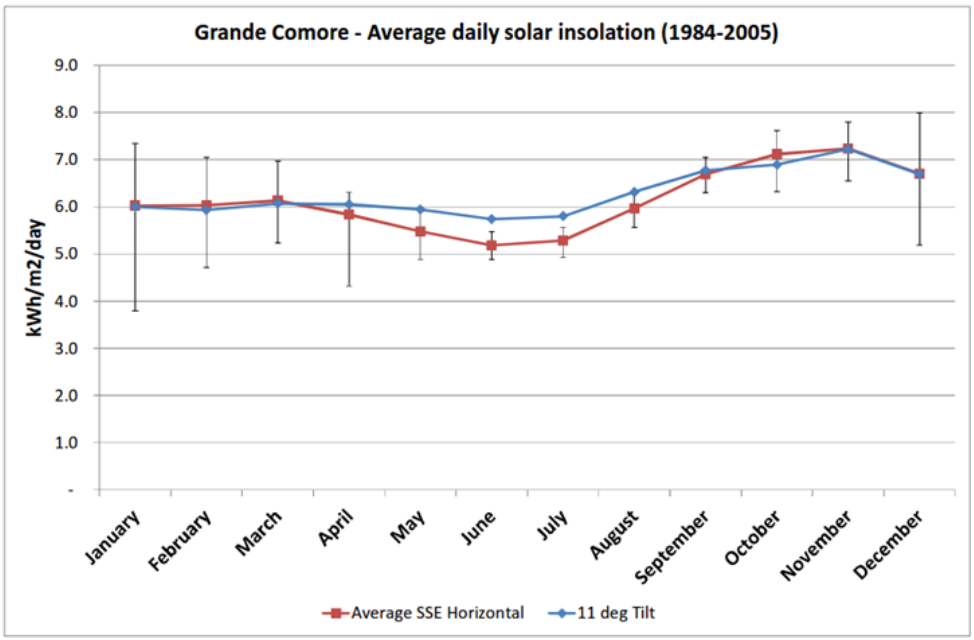

Figure 3: Average Daily Solar Insolation (Horizontal and at 11° Tilt) in Grande Comore (1984-2015)

Given the above insolation data, Table 1 shows the estimated monthly and annual output from a 1kW PV array (e.g. four 1.65 m^2 250 Wp PV modules) flush mounted on a north facing roof with a 10-15° slope in Moroni, Grande Comore.

Table 1: Estimated monthly generation from a 1 kWp solar PV array facing North tilted at ~11° in Moroni

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Generation KWh	146	130	147	142	144	136	142	155	161	169	170	164	1,805

4. INTEGRATION OF RENEWABLES (GEOTHERMAL AND SOLAR) INTO THE GRANDE COMORE SYSTEM

In order to consider the impact that renewables could have on the Grande Comore electricity network system, a synthetic daily network was developed and load a profile for Grande Comore based on the 2014 MA-MWE[4] monthly electricity demand data (total of 38,851 MWh) and applying a typical Caribbean island weekday /weekend load profile curve. The total annual load was doubled to 77,700 MWh per annum to reflect the impact of the future replacement of the diesel generators on Grande Comore to meet a peak demand of 15 MW and assuming that sufficient diesel is available to meet latent demand growth. This gave an average daily profile curve for the island as shown in Figure 4.

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[1] Atmospheric Science Data Centre, NASA, https://eosweb.larc.nasa.gov/cgi-bin/sse/grid.cgi?&num=224079&lat=-11.66&submit=Submit&hgt=100&veg=17&sitelev=&email=skip@larc.nasa.gov&p=grid_id&p=ret_tlt0&step=2&lon=43.33

[2] As a general rule of thumb, the near optimal angle for a fixed position solar panel facing towards the equator (north in the Southern Hemisphere) is approximately the latitude of the location. In the case of the city of Moroni on Grande Comore the latitude is 11°42' South.

[3] To put this in perspective the average annual solar insolation for Auckland, New Zealand is 4.22 kWh/m /day on a horizontal surface and 4.58 kWh/m2/day on a surface facing north at a 36 degree tilt

[4] Madji na Mwendje Ya Komor (Society of Water and Electricity)

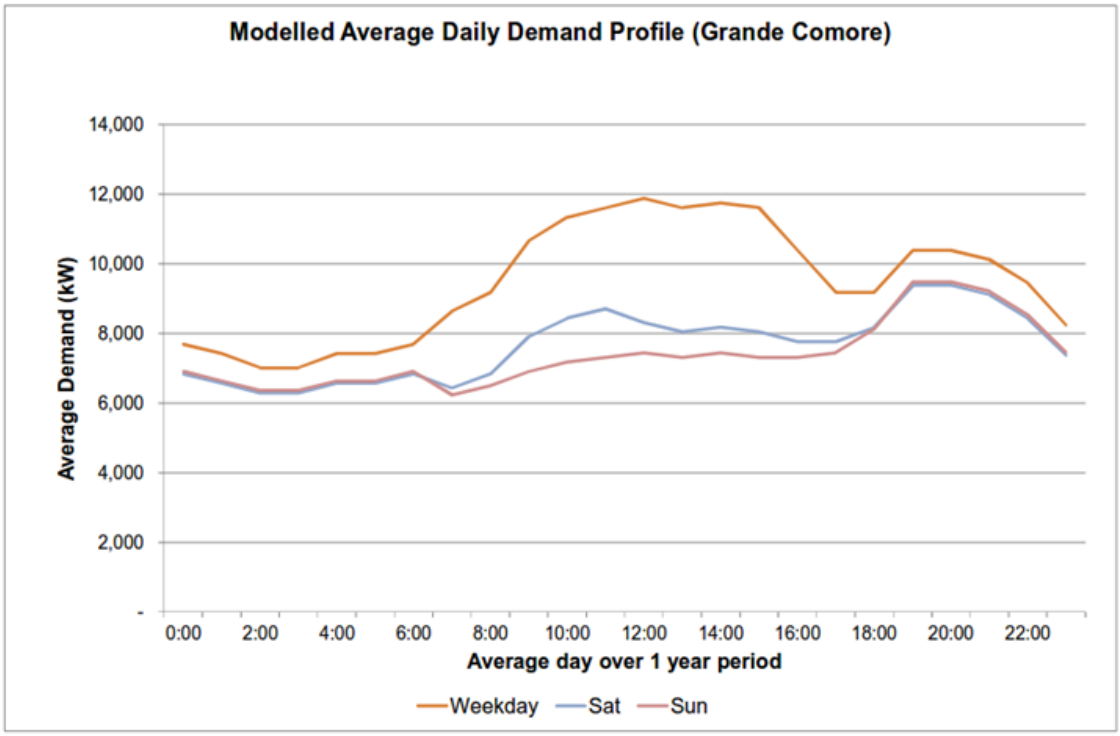

Figure 4: Modelled Average Demand Profile for Grande Comore

A number of renewable scenarios were modelled to show the potential impact of different configurations of solar farms and the proposed Karthala geothermal plant on the amount of diesel generation. For the purpose of the exercise network losses were ignored and a nominal amount of diesel generation was kept operational to manage frequency even when sufficient renewable generation was available to meet the load. The results are tabulated in Table 2 and shown in other figures below.

Table 2: Estimated Impact of Renewable Generation Scenarios on Grande Comore Diesel Generation

Scénario	Diesel Generation (MWh pa)	Solar Generation (MWh pa)	Geothermal Generation (MWh pa)	Diesel Required (litres pa)	% Renewable	Diesel Saved (litres pa)
Diesel generation only	77,702	0	0	21,756,600	0%	0
5 MW Solar	66,403	11,300	0	18,593,000	14.5%	3,163,500
2 x 5 MW Solar Farms	56,107	21,594	0	15,710,200	27.8%	6,046,400
3 x 5 MW Solar Farms	50,056	27,646	0	14,015,600	35.6%	7,741,000
10 MW Geothermal Plant	7,150	0	70,553	2,001,900	90.8%	19,754,700
5 MW Solar + 10 MW Geothermal Plant	3,949	11,300	62,453	1,106,000	94.9%	20,650,600

As an extreme example Figure 5 shows the impact of three 5 MW solar farms on the amount of generation required from diesel. Table 2 shows that there are diminishing returns from increasing the amount of solar on the network as there are more instances of the daily solar generation peaks exceeding peak demand in the weekends and so excess solar energy has to be spilt. It is unlikely that even with new diesel generators the Grande Comore system could cope with this amount of intermittent generation without adding expensive large scale energy storage (batteries).

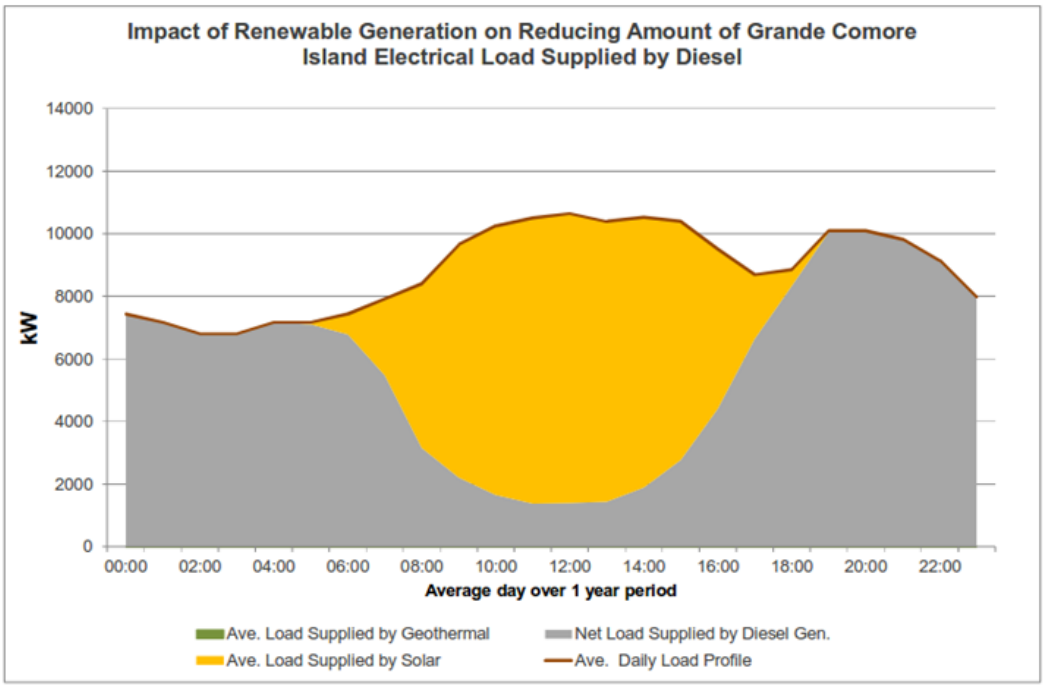

Figure 5: Impact of 3 x 5 MW Solar Farms on future Grande Comore Diesel Generation

Figure 6 shows the significant impact of a baseload 10 MW geothermal plant on reducing the amount of diesel generation required to meet the load. Based on the load profile assumptions the geothermal plant could generate up to 91% of the electricity demand with diesel generation required to meet day time and evening peaks. The capacity factor of the geothermal plant would be initially be around 80% but this would increase over time as electricity demand grows in response to lower cost of electricity and higher levels of electrification are achieved.

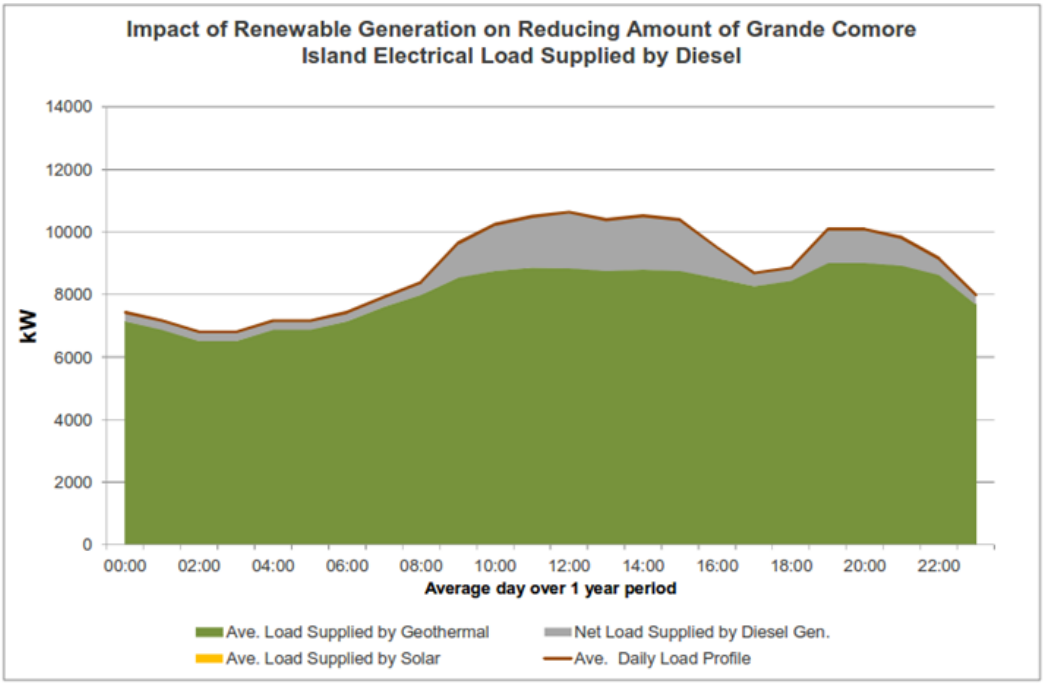

Figure 6: Impact of 10 MW Geothermal Plant on future Grande Comore Diesel Generation

Figure 7 shows the combination of a 5 MW solar farm and 10 MW geothermal plant on reducing the amount of diesel generation required. As noted in Table 2, this would achieve 95% renewable generation.

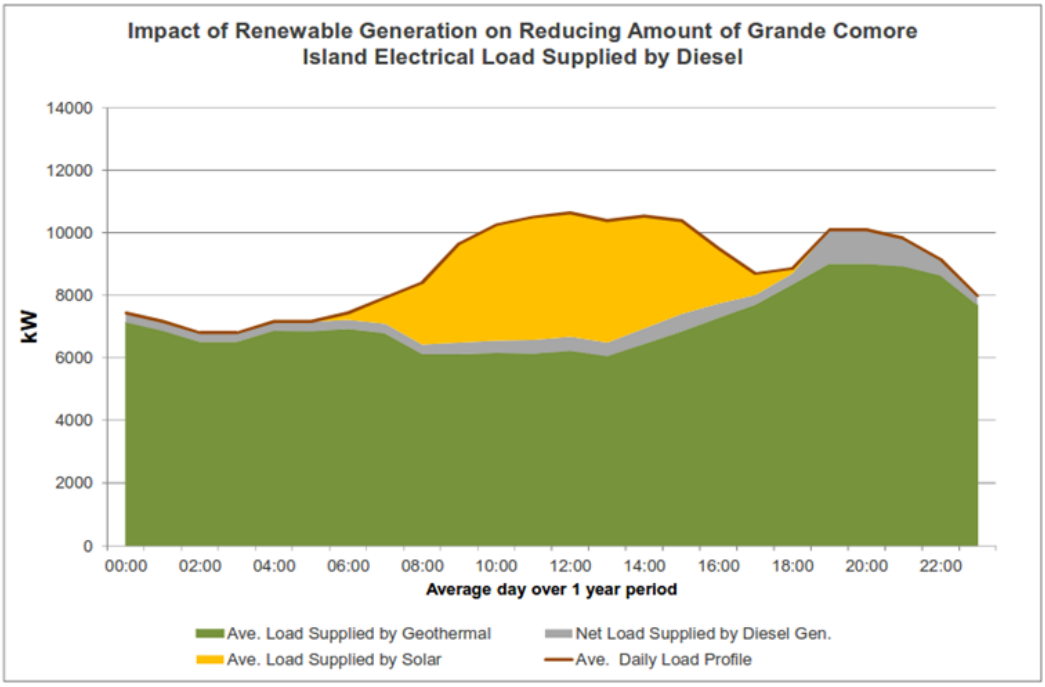

Figure 7: Impact of 5 MW Solar Farm and 10 MW Geothermal Plant on future Grande Comore Diesel Generation

In this scenario the geothermal plant capacity factor is lower than the geothermal only scenario, however this would improve over time as the underlying network demand grows and the solar farm output drops by about 0.5% per annum from gradual degradation of the solar panels.

5. CONCLUSION

In terms of large scale renewable electricity options for Grande Comore there is no single winner that should be adopted to the exclusion of others. As with many other power systems around the world, there is always value in having diversity of energy supply options and a combination of solar and geothermal probably has the greatest potential for reducing Grande Comore's reliance on diesel generation.

Subject to resource proving, a 10MW geothermal plant has the most potential to provide a significant long term base load renewable option for Grande Comore and have the greatest impact on reducing the amount of imported diesel.

To use solar to produce the same amount of annual energy as a 10 MW geothermal plant would require around 34 MW of solar arrays on 50 ha of land (or roof area) and 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.

On the basis of these conclusions, geothermal energy remains the most stable energy and can be considered as a basic energy that can replace thermal energy.

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