CHALLENGES OF GEOTHERMAL DEVELOPMENT IN SMALL ISLAND DEVELOPING STATES (SIDS)

Alastair Brookes[1]

[1]Jacobs New Zealand, 12-16 Nicholls Lane, Parnell, Auckland New Zealand

alastair.brookes@jacobs.com

Keywords: *Geothermal Energy, SIDS, Small Island Developing States, Development Finance, Climate Change*.

ABSTRACT

Driven by all the competing factors of sustainable development, the Governments of Small Island Developing States (SIDS) are looking to renewable energy as a way of meeting their climate change obligations whilst simultaneously developing the economy and improving social outcomes. Typically, these islands rely on imported diesel fuel for power generation resulting in high power prices, proving to be a drain on foreign capital, and making a significant contribution to their annual carbon emissions (from both transportation and consumption of the fuel).

Globally, there are many Small Island Developing States with geothermal energy potential, from the Pacific (Vanuatu, Solomon Islands) to the Eastern Caribbean (Dominica, St Lucia, St Vincent, Grenada), outer islands of Indonesia and coastal Africa (Comoros). A small geothermal project (e.g., 10MW) holds the potential to transform a small nation and supply much of the country's power needs from an indigenous, low carbon, a renewable resource. Whilst some renewable energy options are cheaper, faster and easier to implement, the geothermal promise remains enticing and a key component of transforming a nation to be 100% renewable in the most reliable and affordable way.

The Governments of Small Island Developing States have recognised the potential of geothermal energy and utilised various approaches to attract public and private sector support to realise the geothermal promise. The New Zealand Aid Programme and many other donors have provided technical, legal and financial assistance to partner governments, yet to date, an operating geothermal power plant remains elusive. In this paper, we discuss the unique challenges that geothermal developments encounter in Small Island Developing States and approaches to overcome these.

1. THE GEOTHERMAL PROMISE FOR SMALL ISLAND DEVELOPING STATES

Generation of electricity on Small Island Developing States (SIDS) is typically provided by diesel generators, resulting in high costs for electricity (often more than US$0.40 / kWh), supply interruptions, as well as vulnerability to oil price shocks. The use of diesel makes a significant contribution to the country's carbon emissions, and the expenditure creates a drain on foreign capital. Geothermal resources are present in many small volcanic islands around the world. The 'geothermal promise' for such islands is that a single geothermal power project can deliver a secure, indigenous, low carbon source of renewable electricity that will reliably provide much of the power for the island, reduce dependence on imported diesel and provide lower-cost power.

Globally, there are few successful examples of geothermal power projects on small islands. Where this has been achieved, such as in Hawaii, Guadeloupe and the Azores, the islands have benefited from the financial and political strength of being associated with larger nations, respectively the USA, France, Portugal and the European Union. Often with higher standards of living than Small Island Developing States, the demand for electricity tends to be greater, and these political allegiances provide investors with greater confidence that a robust economy exists.

On the other hand, Small Island Developing States such as those in the Pacific and Caribbean have been trying to realise the geothermal potential for many years but have not yet been able to overcome the various obstacles to development. Alongside common hurdles experienced by developing nations, such as attracting drilling finance to prove the geothermal resource and complications over land ownership, Small Island Developing States are uniquely disadvantaged due to the particular characteristics due to their size and geography and the corresponding impacts on the electricity, political, financial and economic systems.

2. IDIOSYNCRACIES OF SMALL ISLAND DEVELOPING STATES

The small Island Developing States share common traits that influence the viability of developing geothermal power projects. A geothermal project of modest scale (say 10MW) represents an investment of national importance as it will become the main generator of electricity for the nation, perhaps supplying 50 - 70% of an island's power. As a potential game-changer, it will be one of a few major projects being progressed in the nation and will attract significant political interest. Whilst it may be a game-changer, there is a range of challenges to overcome that are common across Small Island Developing States. These can be grouped as:

- Economic – Fragile economies with little industry, small private sector and a reliance on the public sector.
- Financial – Unfavourable investment environment due to weak regulations, limited government borrowing capacity, a small power utility and balance sheet.
- Infrastructure – Weak infrastructure, limited access to equipment and supplies.
- Physical – Remoteness creating high fuel/equipment transport costs and a propensity to be severely disrupted by extreme weather events.

Proceedings 43rd New Zealand Geothermal Workshop
23-25 November 2021
Wellington, New Zealand
ISSN 2703-4275

- Human – Limited human capacity due to the small population, private sector and Government.
- Political – Propensity for nepotism, vested interests in power companies and project timeframes crossing political cycles.
- Technical – Relatively low demand for power and weak grids requiring investment to maintain grid stability and security of supply.

3. IMPACT ON THE GEOTHERMAL DEVELOPMENT APPROACH

3.1 Project Scale

The demand for power in Small Island Developing States tends to be low on a per capita basis due to low incomes, small commercial and industrial sectors, and in some cases, low rates of access to electricity. The overall low demand for power and accompanying load profiles means that a single geothermal generator can in theory, provide all the overnight baseload requirements (defined as the permanent minimum load that a power supply system is required to deliver). The result is that a geothermal development will be small by global standards, with plants of 5MW - 10MW often sufficient for baseload. This presents several technical challenges and increases the risk associated with generating a reliable return on investment. Key impacts include:

1. The small number of wells required for a project places increased importance on drilling success.
2. The relative cost of development per kW installed capacity is higher than for larger projects.

3.1.1 Drilling Success

All geothermal projects benefit from successful drilling campaigns, and a larger project may have several stages of drilling to explore, delineate and exploit the proven resource. However, in Small Island Developing States, one production well and one reinjection well may potentially be sufficient for the project. This makes exploration drilling also serve as the production drilling and makes success particularly critical. Such projects are likely to have a higher proportion of total project cost associated with drilling, and therefore there is less tolerance for unsuccessful wells. Modelling by Jacobs displays this impact in Table 1 in terms of total project cost under three scenarios. Firstly, a highly successful drilling campaign resulting in a total project cost of $83M with three wells. Secondly, a drilling campaign of medium success requiring five wells and associated cost total project cost of $101M. Finally, a project where drilling success was low and costing $130M with eight wells required.

	Low	Medium	High
MW per full-size successful well	4 MW	7 MW	11 MW
Exploration drilling success rate (first 3 wells)	35%	50%	60%
Development drilling success rate	60%	70%	80%
10 MWnet - Total wells including 1 injection well	8	5	3
Capital cost for full development (USD)	$130m	$101m	$83m
Development cost per kW	$13,000	$10,100	$8,300

Table 1: Indicative cost of 10MW plant under three different drilling scenarios

3.1.2 Higher Development Cost per KW

Lazard's levelized cost of energy (2018) reports geothermal development costs of between US$4000 – US$6,400 per kW. As shown in Table 1, Jacobs modelling indicates that costs for a 10MWe geothermal development in Small Island Developing States maybe double that estimate. The higher unit cost of development occurs for several reasons:

- Drilling as a higher proportion of development costs, often coupled with higher relative infrastructure costs due to limited availability of materials and equipment on the island.
- Access to geothermal resources is limited by protected areas (normally underwater catchment and forest reserve/national park status) and often requires directional drilling.
- Higher relative owner's costs, covering project management, procurement, financing and commercial aspects.
- Small geothermal turbines are less common and suffer from diseconomies of scale and a less competitive market.
- More than one geothermal generator (smaller units) may be required to meet power system security requirements.
- Remoteness, scale and lack of facilities on the island often require the import of all equipment and materials.

3.2 Power System Considerations

Geothermal power plants have high availability and can provide consistent output 24 hours per day. Not only does this differentiate geothermal from other sources of renewable energy but achieving a high capacity factor is important in delivering the lowest cost of power and making the economics of a geothermal investment more attractive. Geothermal proponents naturally cite this generation profile as being well aligned with providing all the baseload power for an island. For a small island, this baseload may only be a few megawatts, so a 10MW geothermal plant could potentially provide a 10MW base load requirement.

On closer inspection, this assumption is poorly aligned with the reality of maintaining power system security on a small island grid. Specifically, the impact of short and long-term outages from a geothermal plant has impacts on the power company's total cost of operation.

3.2.1 Short Term Outages

Perhaps the most critical item affecting the ability of a geothermal power plant to provide baseload power is the requirement for a 'spinning reserve' to maintain power system security during unexpected outages. The spinning reserve is the amount of unused capacity in online energy assets which can compensate for power shortages or frequency drops within a given period of time. If the largest generator in the power system is tripped, the remaining generators should increase their output to recover the power shortage.

In large grids, the spinning reserve is typically achieved by quickly ramping up one or more generators, often open-cycle gas turbines, hydro plants or unused generation capacity on operating thermal plants. The power markets are structured to financially reward generators that provide a spinning reserve. In Small Island Developing States, this spinning reserve is typically achieved by operating multiple diesel generators at less than 100% output, allowing for a quick increase in the generation when required. Alternative power generation options are typically not available, and when they are (such as small hydro plants), there may be technical limitations that prevent them from being able to provide such a quick response.

In the case where a geothermal power plant provides all the baseload, the system operator must have access to a spinning reserve equal to the largest generator on the power system, which, if it is a 10MW geothermal generator, would require 10MW of spinning reserve. In principle, diesel generators could provide this by idling with 100% of potential output available. However, this approach would see diesel generators permanently using fuel with no power production. As well as being inefficient, this approach may be against regulations designed to minimise the cost of power to the consumer. In reality, the diesel generators will be required to operate with some output, probably around 50% capacity, so that they are working efficiently. This would then provide 50% capacity to be used instantaneously. This approach, however, will reduce the amount of potential baseload generation a geothermal plant could provide as diesel generators would be providing power equivalent to the largest generator on the system. This impact is illustrated in Figure 1, modelled on the Caribbean island of St Lucia, which shows a typical weekday load and assumes a 30 MW geothermal plant meets baseload requirements, and the largest generator is assumed to be 7.5MW (based on the geothermal plant being 4 x 7.5MW units).

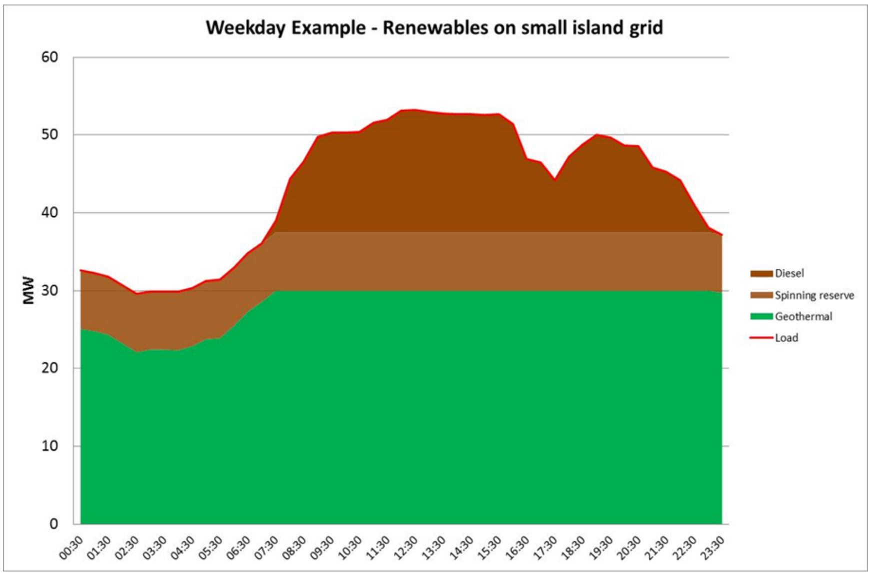

Figure 1: Impact of spinning reserve on the output of 30MW geothermal project

As can be seen, the impact of this is that during overnight periods the output of the geothermal plant is reduced to ensure the spinning reserve is available. The upshot of this is that it may be necessary to either reduce the size of the geothermal generator to less than baseload or to have multiple units (in this example 4 × 7.5MW) to reduce the amount of spinning reserve required. There may also be additional requirements placed on the geothermal generator, for example, by increasing its inertia. Alternatively, the utility will need to invest in either fast response equipment, such as can be achieved through a battery system. These factors contribute to the higher capital cost of a geothermal plant in a Small Island Developing Nation, which may reduce the revenue stream or require additional investment from the utility, which in turn impacts the overall cost of electricity generation on the island.

3.2.2 Long Term Outages

Long-term outages due to planned maintenance of a geothermal plant present a different challenge. During such times, the geothermal plant may be unavailable for days or weeks. To maintain power to the island, the utility must be able to provide the equivalent output that the geothermal plant has been providing. In this case, a battery is of no use, and so the utility will likely retain a fleet of diesel generators for use during these periods. This has obvious financial implications for the utility as they must maintain the generators and also keep the assets on their books. It increases the fixed component of the electricity charge, and during periods when the diesel plants must operate, the price of power to consumers will increase. This can create complications around tariff setting and ensuring the lowest cost of power is achieved.

3.2.3 Impact of Variable Renewables

Other renewable energy options, in particular solar and, to a lesser extent, wind, have become the lowest capital cost renewable generation. Private developers note the high price paid for power in small islands and see this as an easy win for making solar and wind projects attractive. Solar, in particular, has attracted a lot of interest due to the relatively low capital requirements, relatively simple project execution and speed to market, which also makes for a more politically enticing option. Wind farms tend to lack scale and may struggle with available infrastructure, leading to the use of smaller turbines and a less financially attractive project than initially envisioned.

From the geothermal developer perspective, the generation profile of a solar farm aligns reasonably well with a geothermal generation profile. Daytime generation may not adversely impact the geothermal plant's ability to evacuate power (depending on the capacity installed). Wind, on the other hand may be available day or night and will likely take precedence over geothermal output as it will have been financed on the back of a take-or-pay power purchase agreement. The net result in a small grid with multiple renewable energy sources is that the geothermal power plant sized to meet baseload requirements is likely to have to curtail generation and follow load, resulting in a lower overall capacity factor (the ratio of actual electrical energy output to the maximum possible electrical energy output over a period).

Figure 2 builds on the previous example, showing how the addition of 10MWp of solar and 12MWp of wind could impact the daily output from the geothermal power plant, reducing the geothermal plants' peak output to just 43% of installed capacity during overnight lows. If this were to occur over the course of the year, the capacity factor would be reduced to around 80%.

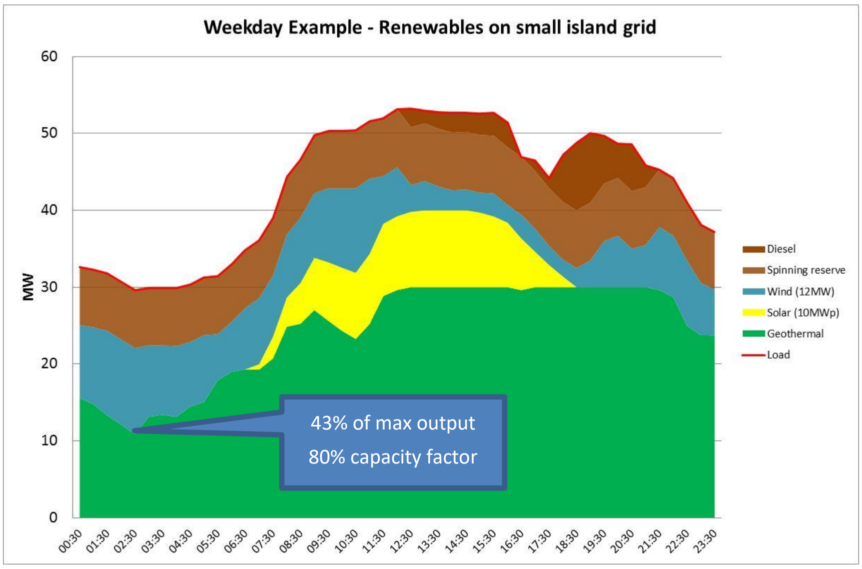

Figure 2: Impact of variable renewables on the output of 30MW geothermal project in Small Island Developing State

The reduction in annual capacity factor has a negative impact on the project economics. For example, reducing the geothermal plant annual capacity factor from 90% to 80% requires an increase in the electricity tariff received of approximately 10-15%. When coupled with an already high capital cost of development, this impact starts to make the promise of low-cost electricity harder to achieve.

3.3 Investment Environment

The energy investment environment in Small Island Developing States has particular risk attributes that make it challenging to attract financing of the scale required to develop a geothermal energy project. Whilst some of these are common in developing countries, the size of the islands reinforces certain aspects, in particular:

- High costs of financing and limited financial services.
- An absence of supportive regulatory frameworks and capacity to police.
- Small energy markets constrain the establishment of an independent regulatory agency.

- Power purchase agreements that must be backed by Sovereign Guarantees, and where such Guarantees may not be available due to high Government debt.
- Lack of negotiating capacity.
- Low financial transparency and sustainability of the utility, which is often state-owned.

A key impact of these factors, when combined with the small project scale, is that credible developers and investors are often hard to attract. Second-tier or newly formed geothermal developers see an opportunity and so approach Governments with gusto promising cheap and bountiful electricity. Lazard (2018) reports the levelised cost of geothermal energy as US$71 - $111 / MWh (7 – 11 cents per kWh), and such numbers are often used to secure a concession and power purchase agreement. These key commercial documents are then leveraged to raise capital for drilling and development. However, raising private equity for such projects is not always easy, and such investors typically have high expectations for a return on investment, which may surpass 20%.

Assuming this can be achieved, drilling is successful, and debt can be attracted, commercial banks will also command a relatively high-interest rate of say 8% with a 15-year tenor. Modelling by Jacobs indicates that a privately financed 10MW geothermal project with a capital cost of US$80M will require a tariff of over US$0.20 per kWh to meet the required hurdle rates (30% equity at 20% return, 70% debt at 8% interest over 15 years). A tariff of 20 cents per kWh is broadly equivalent to the cost of generating from diesel.

Once Government and the developer enter negotiations, the above-mentioned factors generally slow down progress, as the Government's grasp the impact of the project on the utility, tariff and associated investment requirements. After a period, it becomes clear that the promise of cheap power is not so cheap after all, and negotiations are prone to stalling. And all this may occur before any drilling has occurred and a resource has even been discovered.

4. ADDRESSING THE CHALLENGES

4.1 Policy and Regulation

A key starting point is having the right policy, legal and regulatory environment to create clear market signals and attract finance. The small Island Developing States will normally require technical assistance to prepare these documents and can normally attract a grant from a multi-lateral or bi-lateral partner. The policy is relatively easy to develop, as commitments are far into the future and the actual action is not urgent. Canny politicians know that this is a necessary step to accessing finance and need not necessarily interfere with their agendas.

The enactment of Laws, such as the Geothermal Act and Electricity Supply Act, is another matter altogether. The creation of Laws becomes highly politicised, and lengthy constitutional processes must be undertaken. Development partners have been all too willing to produce good pieces of draft legislation. However, these are often subject to numerous revisions, and in some instances, key aspects are removed that diminish their effectiveness. This often relates to the balance of power in decision making, with Minister's reticent to give power to other newly established authorities.

The regulations necessary to administer the Law are typically complex and require extensive consultation, substantial technical support and are similarly subject to watering down or amendments that can diminish effectiveness. They will also likely take many years to be developed and become effective.

Whilst these behaviours and challenges are not necessarily limited to Small Island Developing States, we wonder whether a Geothermal Law is really necessary at all. The reason for this is that there is typically only one geothermal resource and, therefore, only ever likely to be one project developed. Experienced international consultants typically overlook this aspect when drafting Laws, and it could be considered that a contractual mechanism would be sufficient to achieve the security of income and access to the resource required by a developer.

4.2 Development Finance

The Paris Accord 2015 created a unified global approach to reducing carbon emissions by letting nations determine their own carbon emission reduction targets. For Small Island Developing States, many of the proposed targets are premised on receiving financial support to support the transition. The funds available from bi-lateral development partners and the international community, for example, through the Green Climate Fund and philanthropic organisations such as the Clinton Climate Initiative, provide much-needed resources in the form of grants, low-cost funds and technical assistance. The challenge for Small Island Developing States is prioritising funds against the many competing needs to actually achieve other development outcomes.

One approach is to utilise dedicated financing for geothermal development, as the Caribbean Development Bank has established through their GeoSmart programme. Use of grants and contingent grants (repayable as a loan if the well is successful) to determine if there is a resource is an approach that has been adopted in many developing countries. The difference for Small Island Developing States is that all the drilling for the project (or close to it) needs to be financed in this way in order to end up with a project that minimises the electricity tariff.

Jacobs modelled the impact of grants, contingent grants, and concessional finance (World Bank will offer 0.75% interest, 40-year tenor, 10-year grace) on the final electricity tariff required. As shown in Figure 3, the combined approach can reduce the required tariff by around 30% from a privately funded development.

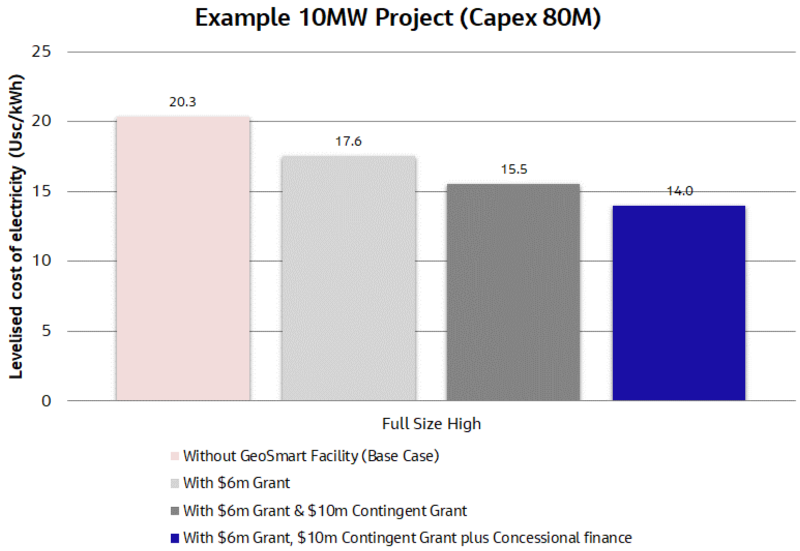

Figure 3: Impact of financing mechanisms on geothermal energy tariffs for 10MW project

This approach has clear benefits to making a geothermal project more financially attractive. However, access to finance alone has not yet proven to be sufficient to achieve an operational geothermal plant in Small Island Developing Nations. It is, however, an important piece of the puzzle.

4.3 Development Approaches

As discussed above, a privately funded geothermal development in a Small Island Developing State is likely to result in an electricity tariff that is unattractive for the Government due to the cost of finance. This means that development should be progressed using public funds or through a public-private partnership.

Public funds, in particular, grants if they can be attracted, provide the logical first step in identifying a geothermal resource through surface exploration and then drilling. This approach helps to de-risk the resource and replaces high-cost finance (private equity) with funds that do not require a return on investment. Slim hole programmes may be appropriate due to resource risks or because there is insufficient grant funding for standard size wells.

Discovery of the resource may have been achieved; however, there likely remains drilling and development risk (in particular the bankability of the PPA) which may prevent debt from being used to complete the development. The Government may look to bring in the private sector at this stage or proceed with further drilling using public money. At this stage, a contingent grant provides the lowest cost financing option to progress. Regardless of whether the venture is publicly funded or a public-private partnership, at this stage, the project must be well thought through with plans in place for development, power system upgrades and all other associated factors, not least the development vehicle. At this point, the setting of a realistic tariff for electricity sales is necessary. This can include using a tariff range, a target amount with a pain/gain mechanism or a fixed tariff.

With the contingent grant, funds are made available for the drilling programme and if the wells are successful the grant is converted into a loan at favourable terms. Importantly, proving the ‘success’ of a well need not be overcomplicated, as the low number of wells required for a geothermal project in a Small Island Developing State means that success can simply be judged by whether the power project proceeds to construction and operation, with repayment of the loan commencing after financial close or following commissioning.

With few business opportunities on islands, Governments will often seek to be a partner in the development, leveraging the grant money and land for an equity stake in the project company. In principal, this can be attractive to a private partner as it can help with risk allocation and reduces the risk of the Government exercising its power of eminent domain and seizing the asset. In practice, setting up a public, private partnership introduces another layer of complexity and may require new laws and regulations to be developed. The process of establishing the Special Project Vehicle can frustrate private partners as Governments may lack capacity or bring in political motivations to achieve the lowest tariff possible, which may be at odds with what the private partner is seeking. An open book approach is essential at this stage.

Whilst a publicly funded approach can avoid the above scenario, development agencies and international funds often come with a plethora of requirements that make accessing the funds complex, slow and outside the capacity of already stretched public servants. This process can often extend geothermal development horizons out to a decade or more, during which time the policy imperative may change due to external factors (for example, oil prices may plummet), political parties may change, or the financial situation of the country may change. Consistent and deep technical support is required for long periods in technical, financial, legal and safeguards (environmental and social) disciplines.

Attracting and appointing a competent contractor to construct a geothermal project is in itself no easy task for Small Island Developing States. The lack of project replicability and challenges of working in a new, often remote, territory do not bring the financial reward that established international geothermal Engineer, Procure, Construct (EPC) contractors seek. For example, an EPC contract for a 10MW plant may be of the order of US$40M - $50M. A return of say 10% after-tax leaves a potential profit of US$4M - $5M for up to two year's work. Regardless of the development approach, Governments will require assistance to ensure the EPC contract is in the best interest of the project, the power utility and the country.

4.4 Technical Advice

The provision of reliable technical advice to identify, discover and prove the geothermal resource is an essential part of attracting finance. The process of building partnerships and becoming a trusted advisor should not be underestimated. Individual's political careers may be made or lost on the basis of such partnerships. The international community is typically able to provide geothermal technical advice, however, differences in technical opinion or unsuccessful drilling campaigns can quickly sour relationships and partners may seek to distance themselves from poor outcomes. The key to longevity in such relationships is able to set the right expectations about potential outcomes, and to be in it for the long term.

Development partners must be willing to stay the course if they are to realise the geothermal promise. International development partners are subject to budget restrictions, changes of policy and other external factors that can make this hard to achieve. Disappointed by slow progress and with their own career aspirations, champions of geothermal can move on and leave Small Island Developing States Governments looking for a new partner. Once found, these partners bring their own ideas on geothermal development, along with unique requirements that can hinder progress or change its direction.

4.5 Operations and Maintenance

Operations and maintenance (O&M) of the geothermal power plant once commissioning has been achieved also requires bespoke approaches. O&M contractors are unlikely to be attracted to the island for a contract worth perhaps US$1M - $2M per year. Aside from actually finding and training local staff to perform maintenance activities, the projects do not have the scale and income necessary for all the full-time staff that a larger project can afford. Essentially the core capacity must be developed on the island, with specialist contracts in place for reservoir management, turbine maintenance and perhaps other technical disciplines.

As the projects will be reliant on just a few wells, is it important that funds are available for workovers or additional drilling. The revenue stream will be insufficient to build a reserve drilling fund of the size required during the first years of operation. Given this risk, continued access to contingent grant resources provides a helpful tool to allow the project to become financially self-sustaining.

5. CONCLUSIONS

The case for geothermal development in SIDS remains strong as the single greatest project that can transform a nations energy landscape. The impacts of climate change and ongoing energy transition will see the requirement for electricity increase as electric vehicles and other technologies are adopted. They may be considered as "100-year projects" as the resource is typically much greater than the power demand and, once the development challenges are overcome, provide many years of electricity and opportunity for economic development.

This paper highlights a range of benefits and challenges to realising a geothermal project in a Small Island Developing State. The unique economical, political and logistical challenges of working in these locations requires extensive financial and technical support from the international community to facilitate a project that delivers the envisioned benefits. Figure 4 highlights prominent benefits and challenges.

In the author's opinion the following ten points highlight the key aspects to realising a development:

1. The project must be politically supported at the highest level in Government to attract external funding and allocate Government resources to exercise their functions in a timely fashion. Recognise that politics on a small island is deeply personal and that there are vested interests in maintaining the status quo.
2. Remember that this is a project of national importance and that achieving a low cost of power for the general population is the Government's main aim. Investment in associated infrastructure (i.e., roads, poles and wires, batteries, etc.) is likely to adversely impact the final cost of power to the consumer, but if done well, can bring additional benefits to the community (e.g., providing water or strengthening infrastructure).
3. Development finance through grants, contingent grants and low-cost loans will be necessary to develop a relatively small geothermal project that can deliver power at a cost that is acceptable.
4. Development partners must be willing to provide deep technical and financial support for the long term until such time as the project is either proved technically unviable or is operating.
5. Discover the geothermal resource using grant money before bringing in the private sector. The range of risks associated with the development in a remote island nation requires that technical resource risk is minimised as much as possible before bringing in finance with a need for high returns on investment.
6. Understand the impact of the project on the utility from numerous angles. The electricity utility is an essential partner and will be required to invest in a variety of assets to maximise the benefits of the project.
7. Keep the development as simple as possible to minimise development costs and ongoing maintenance challenges.

8. Recalibrate assumptions that a geothermal plant will operate 24/7 as baseload power. Achieving a capacity factor of over 90% may be unrealistic.
9. Attracting the right private sector partner may not be easy or even achievable. Almost certainly, the legal and regulatory environment will require refinements to do so, and the complexities of public-private partnership can stall the development.
10. Expect human capacity to be stretched and delays to occur due to the limited availability of key people.

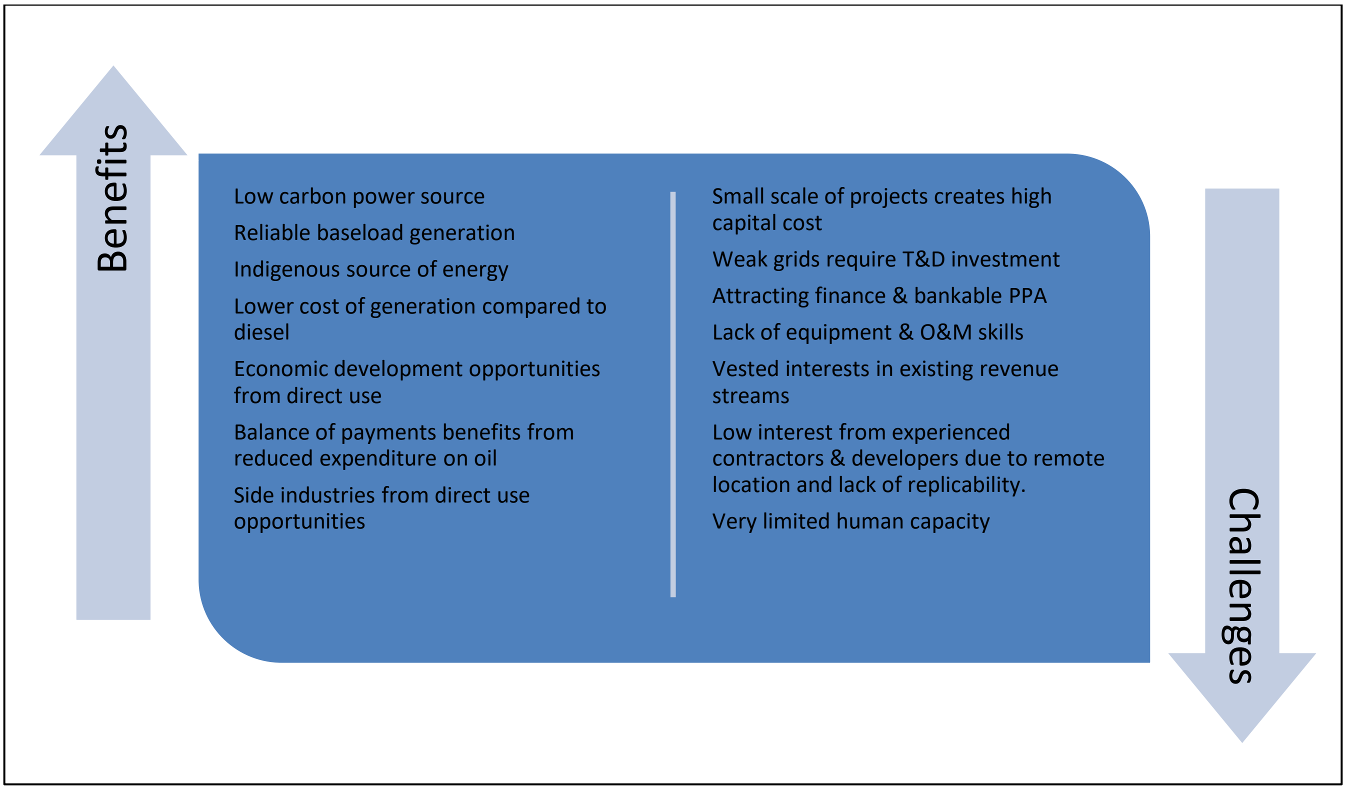

Figure 4: Benefits and Challenges of Geothermal Development in a Small Island Developing State

ACKNOWLEDGEMENTS

This paper draws on the author's experience working for Jacobs New Zealand on projects funded by the New Zealand Ministry of Foreign Affairs and Trade, private equity firms, the Caribbean Development Bank and World Bank.

REFERENCES

Lazard's Levelized Cost of Energy Analysis – Version 12.0 (Accessed Aug 2021 at https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-vfinal.pdf)