Key Success Factors for Deploying Remote Microgrids

Aligning Community and Funding Priorities with Standardized Modelling and Automation

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Introduction

Progress has been made in expanding access to electricity across the globe. However, much of the world – particularly in Africa and isolated pockets of islands in the Asia Pacific – still do not have access to electricity. While over 90 percent of the world's population[1] has access to electricity today, the International Energy Agency[2] (IEA) estimates roughly 775 million people currently lack electricity. On top of that, most citizens living in emerging economies such as the Pacific Island Countries still burn polluting fossil fuels to generate electricity. By 2030, The United Nations[3] estimates that 660 million people will still not have access to electricity unless new innovative solutions incorporating distributed on-site renewable energy or Microgrids are brought to market that marry stakeholder engagement with new data-driven modelling and design technologies.

These systems, which may incorporate batteries, renewable energy technologies, and other on-site Distributed Energy Resources (DER)- and may or may not be grid-connected - are commonly called Microgrids or Minigrids. Although definitions of these two terms may vary, we'll use them interchangeably in this guide.

Sources:
[1] United Nations. (n.d.). Energy - United Nations Sustainable Development. United Nations. https://www.un.org/sustainabledevelopment/energy/
[2] International Energy Agency. (2022, June 20). For the first time in decades, the number of people without access to electricity is set to increase in 2022. https://www.iea.org/commentaries/for-the-first-time-in-decades-the-number-of-people-without-access-to-electricity-is-set-to-increase-in-2022
[3] United Nations. (n.d.). Affordable and clean energy: Why it matters. United Nations Sustainable Development Goals. https://www.un.org/sustainabledevelopment/energy/

The U.S. Department of Energy (DOE) defines a Microgrid as a group of interconnected loads and distributed energy systems (e.g. PV, battery systems, wind turbines, but also thermal resources such as Combined Heat and Power running on hydrogen, among others) within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A Microgrid or Minigrid can operate in either grid-connected or in island mode, including entirely off-grid applications.

Minigrids that use DER to power remote areas of the world are oftentimes challenging due to a lack of data or because of the remote location itself. Funding and community support can be a challenge too.

In this white paper guide, some of these key questions and challenges that have plagued projects in the past will be pointed out, using a project to electrify 75 communities with hybrid solar Microgrids[4] in the outer islands of Fiji as an example to illustrate them and proven solutions for how to overcome them.

One of the key success factors for remote Minigrids that we will highlight is the effective and fast modelling of hundreds of sites to quickly arrive at decisions that can be supported by the communities and funding agency. It is key to avoid additional delays due to burdensome techno-economic modelling of an enormous amount of possible sites, technological combinations, and possible cost savings or levels of upfront costs. The modelling and design of Microgrids needs to build trust, engage the communities, and allow for quick and reliable changes in Microgrid setup. In other words, the modelling approach needs to act as a reliable guidance system for the whole engagement and design process.

Other key success factors include early community engagement, effective modelling of historic information (e.g. load profiles), as well as strong partnerships. We will touch on these key factors in this paper.

Key Success Factor 1: Early Community Buy-In

The first step in any effort to develop an energy access project powered by renewable energy such as PV is to engage with the communities to learn from them about what their primary use cases for electricity are. This stakeholder engagement creates an ideal opportunity to explain the purpose and advantages of what a hybrid solar Microgrid, for example, can bring to the table. There is a need to build awareness of how these Microgrids, work and why they are the key to unlocking a long list of benefits to the community:

- Basic services such as lighting and telecommunications, enabling health centers to provide basic care and entrepreneurs to create viable small-scale enterprises
- Reducing reliance upon cooking fuels that consume immense amounts of time that could be better spent on other productive activities, and which create local air pollution
- Allow people to communicate with relatives and the rest of the world
- Allow them to create a better life for themselves and their children as well create local jobs.

Sources:
[4] Laboratory for Energy and Power Solutions. (2024, June). Fiji sites electrified with hybrid solar mini-grids. Arizona State University. https://leaps.asu.edu/2024/06/fiji-sites/

The community needs to buy-in to these projects to realize they can also mean local jobs, reduced health risks and more diverse opportunities to improve their respective lives generally. These communities themselves need to become vital partners if such energy access projects are to be successful. Yet once the conversations signal acceptance, some practical challenges loom. For example, how does one design a project for a site that has never consumed electricity? At each stage of any project's development, there is clearly a need for technical and economic analysis. This analysis complements the stakeholder engagement process led by the project consortium. A process which involves multiple modelling steps can help. With a simple-to-use modelling and design approach and some high-level assumptions the benefits of the project can be demonstrate to the communities early on. Along the way these projects can be refined with better data, and this highlights the need for an easy extendable modelling approach that can guide the stakeholders and community through the different steps of their engagement.

During the feasibility study stage, for example, it's critical to take all the inputs needed for the cost and carbon emission reduction analysis, run different scenarios using different DER configurations and other variations of a potential solution, and perform the calculations. To achieve this, sophisticated and flexible modelling tools help the community and project developers arrive at the best solution for projected cost savings, resiliency, and carbon reduction to match any mini-grid or microgrid's priorities in a standardized and repeatable process.

Next, at the design stage, the feasibility study is used as the starting point to create the detailed real world technical designs for a Minigrid or any other DER-based project. Following an integrated process, the project design needs to be moved into detailed design. This process should be seamless, which is very different from typical approaches used in the past for Minigrid or Microgrid projects where disparate systems and spreadsheets are used, making it hard to ensure accuracy, which leads to lower confidence in the outcomes matching the original economic and environmental benefit projections.

With a trustworthy and seamless process that supports answering questions the communities may have at the different stages of the project, a successful community engagement of the project can be achieved.

Key Success Factor 2: Partnerships Are Key

Another key theme running through successful deployments of hybrid solar Minigrids in remote places such as the outer islands of Fiji are strategic partnerships. In this case, a consortium including Arizona State University's (ASU) Laboratory for Energy and Power Solutions (LEAPS), Xendee Corporation, the Global Green Growth Institute (GGGI), Comet, the United Nations Development Programme (UNDP), the Fiji Ministry of Finance, and Fiji Department of Energy teamed up.

For a successful deployment of a project like this one, on-site engagement and data collection is important, and this has been very successfully facilitated by ASU staff, enabling the use of Xendee's

Microgrid design tool in an effective way. Of course, the involvement of local governments and the ministry ensures local community engagement. A close relationship between the government entities and the modelling team (Xendee and ASU), helps create realistic assumptions for the modelling and in return better decision making for the local governments based on the outcome of the modelling. In terms of financing, it is best practice to reference data-based models to look at cash flows and how best to set tariffs to increase the prospect that these mini-grids being built in Fiji are sustainable. In this project ASU collaborated with the Global Green Growth Institute, Fiji Ministry of Finance, Fiji Rural Electrification Fund, and United Nations Development Programme to identify sustainable financing mechanisms.

In-person site assessments, power system design, geospatial site planning, business model review, and climate change impact assessments have been performed leading to tender and construction of sites representing a $40 million investment to serve 17,820 people without reliable electricity access. This partnership has completed over 100 site designs for Microgrid projects, representing 8 megawatts (MW) of clean power, over the past three years and is on track to complete a similar amount in the next year to address increasing demand.

The team can keep pace with this rate of growth by using standardized and integrated Microgrid design and modelling methodologies to integrate feasibility analysis, detailed engineering and proposal building tasks into a comprehensive deployment plan designed to deliver successful outcomes that supports the stakeholders and communities at every step of the project. The standardized and replicable industry framework and set of tools that the team uses to combine data inputs about different DER technologies during the project design process allows for long- and short-term weather data input that impacts the potential electricity generation from renewables such as solar and other technologies. Then, project proponents can feed data into an analysis to explore potential solutions, weighing the pros and cons of specific sites, sizing of systems and other factors. In the end, the optimal solution from both a technical and financial perspective can be configured to inform final decision making.

Fiji Sidebar

Outside of Australia and New Zealand, oil makes up 80% of the energy supply[5] throughout the Asia Pacific islands. Approximately 37% of this fossil fuel supply is used to generate electricity. A National Energy Plan[6] adopted in 2023 sets a goal that all electricity generated in Fiji needs to come from renewable resources. Whereas 60% of Fiji's current electricity comes from renewable hydroelectric resources, this supply is concentrated in serving urban areas on the biggest islands. Most electricity for rural populations on the more than 100 islands which comprise Fiji (approximately 40% of the nation's electricity) is generated from imported oil products such as diesel fuel. Since Fiji has set a goal of net zero carbon emissions by 2050 for its entire economy, the nation will need to diversify its energy supply not only for electricity, but also transportation (including aircraft and marine options.) The good news is that Fiji has an abundant and diverse set of renewable resources that include solar, wind, geothermal, marine hydrokinetic, biomass and biofuel resources. With the right blend of sources and intelligent, standardized data-driven deployment strategies, Fiji can shift to a sustainable energy system and economy and simultaneously decrease electricity costs, increase energy access and promote energy independence.

Figure 1: *Map of Fiji and the surrounding islands. Below is an example of a typical island community (image courtesy of ASU).*

Sources:

[5] United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). (n.d.). Making the energy transition a reality in the Pacific. https://www.unescap.org/blog/making-energy-transition-reality-pacific

[6] International Trade Administration. (n.d.). Fiji - Renewable energy. U.S. Department of Commerce. https://www.trade.gov/country-commercial-guides/fiji-renewable-energy

Key Success Factor 3: Techno-Economic Modelling

Minigrids are typically kilowatt-scale systems which, if developed as one-offs, will hardly be cost effective. So, the question becomes, how best to scale up a portfolio of hybrid solar Minigrids to capture economies of scale on the engineering side, thereby enhancing the project's economics?

To evaluate the proper sizes of the DER technologies such as Photovoltaics (PV), batteries, or wind to supply the needed energy at minimum costs or maximum reliability, a sophisticated standardized engineering modelling approach is needed. Applying the same design and engineering principles across a fleet of hybrid solar Minigrids also reduces the development timeline, simplifies installations and makes the project fleet more attractive to potential investors. Small Minigrid projects are best developed as a portfolio with modular projects sharing key attributes to facilitate financing.

This is where advanced modelling tools can determine balance of system components that are necessary for the renewables' supply and energy storage assets to deliver the most value for consumers and developers alike. These models will also deliver the optimal investment costs, levelized costs of electricity ($/kWh) as well as resiliency indicators for natural disasters like hurricanes or earthquakes.

Also, there is a high chance that multiple iterations and sensitivities are needed for each site or the entire portfolio, creating the need for hundreds of designs and optimization as well simulation runs as in the case of this Fiji project. The setup-times for these runs need to be efficient, and assumptions need to be changed quickly. A manual process that defines each project via an individual site set-up or input form can be very burdensome. Thus, direct connections to data sources (e.g. weather data, DER technology data, load profiles) can help.

Key Success Factor 4: Overcoming Lack of Historical Data

Over 300 remote communities in Fiji lack grid connection because they are outside the reach of the main utility, Energy Fiji Limited, that serves the primary three islands. This lack of energy access is characteristic of the broader Pacific region, where 67% of the population lack a reliable source of power. Given the lack of historical energy usage for these future Microgrid sites, computer models or databases are required to create the data that can justify investments in energy access projects. This lack also means that sensitivity and design runs around load profile variations need to be performed in a simple and fast way. Also, growth projections need to be considered in the techno-economic design. The work on the Fiji project has clearly shown that manual processes that require manual establishment of each single Minigrid model will be a limiting factor. Whenever possible Application Programming Interfaces (APIs) need to be utilized to quickly provide, exchange, and change data as well as send a large amount of data to the techno-economic modelling engine. At the end hundreds of design processes need to be executed in parallel.

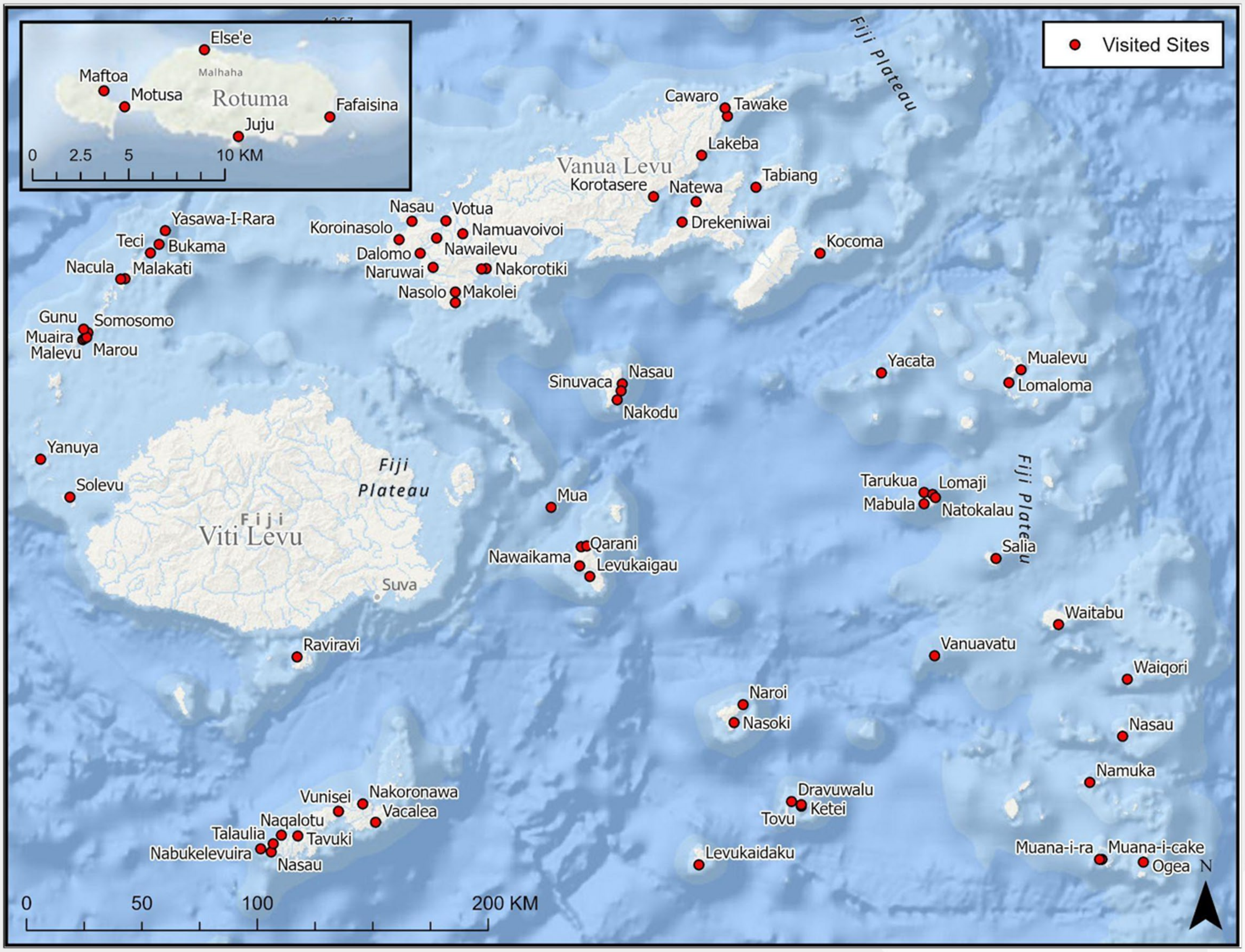

Figure 2: *Map of Fiji showing the 75 visited microgrid sites from the 300+ considered in the program. (Image provided by ASU)*

The Standardized Modelling Platform that Glues all Succes Factors Together

As a result of our research and implementation work, a successful Microgrid and DER implementation process needs to involve all different steps for modelling, design, implementation, and control in one effective platform. All these steps and phases need to be linked to minimize latency and maximize continuity by removing unnecessary steps and facilitating coordination, meaning that the proposals or screening results from an early multi-site analysis process can be seamlessly transferred to your system for detailed techno-economic and engineering analyses. When, the project is finally built, it is important to control the assets with the same planning principles in mind. Thus, even the control needs to be implemented via the same platform (Figure 3). This is the philosophy of Xendee and parts of the different Xendee steps have been used within this Fiji project.

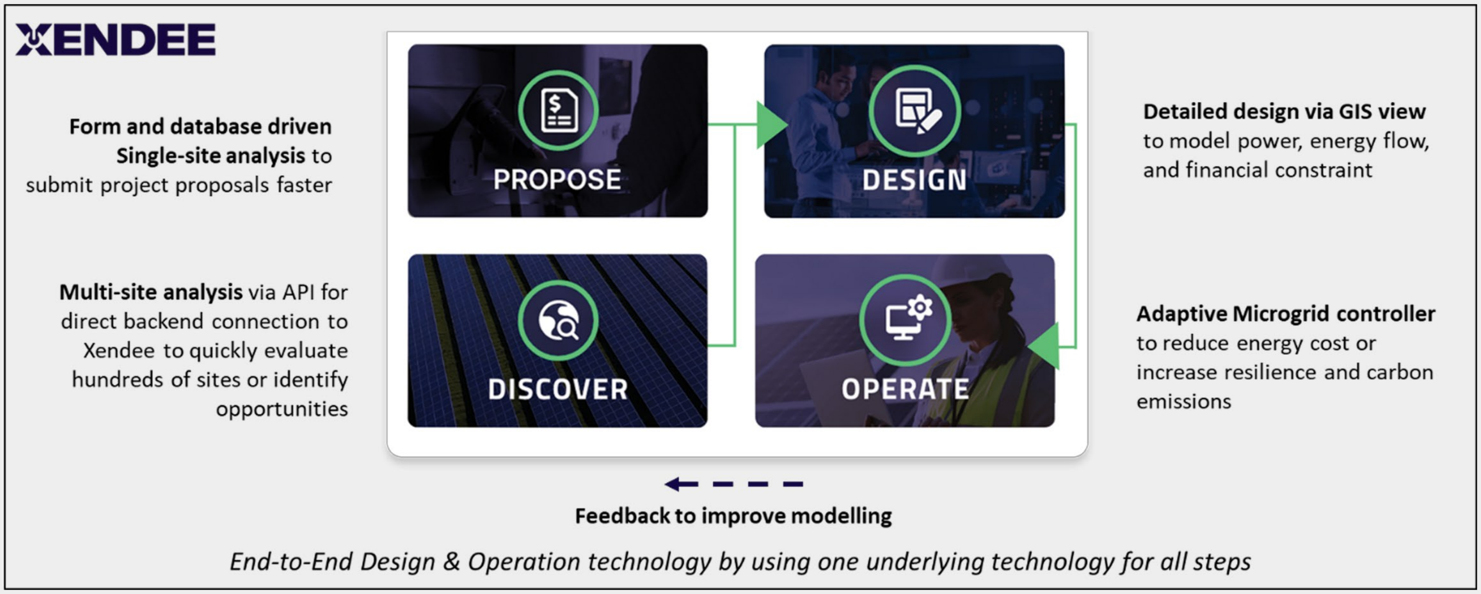

Figure 3: *Xendee's platform provides an integrated approach to Microgrid and Minigrid site selection (single or multi-site), design, and control. This reduces the cost of customer acquisition, aids community engagement, and helps get more projects funded that reach or exceed organizational goals.*

PROPOSE

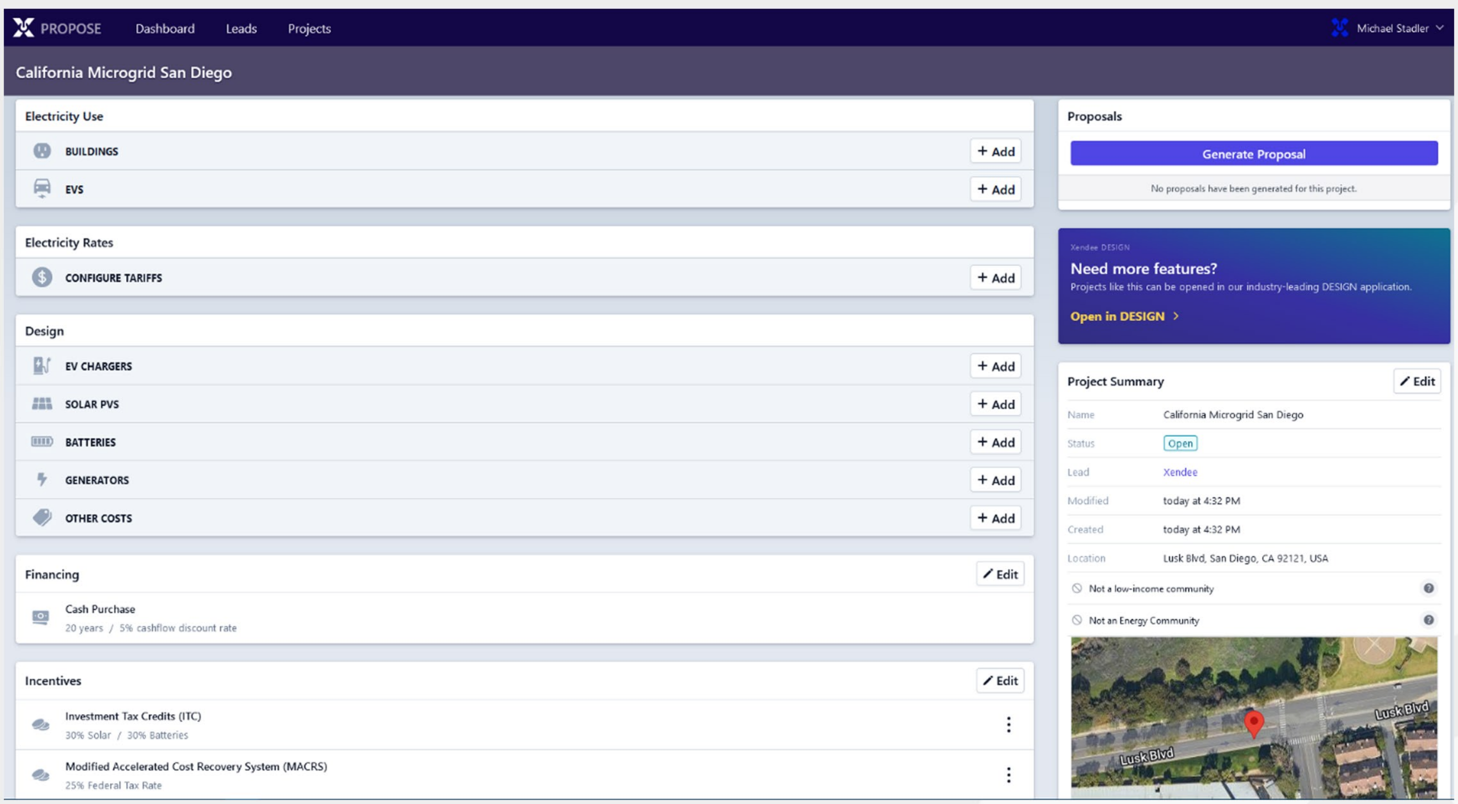

Figure 4: *The main dashboard for a project in PROPOSE. Add technologies like EV chargers, solar PVs, batteries, and generators to the project through a catalog-driven rapid selection process. Financing options, utility tariffs, building loads, and government incentives are also considered.*

DISCOVER API

The Xendee API allows the user to send large amounts of modelling data automatically to the Xendee optimization engine. There is no need to enter data manually as in PROPOSE or DESIGN (see below). All the data can be taken from databases directly on the client's site and manipulated via scripts. In this way hundreds or thousands of sites can be easily analyzed. For example, the user can send a batch of data to Xendee's servers at the end of the business day and then the next morning all those results are back and can be analyzed. For this Fiji project, the team used the API for discovery of options and solutions. Then after many scenarios, when the community and the project team made a decision, the final design of the Minigrid was created within DESIGN (see below). All scenarios and projects modelled via the API are directly available in the detailed DESIGN of Xendee and can be further analyzed and improved.

A full an extensive API documentation is available so that every user can interface easily with Xendee.


```
{
   "FolderName": "My Favorite Projects",
   "Name": "Api Test Project",
   "UserId": "bob@example.com",
   "GridConnected": true,
   "MetricUnits": false,
   "CurrencyId": "USD",
   "PayBackPeriodInYears": 15,
   "InterestRate": 4.5,
   "DiscountRate": 3.75,
   "FedTaxRate": 28.8,
   "ProjectAddress": "1234 Tourmaline St., San Diego, CA 92109",
   "ProjectYear": 2019,
   "Locale": "us-CA",
   "Latitude": 32.802353,
   "Longitude": -117.241676,
   "IncludeSolarPV": true,
   "IncludeBatteryStorage": true,
   "IncludeWind": true,
   "IncludeEVCharging": true,
```


Figure 5: *Example json file for the Xendee API. There are multiple json files required, which are compiled and analyzed with Xendee's Mixed-Integer Linear Program (MILP) algorithm.*

DESIGN

After having screened a project with PROPOSE or done multiple automated design processes with the DISCOVER API, the single projects can be designed in every detail in this phase. Power flow and distribution system modelling is also possible as very detailed outage modelling or multi-year scenarios.

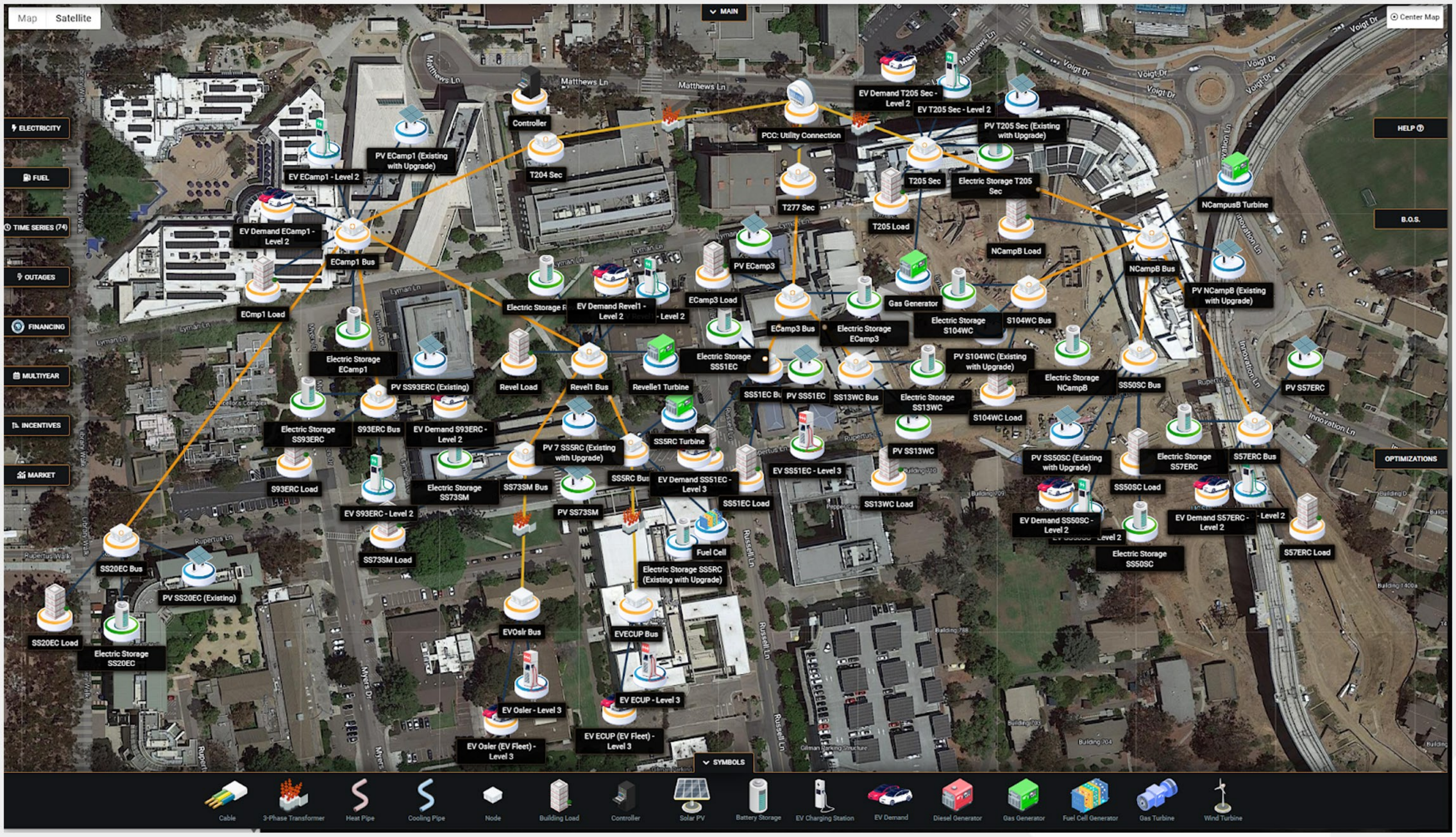

Figure 6: *A campus multi-node microgrid modelled in detail in Xendee DESIGN. Different nodes are used to minimize transmission losses and co-locate with loads. Technologies are added by selecting the icon from the menu bar and selecting from vendor catalogs or uploading your own DER data. Fuel pricing, incentive programs, funding methods, multi-year project analysis, utility tariffs, and EV fleet support are also considered.*

OPERATE

The final step in the Microgrid deployment is the control of the optimally designed projects. The same algorithms (as in the DISCOVER API, PROPOSE, or DESIGN) in combination with AI forecasting and real-time measurements are controlling the DERs to achieve the projected savings and benefits. This step has not been implemented in the Fiji project.

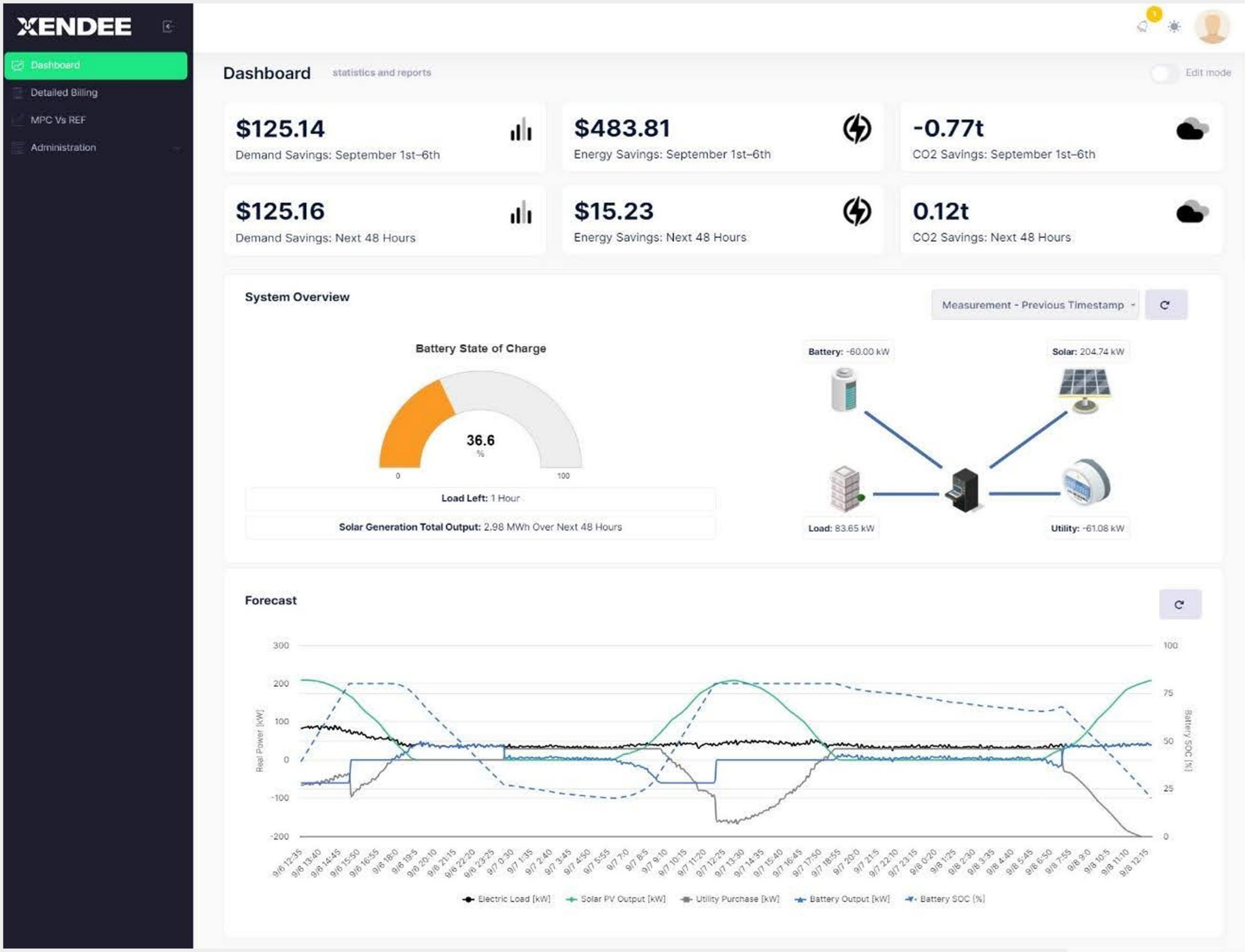

Figure 7: *The main dashboard of the Xendee OPERATE interface. Here, owners and operators can analyze daily operations and compare forecasts to realtime microgrid performance as well as see an overview of active technologies, energy savings, emission reduction, and battery state-of-charge.*

All these different steps (PROPOSE, DISCOVER, DESIGN, and OPERATE) use the same optimization engine and mathematics in the background and can be transferred between the different phases with the click of a button, minimizing the costs and design times.

Additional Challenges to be Considered

Existing tariffs and **proposed tariff changes** can have a major impact on the viability of projects. A related issue is how to collect payment for services rendered when end-use customers are of limited means. **Tariff design** can become part of an energy access project's path to viability. And that's why using data-driven modelling tools as provided by Xendee are so important since they can perform sensitivity runs to compare different rate structures to explore how best to make projects viable - without imposing undue burdens on customers. Creative business models such as "pay as you go" and pre-paid metering programs whereby the end-users can incrementally pay for electricity service is one option. Analysis conducted by the team looked at sustainable business models, including ownership options and related O&M concerns. In this project, it was decided a public-private partnership was the best approach to maintain the installed equipment due to the logistics and skillset available in these remote island environments.

Logistical issues for project implementation vary from extreme weather conditions, seasonal challenges and remoteness of sites. **Supply chain challenges** for key hardware components, such as solar PV inverters, vary immensely across the globe. However, project proponents and developers have little control over supply chain shortages, but what they can do is lean on partners and good data on availability of components to increase the likelihood of picking suppliers who deliver key components on time and without unexpected price increases.

Operation and Maintenance of the Microgrids can be a challenge due to the remote location. Thus, when modelling DER technologies in a techno-economic modelling platform like Xendee, technologies that have less maintenance requirements, but maybe higher capital costs can be a solution. In any case, it is important to create a plan to keep systems up and running optimally, including parts replacements and fine-tuning of control regimes or other technical fine-tuning of the system. Operations and maintenance (O&M) can be the downfall of well-engineered projects if not properly planned for. Thus, warranties for project performance are critical as is the ability to remotely monitor project performance, leveraging data feeds to optimize results. Merging local know-how with advanced diagnostics fed by real-time data input like the Xendee OPERATE platform brings together the best of both worlds to trouble-shooting and maintaining optimal performance of the system. Simulations of operating expenditures in the planning process can add certainty to ongoing costs estimates for O&M.

The Fiji project team noticed the importance of Local Workforce Development when it comes to O&M plans. If an outside workforce is used to perform O&M, costs for ongoing operations may increase. How can the costs attached to O&M to ensure optimum performance be leveraged for local economic benefit? The best way to sustain operations, as well as maintain community buy-in for any hybrid solar mini-grid, is to also create economic opportunities for local citizens. For example, the most sustainable way to reduce O&M glitches is to develop and train local labor to maintain energy access systems. This can influence the project design, based on availability of local skilled labor. Workforce development can also maximize economic benefits during construction. In Fiji, ASU and Xendee are offering training programs and a course in mini-grid operations, setting the stage for local employment opportunities (available at xendee.com/asu).

Conclusion

Hybrid solar Microgrids like the ones being developed in Fiji highlight both the challenges and the solutions to barriers that face energy access projects around the world. As noted, each project in any given geography will face some unique challenges, whether they be logistical, financial or engineering. The process to increase success rates that were deployed by the team and partners in Fiji provides a path forward for a framework combining human outreach with sophisticated technology that can be replicated throughout the world where energy access remains a dire need.

The ability to combine sophisticated engineering and software tools with on-site community engagement and diverse partnerships offers a powerful means to guide project development in the most efficient and cost-effective way possible, while still meeting the needs of communities.

In the end, the primary lesson learned from this project in Fiji is that the best solution to speeding up Microgrid deployments and thereby reducing costs is to use a single process and modelling approach that combines analysis of required electricity generation (including the sizing of intermittent renewable resources), distribution infrastructure upgrades, customer loads and ROI to get a holistic view of a microgrid fleet. Trends in the industry point toward the need for reducing customized engineering and shifting to a more standardized and modular approach as deployed by Xendee. This is a perfect fit for energy access projects where there is little or no infrastructure currently in place.

While the focus of this paper is on the specific geography of Fiji, the principles and tools used by ASU and Xendee to reduce engineering time significantly and thereby shrink upfront costs can be applied universally. This collaboration represents the current state-of-the-art in energy access project planning and data analysis.

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Since July 2018, Dr. Michael Stadler has been the Chief Technology Officer of the San Diego-based XENDEE Corporation, which he co-founded. Before that, Michael Stadler was a Staff Scientist at Lawrence Berkeley National Laboratory, California, leading the Grid Integration Group. He is a recipient of the 2013 PECASE Award of the White House. The PECASE Award is the highest honor bestowed by the U.S. government on science and engineering professionals in the early stages of their independent research careers. Michael has published 260 papers, journal papers, and reports to date and holds 14 copyrights/patents.

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Dr. Nathan Johnson leads numerous efforts at Arizona State University to accelerate the advancement of sustainable development goals through innovation in stakeholder value propositions, technology, business models, and policy. In this, Dr. Johnson builds public-private partnerships in the US and internationally to develop energy decarbonization solutions leading to pilot demonstration and scale. This work co-creates benefit to all stakeholders through value propositions that increase energy access, energy security, and economic development. He presently directs the efforts of 200 people working on over $400M of research, demonstration, development, and scaled implementation.

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