R.P. DELIO WHITE PAPER SERIES

# Going Micro to Power the Pacific

## ASSESSING THE MICROGRID POTENTIAL OF THE PACIFIC BASIN AND ITS ISLANDS

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R.P. DELIO & CO.

# Going Micro to Power the Pacific

## ASSESSING THE MICROGRID POTENTIAL OF THE PACIFIC BASIN AND ITS ISLANDS

The switch over to distributed and renewable energy systems is about more than just cutting loose from fossil fuels and embracing new energy sources. The clean energy change-over is demanding new models for electricity generation, and inverting relationships between producers, consumers and infrastructure operators. The monolithic command-and-control grid of the last century is being challenged by the small-scale, community-centric integration of electricity supply, delivery and management services.

Its herald is the microgrid: combining generation, distribution, consumption and storage at a local scale, under the aegis of advanced monitoring, control and automation systems. The microgrid is placing self-generated electricity into the hands of local communities – and reworking traditional energy infrastructure from the bottom up.

And if microgrids are the enabling technology for opening up existing grid infrastructure – bringing new models for distributed energy deployment – then islands are their natural test-beds. With relatively small loads, isolated topologies and ample access to diverse renewable resources, island grids serve as logical starting points for reality-proofing the emerging microgrid technologies.

### ISLANDING IN THE PACIFIC – SMALL BUT SMART

This realization has spurred communities across the vast Pacific basin – home to the full geographic panoply of islands, from tiny isolated research stations, to settled small islands, to developing-world communities and fully-developed island archipelagos – into seizing the opportunity presented by microgrids. The very diversity of its regional and social geography makes the islands of Oceania a compelling testing ground for meeting the challenges the microgrid is seeking to address. And that diversity also reinforces the point that the market for microgrids is far from homogeneous.

The potential market-place may not be large, when viewed through the prism of population – the Oceania region of 13 countries and 25 dependencies, excluding Australia, amounts to only some 13 million people (Table 1). But when looked at with reference to the likelihood for high, and early, penetration of distributed renewable energy, the short-to-medium term microgrid market in the Pacific basin region assumes a critical importance. The disruptive technologies of the microgrid are likely to be proven here first.

| Country/Territory | Population Estimate (latest national census 2009-12) | Annual Electricity Production 2010 (Gwh), EIA | Per Capita Electricity Production (kWh) |
|---|---|---|---|
| Guam (US) | 159,358 | 1.76 | 11.04 |
| New Zealand | 4,462,600 | 43.802 | 9.82 |
| Hawaii | 1,360,301 | 10.836 | 7.97 |
| New Caledonia (France) | 255,651 | 1.978 | 7.74 |
| Nauru | 9,945 | 0.035 | 3.52 |
| American Samoa (US) | 55,519 | 0.159 | 2.86 |
| French Polynesia (France) | 268,270 | 0.672 | 2.50 |
| Cook Islands (NZ) | 14,974 | 0.031 | 2.07 |
| Niue (NZ) | 1,414 | 0.00279 | 1.97 |
| Federated States of Micronesia | 101,823 | 0.1786 | 1.75 |
| Marshall Islands | 55,548 | 0.07 | 1.26 |
| Fiji | 858,038 | 0.869 | 1.01 |
| Samoa | 187,820 | 0.12 | 0.64 |
| Papua New Guinea | 7,059,653 | 3.35 | 0.47 |
| Tonga | 103,036 | 0.0401 | 0.39 |
| Kiribati | 104,573 | 0.025 | 0.24 |
| Vanuatu | 258,213 | 0.055 | 0.21 |
| Solomon Islands | 515,870 | 0.082 | 0.16 |
| Northern Mariana Islands (US) | 53,883 | No data | |
| Palau | 20,770 | No data | |
| Tokelau (NZ) | 1,411 | No data | |
| Tuvalu | 11,264 | No data | |
| Wallis and Futuna (France) | 13,152 | No data | |

Table 1: Most recent population and electricity production estimates, for countries and territories in Oceania (excluding Australia but including Hawaii). Source: National Census and EIA Country Briefs'

## MICROGRID TECH – THE PIECES OF THE PUZZLE

A microgrid is an aggregation of a number of technologies that, together, enable the partial, occasional or complete independent generation, regulation and supply of electricity within a relatively small geographic area. Microgrids can operate in isolation, with respect to the large traditional grid infrastructure (sometimes called the macro-grid), though they are often connected to them. These component technologies have seen much innovation over the last decade, considerably widening the appeal of microgrid implementations to a variety of electricity consumers. But technical progress has unfolded somewhat unevenly, and this has affected the economic viability of microgrids for each specific scenario of deployment.

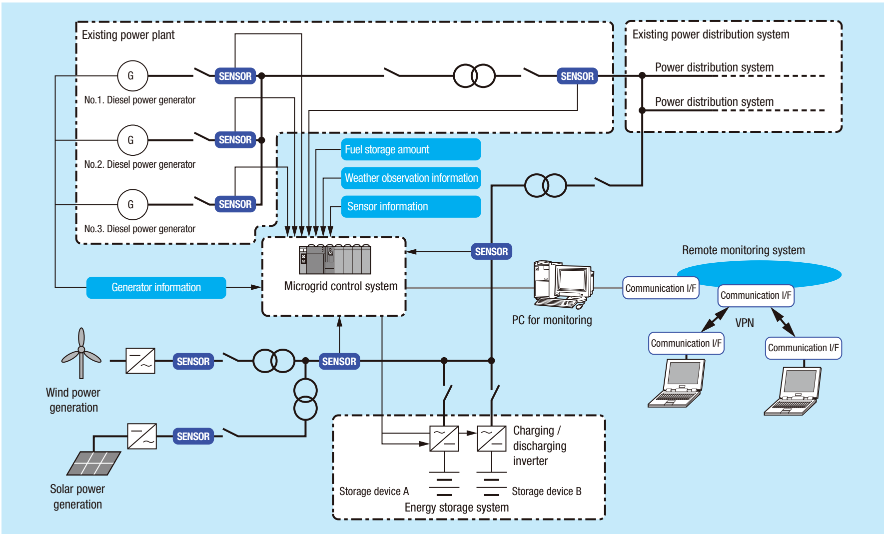


Fig.1 Basic configuration of isolated island microgrid system. Source: 'Microgrid System for Isolated Islands' in Fuji Electrical Review – http://www.fujielectric.com/company/tech/pdf/57-04/FER-57-4-125-2011.pdf

**Generation:** This area has seen the most diverse and rapid advance in technology. First-generation microgrids relied primarily on Internal Combustion (IC) based generation, such as stand-alone diesel generators. But in the last decade, wind turbine, solar photo-voltaic (PV), fuel cells, geothermal and biomass combustion have all seen costs fall significantly, allowing them to compete with IC generation (especially as IC fuel costs have risen). This has resulted in the displacement of IC generators into secondary or backup roles in many microgrid configurations.

**Power Regulation and Control:** The fundamental requirement of a microgrid is that it delivers a reliable and high-quality power service to its users. That raises a significant technical challenge, both for the integration of generation sources as disparate in power supply characteristics as diesel-generators,wind turbines and solar PV cells, and for handling loads that are intrinsically more variable than averaged-out loads of larger grids.

The challenge has been met by advances in intelligent sensors for micro-generation sources, improved power monitoring and adjustment algorithms, and in instantaneous power compensation from new devices, such as lithium-ion capacitor modules[1]. Technology for the integration of intermittent renewable power supply has made significant progress – by allowing, for example, wind turbines to participate in droop control, frequency and voltage regulation, using variable active power controls[2]. These advances mean that each specific microgrid deployment is more able to maximize the particular energy supply potential already inherent to the site being served.

**Grid Interconnection:** Perhaps the most important recent advance enabling wider deployment of microgrids is the combined technical and regulatory jump forward that has allowed microgrids to connect to the wider grid, whilst still facilitating the controlled islanding in the case of grid outages. This allows the microgrid to use the macro-grid for exporting energy, to provide salable power services by the microgrid back to the grid itself, and for the provisioning of significant energy supply and security to the microgrid site, without relying on IC generator sources.

An amended IEEE Standard for grid connection (P1547.4)[3] both prescribes safety protocols for automatic and rapid disconnection of distributed generation, and enables the provision of ancillary services by microgrids (by setting standards for reactive power supply, for example). This parallels the development of smart switch connections to the utility grid, which provide for the automated disconnection (and reconnection) of the microgrid, when grid power quality drops below acceptable thresholds, or ceases entirely.

**Storage:** Storage of power within the microgrid is of greatest importance when the microgrid is to function at an isolated site, or to enable security of supply in the face of major outages. Suitably costed on-site storage could ultimately ease connected microgrids from their reliance on the macro-grid, by flattening the intermittency of renewables such as wind and solar. Such on-site energy storage can be provided by flywheels, compressed air, pumped hydroelectric and various forms of battery technology.

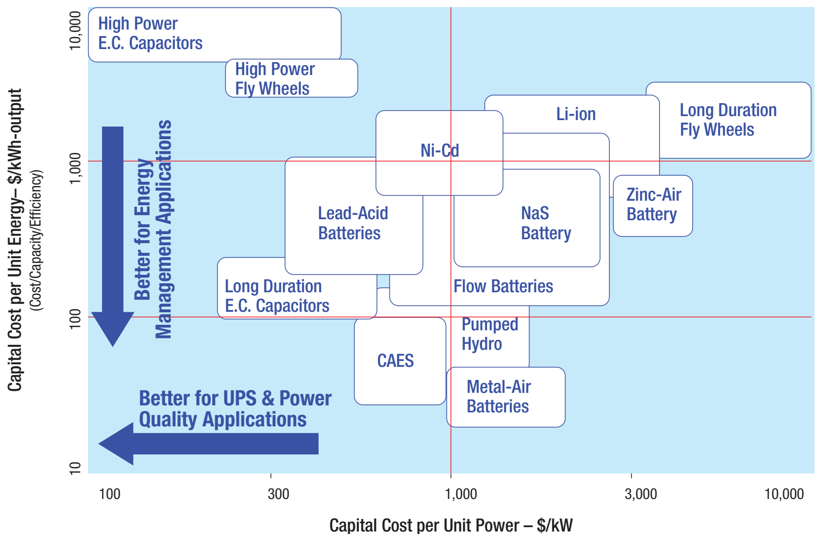


Figure 2: Energy Storage Capital Costs by Technology Type
Source: Electricity Storage Association, Technology Comparison – http://tinyurl.com/d6lc44r

While there have been significant advances in battery technology (particularly for sodium-ion battery approaches ), the cost per kWh is still too high to support their extensive use for primary energy supply applications. They do, however,have a role to play in niche markets, where high costs can be justified, or there is no other practical solution.

Electric Vehicles offer an interesting and complementary alternative to solutions focused on a storage-only end-use. By drawing upon the energy in connected EV batteries, the microgrid could potentially make use of EV storage capacity for managing power quality, small-scale load/supply mismatches and meeting critical loads, when the microgrid is disconnected from the grid. This additional,and salable, utility also helps makes EV economics more attractive.

## SCENARIOS FOR GOING MICRO

There are three broad contexts in the Pacific region for the deployment of microgrids, each of which places a different emphasis on the component technologies. Because those technologies are themselves at different levels of maturity, the current viability of microgrids is very much dependent on the scenario of deployment.

### MATURE GRIDS IN DEVELOPED ISLAND STATES

This market scenario covers microgrids in economically developed states, such as the Hawaiian Islands, which are actively seeking to maximize penetration of renewable energy. There is a strong motivation to achieve significant cutbacks in fossil fuel use for environmental, energy cost and energy security reasons. Here, microgrids may offer a convenient way to package distributed clean generation sources for local communities, small businesses and campuses alike.

Microgrids on these developed islands also emphasizes a community-based renewable energy transition, which may help avoid the social frictions that have been seen with some large-scale renewables deployment. Additionally, because the existing grid is both well-developed, and undergoing a significant transition itself, there is the potential for microgrids to sell ancillary services to it. These include demand response, voltage and frequency stability and reactive power.

Current microgrids are also able to attach to the macrogrid bi-directionally, and in doing so can use the grid as a storage medium through net metering. This reduces the need for relatively expensive in-depth energy storage to bridge troughs in generation, enhancing their economic viability. That linkage is an important influence on microgrid topologies, as it removes the significant costs associated with storage. It is also likely that, as electric vehicle (EV) adoption rates ramp up, there will be significant scope for storing and drawing electric from EV batteries, in these more developed countries.

Given the many advantages, and the relatively low technical hurdles for implementing microgrids in developed markets, there could be significant scope for their deployment. The biggest impediment may be the local utility. Widespread deployment of microgrids implies a considerable change to business model for the utility, who may be reluctant partners. Providing motivation for their positive participation in widening microgrid deployment may therefore be a prerequisite.

## IMMATURE GRIDS IN DEVELOPING ISLANDS

Many developing small territories and nations in the Pacific basin are similarly motivated, by cost and environmental concerns, to be consider switching electricity generation to renewable sources. That again provides a platform for the deployment of microgrids, packaging renewable resources for communities within these markets. There is an additional factor, however, which both reinforces the drive towards an alternative energy infrastructure, and complicates it – the relatively poor state of existing electrical grid in these nations and territories.

In most developing countries, the electricity grid infrastructure is far from geographically uniform, often with a high level of scheduled intermittency (through rolling blackouts). The infrastructure itself may also be in a state of poor-repair, and subject to failure. Because of the unequal distribution of electricity as a resource, its supply can become enmeshed in local politics, with some communities benefiting from greater access to what is a partial resource.

All these factors can be taken as a positive for rolling out microgrids, as they offer a potential solution to many of these problems. Microgrids can readily compete with the low-quality grid electrical resource, and offer a route towards upgrading unstable existing infrastructure. A community-centered model for deploying microgrids could also offer a path for circumventing local political conflicts.

However, these same factors may make microgrids less tenable than in developed country grids. There is less infrastructural depth and stability to the grid being connected to. This means it may not be relied upon as a potential conduit for power export/import, as commonly happens through net metering schemes on developed grids. There is likely to be reduced scope for selling ancillary services from the microgrid to the macro-grid. Where institutions are weak, ensuring that there is a dependable partner committed to supporting the roll-out of microgrids may be problematic.

For this reason, while the potential for microgrids is there for this sector, the risks are higher. They are only likely to be significantly ameliorated by a deep understanding of local institutions, politics and of the technicalities of the host grid infrastructure, and its markets.

## REMOTE GRIDS IN ISOLATED ISLAND COMMUNITIES

Whereas the previous two scenarios for deployment could rely upon a measure of interaction with existing grid infrastructure, there are many communities too geographically isolated for such infrastructure to be a factor. These could be rural communities on larger islands, small populations on very isolated or small islands, or remote outposts or research stations.

It is in these markets that microgrids were first introduced; this first-generation relied primarily on IC sources such as diesel-generators. It is also in such markets that the first wave of distributed renewable energy systems were installed in the 1980's and 1990's.

The remoteness from the grid places heavy reliance on a combination of firm dispatchable generation sources (typically in the form of IC generators) and/or in-depth energy storage (such as battery racks, or stored hydro) to supplement installed variable source (such as solar or wind). Because fuel costs are highest in these markets, renewable resources can more readily displace expensive fossil fuel-based generators. This factor also makes the economics for various forms of energy storage more compelling.

However, while the technology may be feasible, and the economics viable when compared to other energy solutions, the fundamental financial, social and political factors must also support microgrid deployment in these markets.

Recent reports have questioned the long-term viability of supplying microgrids to poorer rural communities,when these factors have not been properly incorporated into the project. In Malaysia, for example, a microgrid installed at Kalabakan, in north-east Borneo, was found to barely working due to poor maintenance and disrepair, just 3 years after its commissioning in 2009.

Those reports highlighted two aspects vital for success in deploying microgrids in isolated communities. First, there must be a viable economic model supporting the long-term costs of the system's installation and operation. And second, there must be a local self-sustaining infrastructure, in terms of supportive institutions and trained staff, to underpin the microgrid throughout its full life-cycle.

These preconditions may act to make only the outposts of richer nations in the region (the US, New Zealand, Japan and Australia) the most immediate prospects for this segment of the market in microgrids.

## CONCLUSION

Microgrid technology has become an increasingly attractive solution to resolving the challenges facing power supply across the globe. It can be an enabling technology for spear-heading the transition to clean energy sources. It can be a useful means for bringing power to those who have been beyond the reach of traditional grid infrastructure. But as with all technologies, success depends as much on taking into account social and political factors, as it does on technical and economic ones.

R. P. Delio & Company understands that the microgrid – as a technology that is inherently orientated towards the local – requires such aspects to be intrinsic to project and program planning, if success is to be achieved. It is only then that the Pacific's early adoption of microgrids will be able to live up to its considerable potential.

## REFERENCES

[1] See 'Microgrid System for Isolated Islands' in Fuji Electrical Review, found at http://www.fujielectric.com/company/tech/pdf/57-04/FER-57-4-125-2011.pdf

[2] See 'Enabling Frequency and Voltage Regulation in Microgrids using Wind Power Plants', found at http://isc.mst.edu/media/research/isc/documents/research/symposium/2012researchsymposiumpapers/Enabling%20Frequency%20and%20Voltage%20Regulation.pdf

[3] See 'IEEE 1547.4 Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems', found at http://grouper.ieee.org/groups/scc21/1547.4/1547.4_index.html

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