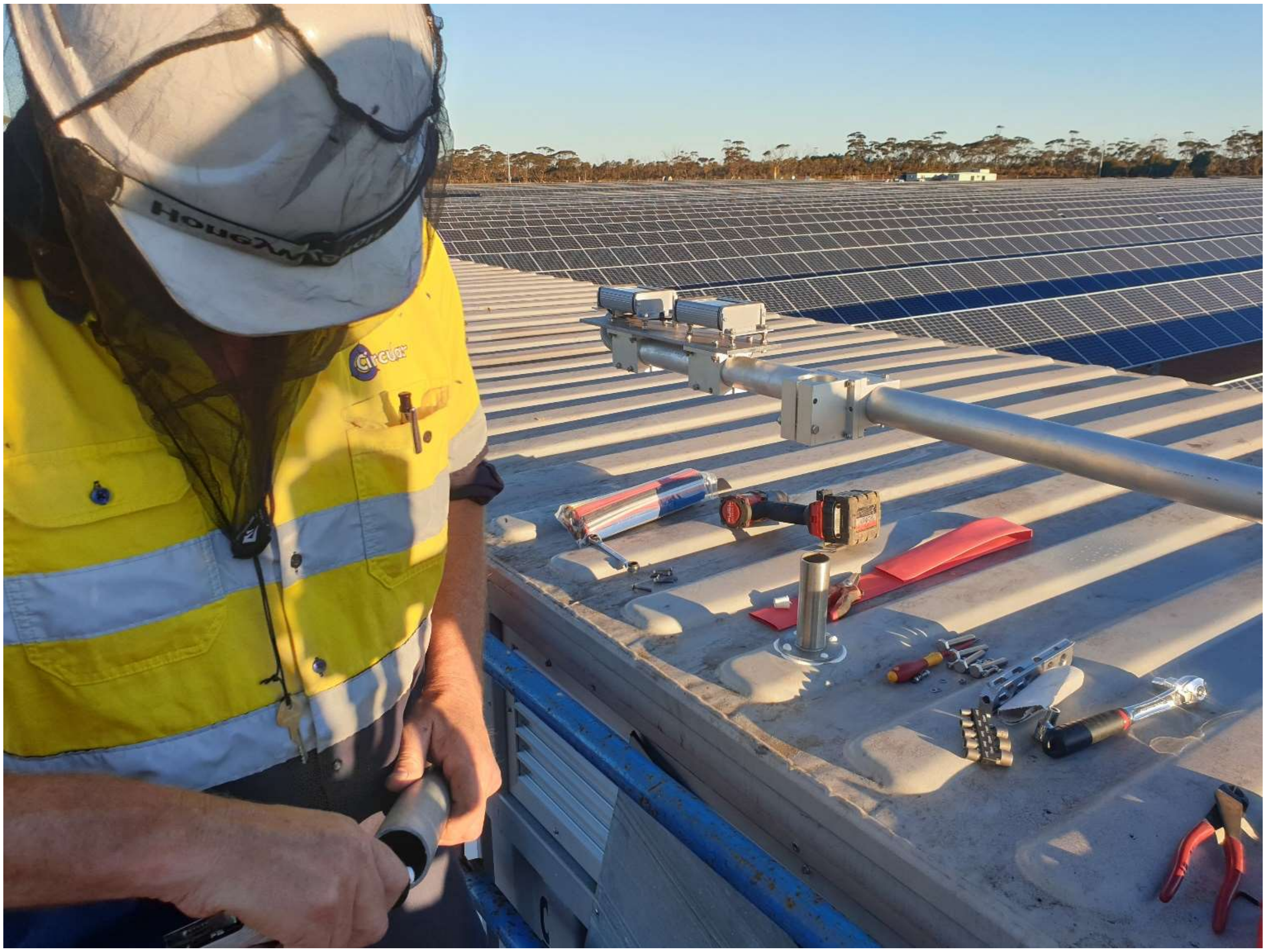

POWERING REMOTE COMMUNITIES

REMOTE POWER PROJECTS

Discussion of typical remote power generation options and integration of renewables.

1. Circular Solutions

Circular Solutions is a specialised renewable energy consultant and contractor. Our services include:

- Concept development including feasibility, design, strategic planning, and regulatory advice;
- Project delivery as a turnkey or EPC contractor, as in house project and contract management for the owner, or as a fully financed (BOO) solution.

Our team are specialists in:

- Concept design and specification of micro-grid and island power systems;
- Detailed design and project delivery of renewable energy projects with significant experience in remote locations; and
- Systems integration and commissioning including thermal power and batteries.

Because we are a consultant and a contractor, we are uniquely placed to provide practical advice to our clients and partners based on current equipment and labour costs and on-site experience.

For more information about Circular Solutions, our team, capability and experience please visit our website www.circularsolutions.com.au.

To contact us to discuss your renewable power projects please email the team at the following email address: info@circularsolutions.com.au.

2. Remote power

Remote power for individual dwellings or small communities was traditionally produced almost exclusively by diesel generators. Diesel is easier to store and transport than petrol and gas and diesel gensets are also generally more reliable.

The cost of renewable generation, in particular wind and solar, has dramatically decreased over the last 10 years. The cost reduction and their increased reliability has made the use of renewable generation to offset diesel consumption quite common. More recently, storage technology including batteries has become a commercially viable option to store energy generated by renewables. The amount of storage installed is usually determined by calculating the installed capacity at which the capital cost is no longer offset by the forecast operational savings.

RENEWABLE GENERATION OPTIONS

Wind and Solar power are the two most common renewable energy sources because wind and sun are available in varying amounts in all locations. There are a number of other renewable energy technologies that could be options in particular locations with if alternate renewable energy resources are available.

Some alternate renewable energy resources are listed below:

- Micro-hydro (rivers, streams or elevated dams)
- Tidal turbines (natural restrictions of tidal flow in coastal locations with large tidal variation)
- Wave power (coastal locations with consistent swell)
- Biomass (plant waste from agriculture or food processing)
- Waste to energy

These technologies are generally used to supplement power being supplied by an electricity network and/or reduce the use of fossil fuels in off grid systems. In some cases energy storage can be used to store power when the renewable energy resource is available to increase the fraction of renewable energy used vs fossil fuels.

CONFIGURATION – CENTRAL VS DISTRIBUTED

Power generation for a community can be either centralized or distributed (or a combination). For diesel generation usually it makes sense to have a centralized system. If the community has one or two houses there will be a generator nearby with low voltage conductor strung between the houses. As the size of the community gets larger, the total energy demand is larger and a power station is required. The power station is sized based on the forecast load of the whole community, power is generated and transmitted to the community houses at high voltage on over head lines or underground cable. It is usually cheaper and safer to install, operate and maintain a central power station and the power network than it would be to operate and maintain distributed generators for each individual residence.

Renewable generation can be either centralized or distributed too. For example, hydropower is the largest contributor of renewable energy to the Australian National Electricity Market, closely followed by wind. Most of this power is generated from centralized generators. Solar is the third highest contributor and the majority of this power is produced from distributed systems on the roofs of people's houses.

Most remote communities have an existing power network. In this scenario distributed renewable generation usually looks like solar panels installed on residents' houses. Typical centralized renewable generation is a large solar farm or wind farm out of town. The decision of which approach is better depends on a number of factors including: community needs, long and short term costs, financing options, existing infrastructure, current and future power demand; and system stability considerations.

INTERMITENCY OF RENEWABLE GENERATION

Most renewable generation technologies product power intermittently:

- Solar produces when the sun is out – clouds or night time stop generation
- Wind produces when the wind is blowing
- Tidal is very predictable, but reduces to zero with the ebb tide
- Micro hydro is quite consistent, but can still reduce to zero or low levels in a dry year
- Biomass and waste to energy is reliably dispatchable, but is subject to the amount of fuel available

Because of the intermittency of renewable generation, thermal generation (usually fuelled by diesel or gas), energy storage or a combination of both are required for the overall power system to be reliable.

In most remote communities whose power system incorporates renewables, there is a central power station that can generate the entire system load for times when the renewable sources are not generating. The renewable generation is used to reduce the diesel use and engine run hour to reduce the average cost of electricity. In locations where the cost of thermal generation is high (usually because the cost of getting fuel to site is high) then it may become commercially viable to install more renewable generation than is required to supply the community load and use energy storage to store the excess energy for use when the renewable generation is not available.

POWER QUALITY AND STABILITY

Power quality is a property of a power system that is often taken for granted in Australia. We expect that the lights in our house will not flicker due to fluctuations in the power supply voltage. We take it for granted that our TV won't stop working for ever after being hit by a power supply voltage spike. We don't expect our alarm clock to lose time everyday due to low power supply frequency.

The examples above are just some of the issues caused by poor power quality. The power quality on microgrids is arguably more difficult to control than no the big nation-wide grid because it is more susceptible to small changes in the network (large loads starting, generators failing or not operating correctly, etc). Power quality and stability needs to be a significant consideration when integrating renewable generation into a microgrid. In some cases, energy storage technology can provide support to the power quality and stability of the network.

ENERGY STORAGE OPTIONS

There are a number of energy storage options that are now at a commercial stage. The choice of system depends on the application case. Technologies include:

- Batteries:
  - Lead Acid
  - Lithium Ion variants
  - Nickel Cadmium
- Flow machines (flow batteries)
- Flywheels
- Hydrogen
- Compressed air
- Thermal storage variants:
  - Graphite
  - Water
  - Thermal oil

The most appropriate storage technology is heavily dependent on the application.

SYSTEM INTEGRATION

A large part of the challenge for the uptake of renewable energy is related to the risks of integration of renewable energy resources into the existing system. This is true for both large networks and microgrids in remote location. There are a number of risks to consider. Some of the key risks are:

- The variability of some renewable resources (including wind and solar) and intermitant nature of the power produced by generators. The variability in output can cause issues with matching the generation with the load, which in turn can cause fluctuations in frequency, voltage and in the worst case, blackouts.
- Many renewable energy technology including wind, solar and batteries contribute differently to large load spikes, network faults and other system fluctuations than traditional generators. If not properly managed, this can result in faults not being detected and blackouts.

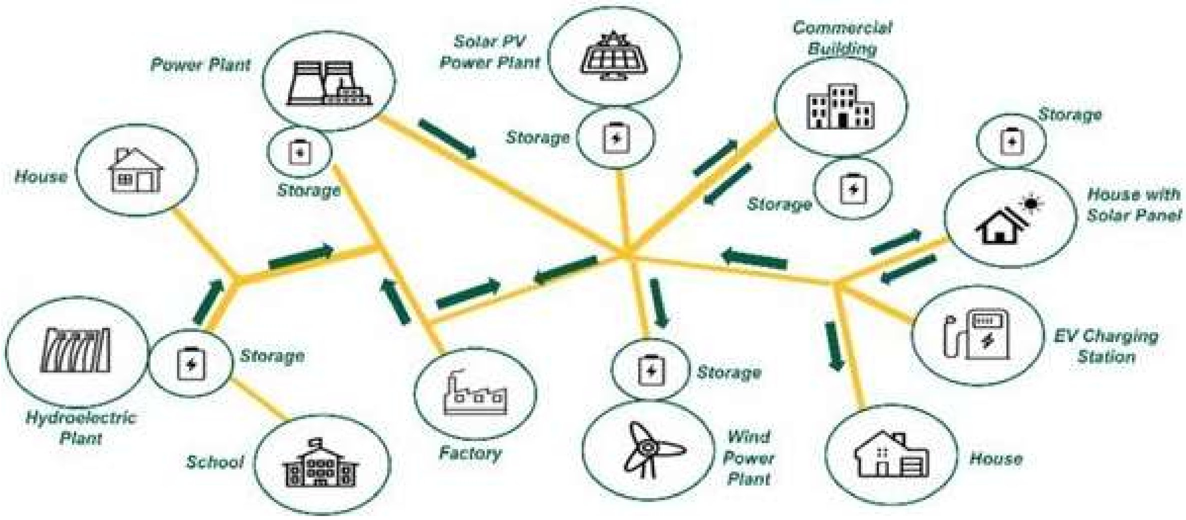

Figure 1 – Integrated system with central and distributed energy systems (NY City Power System Operator NYISO)

Knowledge and technology are catching up fast. The regulations are also changing slowly to take the most advantage of the available technology. Integrating renewables into a remote microgrid has the disadvantage that small changes can have a big impact, but the advantage that there are less generators and less consumers creating the opportunity for greater control of the generation and loads. Distributed energy resources that can be networked together, the potential to control medium sized loads through the network and degreased regulatory requirements all provide opportunities to optimise integration.

3. Project Development and Delivery

Remote power systems require more than just a technology solution. The real obstacles to success are usually a combination of social, cultural, political, regulatory and finance factors. The project lifecycle can be simplified to the five stages shown in Figure 2. Circular Solutions can assist project owners with the whole project life cycle. This section focuses on project Initiation, Planning and Delivery.

Figure 2 – Five project life cycle phases

DEFINITION (INITIATION) PHASE

Often project developers (including communities, consultants, government departments etc) step into a community with a solution in mind. However, careful consideration of the community needs that are unique to a particular situation has the potential to produce an optimized power solution that serves the real community needs. The first step to developing a solution is to define the problem. The following aspects need to be considered:

- Community power needs
  - Present and forecast future demands
  - Power quality and reliability needs
  - Required design life of the solution
- Power system finance options
  - User tariffs
  - Investment by individuals
  - Available grants or debit
  - Investment by the government
  - Investment by community groups
- Energy Resources
  - Access to grid power
  - Existing generation and networks
  - Availability of diesel or gas
  - Availability of renewable resources
- Regulatory
  - Relevant legislation on generation, distribution and sale of electricity
  - Indigenous rights and incentives
  - Incumbent generator rights
  - Existing development programs
  - Development application requirements
  - Environmental requirements
  - Other permitting required

Purposeful engagement of the key stakeholders early in the development process will give a project the best chance of addressing the real community needs.

CONCEPT (PLANNING) PHASE

At the completion of the Definition Phase the development team should have a clear understanding of the current situation including resources and community needs. There should also be a clear definition of the desired outcomes of the project as well as some target areas for the project development Concept Phase.

PROJECT DEVELOPMENT AND DELIVERY

In the Concept Phase the solution is defined and steps are taken to plan and prepare for the Delivery Phase:

- Site studies
  - Geotechnical investigation
  - Topographical survey
  - Flood Study
- Solution Engineering
  - Design optimization
  - Concept Generation design
  - Concept Network design
  - Concept Communications and Control design
  - System stability studies (GPS)
  - Contractor Scopes of Work
- Contracting Model
- Permit and Approvals Application
  - Connection application
  - Development Application
  - Other Permitting as required
- Operating models
  - Cost assessment
  - Commercial analysis
  - Risk management
- Financial model
  - Billing models
  - Finalize Sources of funding
  - Project plan and budget
  - Feasibility Report

DELIVERY PHASE SERVICES

The allocation of roles, responsibilities and risk in the Delivery Phase is dependent on the contracting strategy. In one extreme, the responsibility for the whole delivery phase can be 'wrapped' up by one contractor (EPC contract) and overseen by a representative of the project Owner. Alternatively, at the other extreme the Owner self-deliver and manage all of the consultants and sub-contractors directly. Circular Solutions can assist across the spectrum of delivery approaches, but providing EPC services, owner's representative services or support services to help the Owner self-deliver in an EPCM structure. The tasks that need to be completed in the delivery phase include:

- Design
  - Civil
  - Structural
  - Electrical
  - SCADA
  - Studies
- Procurement including:
  - Sourcing
  - Scopes of work
  - Contract negotiation
- Site and Construction Management
- Project Management:
  - Scope management
  - Cost Management
  - Integration management
  - Communications management
  - Resource management
  - Risk Management
  - Program management
  - Contracts and Contractor management
  - Quality Control and Assurance
  - Safety Management

4. How Circular Solutions Can Help

Circular Solutions excels in working with communities and project owners to find solutions that are beneficial for all. Our team has delivered integrated renewable energy system on microgrids in Australia and in the Pacific.

Successful delivery of projects in remote locations requires a specialised approach. The social, climatic, commercial and political environment present unique challenges at each site. Projects often suffer overruns in time and budget due to inexperience in the management of these challenges. Typically, the overruns are due to significant differences in the project needs when compared with projects in developed urban locations including:

- Logistics – The remoteness of pacific island locations puts particular pressure on logistic requirements. The project team needs to have a clear understanding on the availability of materials and equipment on island as well as the limitations of the infrastructure on the routes to site. Generally a higher level of due diligence and planning is required to minimise assumptions. Often equipment available on site is not capable of meeting its nameplate rating, infrastructure does not meet the assumed standards, and materials that are assumed to be available are not.
- Local culture – Every local community is different. Companies that cannot adapt their systems and processes struggle in remote environments.
- Communications – Communications are more difficult in remote Pacific locations. Telecom and internet are not always available or good quality. There are also barriers to interpersonal communication including language and culture.

The Circular Solutions team has demonstrated experience in managing these obstacles during the design and delivery of power systems in Australia and the Pacific. Including remote hybrid diesel microgrids.

We specialize in complicated projects in remote locations. Our team has played key roles in the following relevant projects:

- Greenough River Solar Farm interconnection design (10 MW connection to the Western Power grid)
- Lungga Power Station (new 10 MW diesel power station in the Solomon Islands)
- Solomon Islands 1 MW solar farm integration (solar integration into a grid with 8-15 MW demand)
- Kiribati solar integration including Fulcrum sky camera (1.5 MW of solar in a 5 MW grid)
- Tonga Power 2MW solar farm HV Integration
- Onsite integration of two solar battery diesel hybrid power systems in the Solomon Islands
- Lord Howe Island Hybrid Renewable Energy Project management (100% instantaneous penetration, 74% diesel offset, solar diesel hybrid system)
- Nova Solar Farm EPC contract (6 MWpk solar farm installed in a microgrid with a 10 MW average load)
- Norfolk Island 2.5MWh BESS (Battery integration into an island grid for generator-off operation)