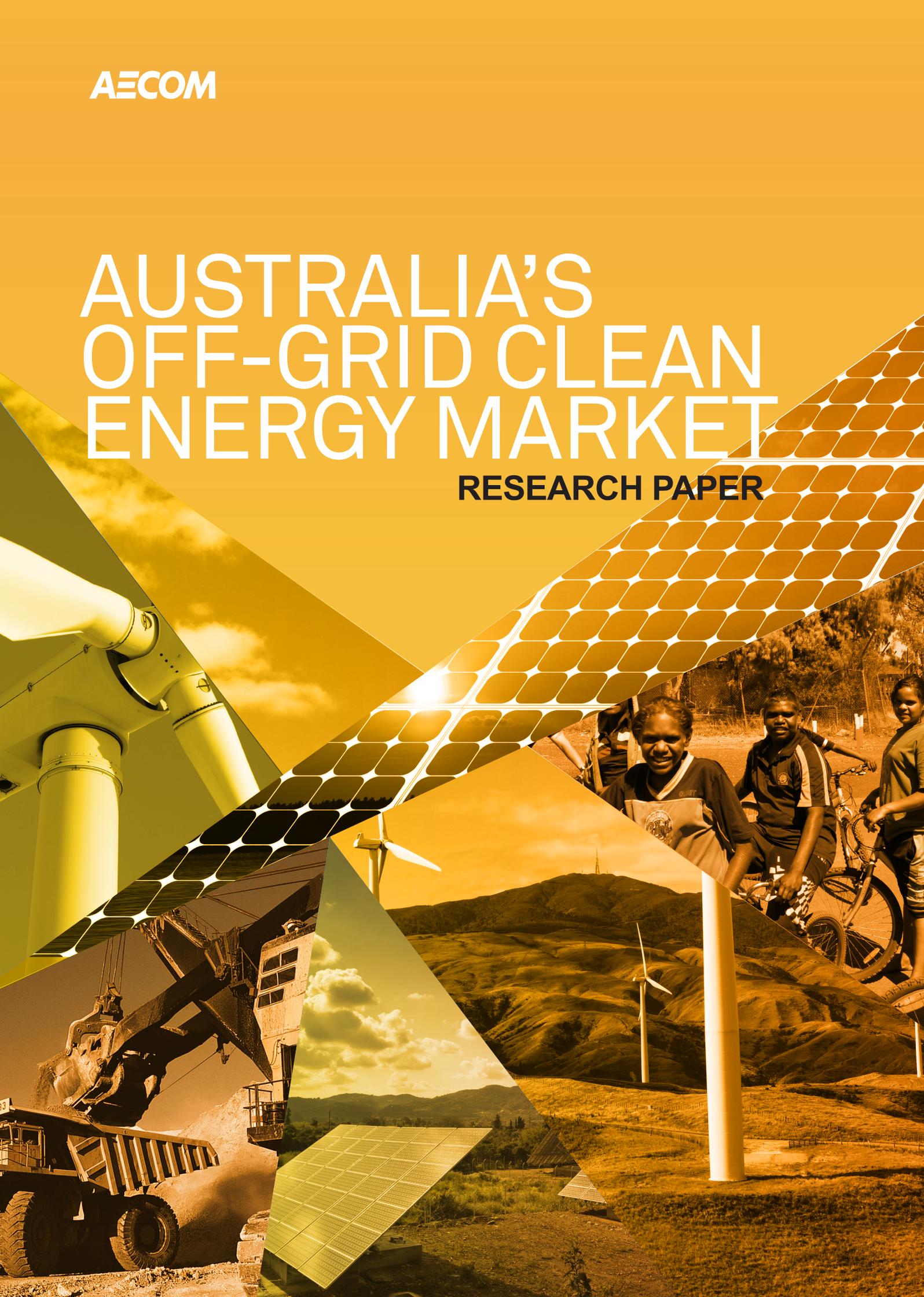


AECOM

AUSTRALIA'S OFF-GRID CLEAN ENERGY MARKET

RESEARCH PAPER



ARENA



Australian Government

Australian Renewable Energy Agency

This report was produced with support from the Australian Renewable Energy Agency (ARENA). ARENA was established by the Australian Government as an independent agency on 1 July 2012 to make renewable energy technologies more affordable and increase the amount of renewable energy used in Australia. ARENA invests in renewable energy projects, supports research and development activities, boosts job creation and industry development, and increases knowledge about renewable energy.

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Australia's Off-Grid Clean Energy Market Research Paper

AECOM

Australia's Off-Grid Clean Energy Market Research Paper

Australian Renewable Energy Agency

Client: Australian Renewable Energy Agency

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Executive Summary

This research paper was commissioned by the Australian Renewable Energy Agency (ARENA) to provide an overview of the off-grid and fringe-of-grid renewable energy market in Australia to assist market entrants and established participants obtain a broader appreciation of this emerging market. The paper provides an insight into Australia's renewable energy resources, electricity markets and regulatory environment through outlining current industry perspectives on Australia's off-grid and fringe-of-grid renewable energy market gleaned from published papers and consultations with key stakeholders.

The paper will also serve as a baseline evaluation prior to the commitment of project funding through the ARENA's Regional Australia's Renewable (RAR) Program and therefore focuses on the remote energy market up to the end of 2013.

Overview of Australia's electricity markets

Australia's main energy markets comprise of the National Electricity Market (NEM) and South West Interconnected Systems (SWIS). The NEM is the world's longest interconnected power system with an end-to-end distance of more than 4,000 kilometres and services over 9 million consumers across Queensland, New South Wales, Tasmania, Victoria and South Australia. The SWIS services 2 million consumers and spans the area surrounding Perth in southern Western Australia. The main source of electricity generation in the SWIS and NEM is through centralised plant fuelled by coal and natural gas. Together these markets supply approximately 93 per cent of all energy consumed in Australia. In 2013, renewable energy contributed approximately 15 per cent of the overall electricity production.

The renewable energy market in Australia is growing rapidly, principally being driven by the Renewable Energy Target (RET) scheme which currently supports growth towards 41,000 GWh of large-scale renewable energy by 2020 in addition to the 15,000 GWh of pre-existing hydroelectric generation. The RET also provides further support for small-scale renewable energy projects.

Australia's electricity markets overview

| Electricity Markets | Capacity | | Consumption | | Emissions |
|---------------------------|----------|-------|-------------|-------|--------------------------|
| | GW | Share | TWh | Share | t CO ₂ -e/MWh |
| NEM | 49.0 | 83% | 199 | 86% | 0.93 |
| SWIS (WA) | 5.5 | 9% | 17.7 | 8% | 0.82 |
| Off-grid Mining Market | 3.9 | 6% | 12.4* | 5% | 0.61 |
| Off-grid Community Market | 1.0 | 2% | 3.4* | 1% | |

Source: AECOM, AEMO, IMO, Department of Climate Change and BREE

* Excludes NSW, ACT, VIC and external territories of Australia for confidentiality reasons

Off-grid electricity market overview

For the purposes of this paper, Australia's off-grid electricity market is defined as a combination of fringe-of-grid areas in remote locations and off-grid areas, defined as:

- Fringe-of-grid encompasses areas in the NEM and SWIS that are remote and have a relatively high likelihood of supply reliability or power quality issues.
- Off-grid comprises of isolated or islanded electricity systems that are not connected to the NEM or SWIS.
- Remote areas are defined as areas classified as 'Remote Australia' or 'Very Remote Australia' in the Australian Statistical Geography Standard (ASGS): Volume 5 - Remoteness Structure, July 2011 (ABS cat. No. 1270.0.55.005)

Fringe-of-grid and off-grid areas



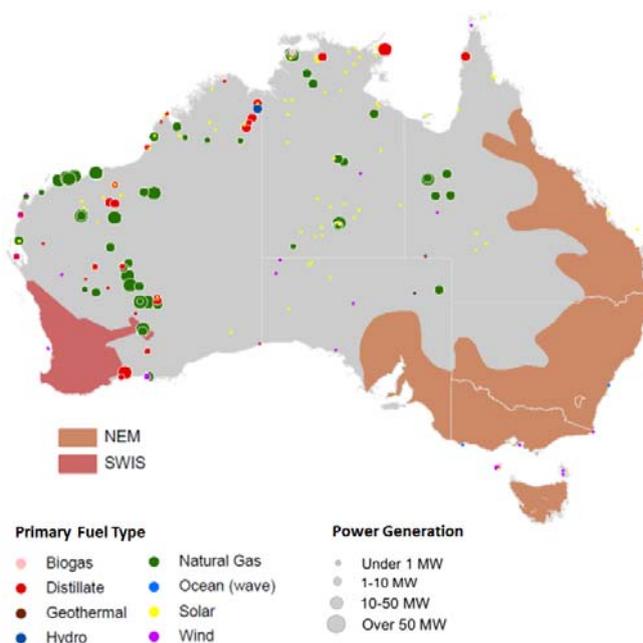
Source: AECOM, ABS

This paper largely focuses on off-grid areas, however, it is acknowledged that there is an extensive fringe-of-grid market which services remote parts of Australia. The adjacent figure geographically illustrates the fringe-of-grid and off-grid areas.

Only 2 per cent of Australia’s population live in off-grid areas, however over 6 per cent of the country’s total electricity is consumed in off-grid areas. Around 74 per cent of that electricity is generated from natural gas and the remainder is mostly from diesel fuel; making it Australia’s most expensive electricity due to the underlying high gas and diesel prices in the remote areas. However, due to lower levels of coal generation, the off-grid market has the lowest average emission intensity of all of Australia’s electricity markets despite only 1 per cent of electricity is generated from renewable sources. An estimated 15,575 GWh of electricity was produced in 2012 by off-grid generation in Australia; supplied from a total installed off-grid generation capacity of approximately 5GW.

Much of the off-grid electricity market has experienced an increase in demand in recent years associated largely with expansion in the mining industry. In general, the off-grid electricity market has also experienced an increasing interest in renewable energy as a potential means to reduce the costs of electricity.

Existing off-grid generation



Source: AECOM

Remote clean energy support

The Australian renewable energy sector attracted \$5.2 billion of investment in 2013 and there is now considerable industry interest in the remote clean energy market. The Clean Energy Council has estimated that 14.8 per cent of Australia’s electricity generation was produced by renewable sources in 2013. Practical experience and case studies will likely facilitate further uptake of renewables, particularly in off-grid industrial and mining applications. ARENA’s mandate to disseminate the knowledge generated from the projects it supports will be essential to progress the industry’s understanding of the lessons learnt and develop the confidence of end users and remote grid operators in the technology’s value.

ARENA’s RAR Program intends to fund up to \$400 million to support investment of renewables in off-grid and fringe-of-grid clean energy projects by 2018. The funding focuses on two market segments:

- Regional communities that are not connected to NEM or SWIS (through the Community and Regional Renewable Energy (CARRE) program); and
- The industrial and mining sector, (through

the industrial program, “I-RAR”), which seeks to support projects greater than 1MW.

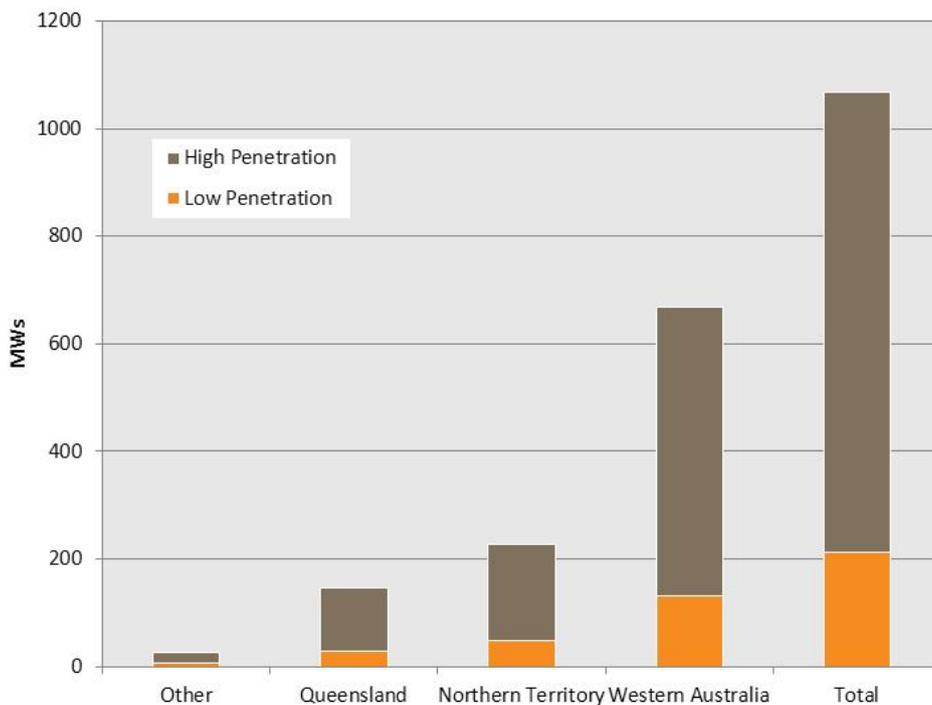
ARENA’s RAR Program will be complemented by other programs and schemes such as the Clean Energy Finance Corporation (CEFC), the Renewable Energy Target (RET) and state based funding towards renewable energy.

Estimated market size

In estimating the off-grid market size, AECOM has considered both high and low penetration potential. The establishment of ARENA’s RAR and other Government support programs were also taken into consideration in addition to future renewable technology development which will enable greater uptake.

In the short to medium term, it is forecasted that hybridising renewables will begin at a low penetration in Western Australia, the Northern Territory and Queensland with up to a possible 150 - 200 MW (corresponding to approximately AUD \$450 - \$600 million in capital value) of project opportunities available. As confidence and demand for more remote energy grows, and technology costs fall and develop over time, there may be potential for higher penetrations of renewables. This could unlock an additional 850 MW or a total of over 1 GW of off-grid renewables at a capital value of over AUD \$2 billion.

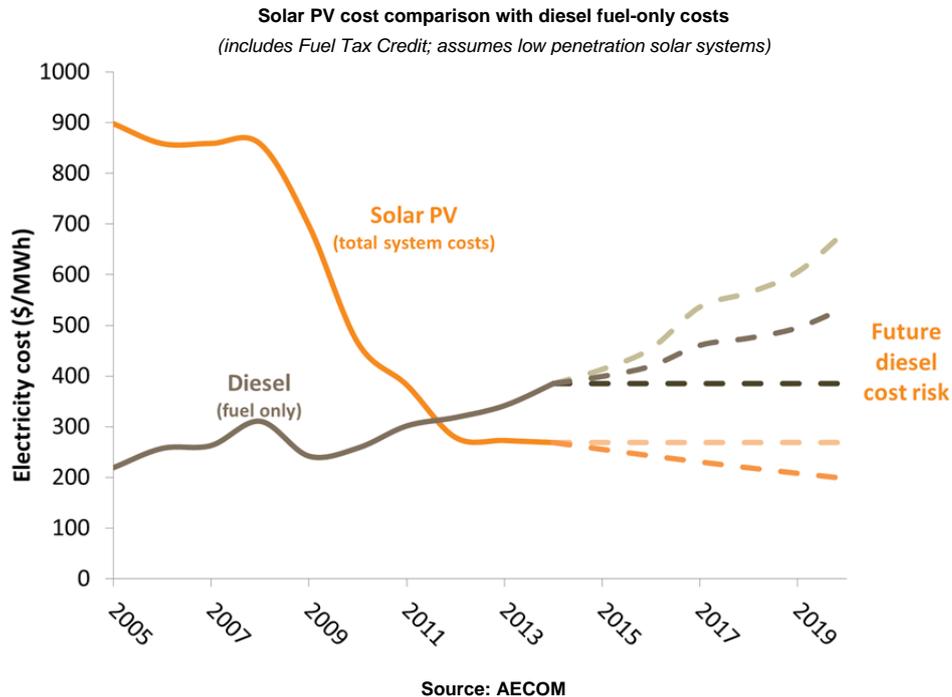
Estimated market size of off-grid renewables



Source: AECOM

The business case

Renewables as a future fuel security and price off-set option has now become a more attractive proposition in off-grid Australia. The modular nature of many renewable technologies (such as wind and solar photovoltaics) and the recent expansion of these industries with associated reductions in cost, means that new opportunities are emerging for developing off-grid clean electricity supplies. Currently there is over 1.2GW of diesel generation capacity installed in off-grid Australia which supplies electricity to mines and communities at a cost of \$240-450/MWh in fuel only (excluding capital costs). These costs are expected to rise over time and are vulnerable to price shock events or supply chain interruptions in international markets.



The off-grid renewable electricity market is relatively undeveloped in Australia, with a number of challenges needing to be overcome before mass deployment can occur. Other than some unique project opportunities, the market is currently focused on adapting mature renewable technologies into existing off-grid power stations to offset operating fuel costs. Each project will likely be evaluated on a levelised cost of electricity (LCOE) basis, with a consideration of system reliability and integration issues associated with constructing and maintaining plant in an isolated location. Traditional fossil fuelled generation is well understood, conversely there remains a lack of experience of integrating renewables into off-grid Australia at scale. Therefore some stakeholders initially may find it difficult to appreciate the value proposition.

The remoteness of these projects is a key factor for consideration, not only for construction, but also for long term operations and maintenance. The need for training of regional maintenance resources will need consideration as the market develops in addition to aggregating smaller projects within remote regions to increase construction, operational and maintenance economies of scale. Also, much of off-grid Australia is susceptible to extreme climatic events which could impact plant longevity and design considerations, and hence viability.

Despite these challenges, many developers, off-grid interconnected system operators and end users are planning to incorporate renewable energy into off-grid applications. In the short term, the focus is likely to be on hybridising wind turbines and solar photovoltaics with existing generation facilities. The reduction in some renewable technology costs and availability of government support programs has made renewables as a future fuel security and price off-set option a more attractive proposition.

In the absence of government support programs, the longer term sustainability of the off-grid renewable market will largely be dependent on fossil fuel prices, the development of enabling technologies (such as batteries, low load diesel engines and 'smart' control systems) and market confidence in available renewable technologies. Furthermore, the finance sector's appetite to support the projects will be critical to future success. The finance sector will be influenced by the risk associated with any technology or project, the size of investment and the policy certainty.

There already is an emerging business case for fuel off-setting through hybridising mature renewable technologies with existing off-grid diesel generation systems at low penetrations. In locations with high diesel prices, the levelised cost of hybridisation of a diesel system with wind or solar is already comparable with the cost of diesel that would be offset by such a system. In the medium to longer term, gas price increases are expected in Australia's eastern gas markets as local producers begin to service the demands of local Asian markets through export LNG. This will further enhance the viability of integrating renewables with gas-fuelled generators, particularly as further technology cost reductions are expected and energy storage technologies evolve.

Conclusion

The largely untapped off-grid clean energy market and funding support available from the Australian Government, creates an attractive opportunity for the Community and Industrial off-grid sectors to pursue cheaper and cleaner electricity supply. The market segments with the largest opportunities include:

- renewable hybridised generation systems represent the greatest potential area for investment, particularly when associated with existing diesel-fired power plants
- industrial/mining growth regions of Western Australia, Queensland and the Northern Territory
- community growth regions where aggregation of smaller projects particularly in growing mining towns such as Roxby Downs (SA), Weipa (QLD), in addition to Karratha, Newman and the greater Pilbara in Western Australia which have shown significant electricity demand growth as a result of fly-in-fly-out and permanent population expansion in recent years
- off-grid interconnected systems such as the North West Interconnected Systems (NWIS) in Western Australia operated by Horizon Energy, Darwin - Katherine System in the Northern Territory operated by Power and Water Corporation and, Mount Isa Grid in Queensland operated by Ergon Energy.

In realising these opportunities it is recognised that deployment of cost effective enabling technologies, development of system integration expertise and remote training programs will be essential to accelerate uptake, ensure reliability and sustain the confidence of end-users.

Glossary

| Term | Meaning | Term | Meaning |
|--------------------|--|------|--|
| ACRE | Australian Centre for Renewable Energy | IPP | Independent Power Producer |
| AEMC | Australian Energy Market Commission | LCOE | Levelised Cost of Energy |
| AEMO | Australian Energy Market Operator | LGC | Large Scale Generating Certificates |
| AER | Australian Energy Regulator | LNG | Liquefied natural gas |
| ARENA | Australian Renewable Energy Agency | LRET | Large-scale Renewable Energy Target |
| AUD | Australian Dollar | MJ | Megajoule |
| BOO | Build Own Operate | MW | Megawatt |
| BREE | Bureau of Resources and Energy Economics | MWh | Megawatt hour |
| CARRE | Community and Regional Renewable Energy program | NEM | National Electricity Market |
| CEFC | Clean Energy Finance Corporation | NSP | Network Service Provider |
| CNG | Compressed Natural Gas | NWIS | North West Interconnected System |
| CO ₂ -e | Carbon dioxide equivalent | PJ | Petajoule |
| COAG | Council of Australian Governments | PPA | Power Purchase Agreement |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation | PV | Photovoltaic |
| CSO | Community Service Obligation | PWC | Power and Water Corporation |
| DNSP | Distribution Network Service Provider | RAR | Regional Australia Renewables (an ARENA program) |
| EPC | Engineer, Procure, Construct | RET | Renewable Energy Target |
| EPCM | Engineer, Procure, Construction Management | SRES | Small Renewable Energy Scheme |
| GJ | Gigajoule | SRMC | Short-run Marginal Cost |
| GST | Goods and Services Tax | STC | Small-scale Technology Certificate |
| GW | Gigawatt | TJ | Terajoule |
| GWh | Gigawatt hour | TNSP | Transmission Network Service Provider |
| IEA | International Energy Agency | UPS | Uninterruptible Power Supply |
| IES | Indigenous Essential Services | | |

Preamble

This research paper was commissioned by the Australian Renewable Energy Agency (ARENA) to provide an overview of the off-grid and fringe-of-grid renewable energy market in Australia to assist market entrants and established participants obtain a broader appreciation of this emerging market. The paper provides an insight into Australia's renewable energy resources, electricity markets and regulatory environment through outlining a summary of current industry perspectives on Australia's off-grid and fringe-of-grid renewable market from published papers and consultations with key stakeholders.

The paper also provides a baseline evaluation prior to project funding being committed through the ARENA's Regional Australia's Renewable (RAR) Program and therefore focuses on the remote energy market up to the end of 2013.

RAR Program Objectives:

- To demonstrate a portfolio of renewable energy solutions, including hybrid and integrated systems, in Australian off-grid and fringe-of-grid areas;
- To ensure knowledge is produced and disseminated regarding the deployment of renewable energy solutions in remote areas catalysing further renewable energy uptake;
- To remove roadblocks, leading to greater deployment of renewable energy solutions in off-grid and fringe-of-grid areas.

RAR Program Expected Outcomes:

- Within five years, result in at least 150MW of renewable energy projects in off-grid and fringe-of-grid locations where fossil fuels are currently or would otherwise be used. This would include two or more \geq 10MW projects;
- The renewable energy capacity is appropriately utilised for at least five years following commissioning;
- Key roadblocks to the greater implementation of renewable energy are removed, including, but not limited to integration and control system risk, and low reliability perceptions;
- Regional communities and industry gain more skills in operating and maintaining renewable energy solutions;
- Knowledge produced and disseminated regarding the economic viability of renewable energy solutions in remote areas catalyses further commercially based renewable energy deployment.

The ARENA's RAR Program has already attracted considerable market interest and the assistance pledged will likely increase the broader acceptance of renewable energy in remote regions. Practical experience and case studies deployed by this program will likely facilitate further uptake of renewables particularly in the off-grid industrial and mining sectors. Dissemination of the learnings from these projects will be essential to progress the industry's understanding of the lessons learnt and develop the confidence of end users and off-grid interconnected system operators in the technology.

Further information about the RAR program is detailed in section 4.3.4.

We would like to acknowledge the support we have received during the development of this research from:

- Australian Renewable Energy Agency (ARENA)
- Clean Energy Finance Corporation (CEFC)
- Department of Resources, Energy and Tourism (now the Department of Industry)
- Australian Government Clean Energy Working Group, represented by State and Territory Governments and;
- Australian industry contacts including ATCO Australia, Atlas Iron, Charles Darwin University, Commonwealth Bank of Australia, Eltek, HST, IT Power, Pilbara Development Commission, Power Water Corporation, Rio Tinto, SA Department of Manufacturing, Innovation, Trade, Resources and Energy, SMA, Solco, Western Desert, Australian Trade Commission (Austrade), Xtreme Power and ZBB.

Initial research work for this study was funded by Austrade in 2012-13 with the purpose of providing foreign investors and developers with a greater understanding of Australia's energy market, in particular outlining the off-

grid energy market opportunities in Australia. Please contact AECOM or ARENA if you have further queries. We look forward to the expansion of the off-grid and fringe-of-grid renewable energy market in Australia.

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Disclaimer

AECOM acknowledges that the datasets used to define the market size may have anomalies and therefore are not complete. As such, some figures presented in the paper are subject to significant uncertainty. All stakeholders should use their own discretion before making any financial investments or decisions based on the information contained in this paper. AECOM does not accept any liability for any decisions made on the basis of this information. AECOM were initially engaged by Austrade to undertake a broad study of Australia's electricity industry to gain detailed insight into how the current policy and market is impacting off-grid renewable investment. Subsequently, ARENA has engaged AECOM to update the paper and provide a summary of current industry perspectives on Australia's off-grid renewable market.

1.0 Introduction

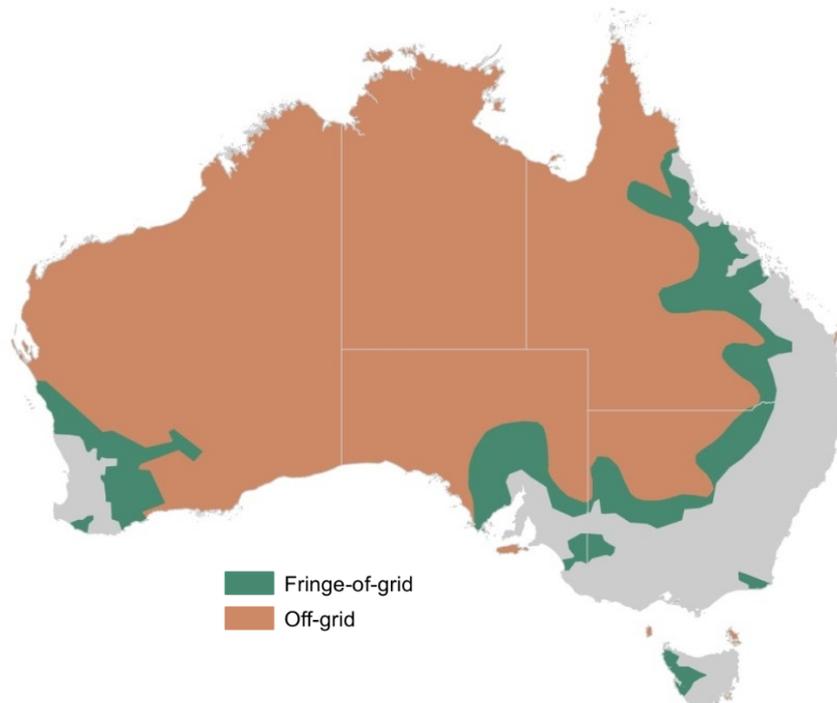
This paper is intended to identify the characteristics of the off-grid and fringe-of-grid renewable energy markets, to highlight key stakeholders and identify project opportunities. The research contained draws upon publicly available literature, various consultations held with stakeholders both in industry and Government and AECOM's market knowledge to articulate the value proposition of the off-grid renewable marketplace in Australia.

This paper has aligned its definition of the off-grid renewable market with the Australian Renewable Energy Agency's Regional Australia's Renewables Program (ARENA's RAR Program), which is;

- a) **Fringe-of-grid:** Areas in the National Electricity Market or the South West Interconnected System that are remote, with a relatively high likelihood of supply reliability and power quality issues being experienced.
- b) **Off-grid:** Isolated or islanded systems (including private systems) or grids that are not connected to the National Electricity Market or the South West Interconnected System.
- c) **Remote:** Areas defined as 'Remote Australia' or 'Very Remote Australia' in the Australian Statistical Geography Standard (ASGS): Volume 5 - Remoteness Structure, July 2011 ([ABS cat. No. 1270.0.55.005](#))

This paper primarily focuses on off-grid areas, although it is acknowledged that there is an extensive fringe-of-grid market servicing remote parts of Australia for which much of the enclosed report is also relevant. The figure below geographically illustrates the fringe-of-grid and off-grid areas.

Figure 1 Fringe-of-grid and off-grid areas of Australia



Source: AECOM, ABS

The paper has been prepared to provide;

- a) an overview of Australia's energy market in the global context, and the market for renewables in Australia;
- b) an introduction to the off-grid market, providing context for those unfamiliar with Australia's energy markets;
- c) an overview of Australian legislation relevant to the clean energy industry in an off-grid context; and
- d) an overview of the commercial and technical considerations for remote renewable projects.
- e) an overview of Australia's renewable resource and corresponding technology status.

Furthermore to align with the market sectors as defined by ARENA's RAR Program, this paper is structured around two main market sectors that are currently expanding or are demonstrating potential for imminent growth, namely:

- **Off-grid Industrial Sector:** The industrial and commercial regional energy market, dominated by the off-grid mining segment and including defence, agricultural and tourist facilities with renewable energy opportunities greater than 1 MW including those connected to off-grid interconnected systems. (section 6.0)
- **Off-grid Community Sector:** The community market, which includes small and very small off-grid communities, fast growing mining towns, islands, small commercial facilities with renewable energy opportunities between 100kW and 1MW, including those connected to off-grid interconnected systems. (section 7.0)

Off-grid interconnected systems – Darwin-Katherine, Alice Spring, North West Interconnected System (NWIS) and Mount Isa span across both these market segments and are discussed in section 5.0.

2.0 Australia in the Global Context

2.1.1 Global renewable energy market

Investment in electricity generation around the world is increasingly moving towards renewables. Although investment in renewable energy fell in 2013 for the second year in a row (totalling US\$2214 billion and 23 per cent below the 2011 record), non-hydro renewable generation accounted for 44 per cent of new generation capacity installed globally. The small investment drop in the last two years compared to previous years was reported to be driven by the falling cost of solar photovoltaic systems as well as policy uncertainty in many countries.

Developing economies made up 35 per cent of this total investment, compared to 65 per cent for developed economies and for the first time in 2013, China invested more in renewable energy than Europe. Hydropower and solar photovoltaic (PV) each accounted for approximately one third of new renewable capacity in 2013, followed by wind which contributed nearly 30 per cent (REN21, 2014). This was the first time that installed solar capacity was greater than wind. By the end of 2011, renewables comprised more than 26.4 per cent of total global power-generating capacity and supplied an estimated 22 per cent of global electricity. Non-hydropower renewables exceeded 560 GW, a 17 per cent capacity increase over 2012 (REN21, 2014). Modelling by the International Energy Agency (IEA) projects that renewable technologies could form half of all new additional capacity worldwide through to 2035 (IEA, 2012)

There are many drivers for this rapid market shift towards renewable technologies, including falling renewable energy costs, energy security, carbon reduction policies, rising fossil fuel costs and avoidance of the externalities associated with fossil fuel generation. At least 118 countries, more than half of which are developing countries, had renewable energy targets in place by early 2012, up from 109 as of early 2010. Renewable energy targets and support policies continue to be a driving force behind renewable energy markets, despite some setbacks resulting from a lack of long-term policy certainty and economic stability in many countries. Since the global financial crisis, and particularly over the last two years, several countries have undertaken significant policy overhauls primarily as a result of austerity measures that have resulted in reduced support for renewable energy. Nevertheless, policymakers are increasingly aware of renewable energy's wide range of benefits—including energy security, reduced import dependency, reduction of greenhouse gas emissions, prevention of biodiversity loss, improved health, job creation, rural development, and energy access.

For the majority of remote electricity users globally, off-grid renewable electricity is less expensive than extending the power grid. Renewable energy projects in developing countries have contributed to energy poverty alleviation by providing education, reducing hunger, disease through the access to safe drinking water and the creation of jobs supporting the increase in living standards.

Ernst & Young have developed a Renewable Energy Country Attractiveness Index (RECAI) score for 40 countries, which ranks countries based on the attractiveness of their renewable energy markets, energy infrastructure and the suitability for individual technologies. The top five countries were (in order) the USA, China, Germany, Japan and the UK. Australia was ranked 8th. (Ernst and Young, 2014)

2.1.2 Australian energy industry

2.1.2.1 Energy Mix

Australia is a stable and prosperous developed nation. Unlike many other developed nations, Australia has historically demonstrated consistent electrical demand growth underpinned by a strong and rapidly expanding primary resources industry. In recent years, demand growth has declined in the National Electricity Market (NEM). Due to significant uncertainty around the impacts of declining manufacturing, energy efficiency measures and continued growth in rooftop solar photovoltaics on future projections, the Australian Energy Market Operator (AEMO) has continuously revised the projected long term demand growth to a slower rate.

Australia has substantial domestic coal resources, which form the basis of a large coal export industry with coal exports anticipated to double by 2020 (BREE, Australian Energy Projections to 2034-35, 2011), and continue to grow through to 2030. Furthermore, the mega LNG projects in development around Gladstone and the development of coal seam gas resources on the east coast of Australia could see Australia overtaking Qatar to become the largest LNG exporter in the world by 2020 (Winning, 2012).

The abundance of coal resources in Australia has led to approximately 75 per cent of Australia's electricity being generated from coal-fired generation. This, combined with economic and political stability, has made Australian electricity cheap, reliable and low risk. Thus, Australia has been a home of energy intensive industry, such as aluminium refineries and smelters for many years.

However, high reliance upon coal-fired generation means that electricity production is highly carbon intensive in Australia. With global pressure to reduce greenhouse gas emissions, Australia’s electricity sector will need to progress towards lower emissions generation in order to maintain its competitiveness. With the expansion of LNG exports out of Australia and expansion of shale gas in the United States, the energy production mix in Australia will be dictated by dynamics in international commodity markets, determining the availability and price of traditional fossil fuels in domestic markets. If international LNG prices fluctuate upwards, future energy production investments will likely continue to be a mixture of fossil fuel and renewable energy. However, if LNG prices fluctuate downward, some are predicting a global trend toward gas as the primary energy fuel source. Global LNG prices could have a significant impact on Australia’s coal and LNG exports and likely influence the uptake of renewables.

In addition to its coal and gas resources, Australia has vast renewable resources. World class wind resources are generally prevalent in the southern parts of the nation, combined with large sunny arid regions mean that Australia is well placed for competitive investment in renewables.

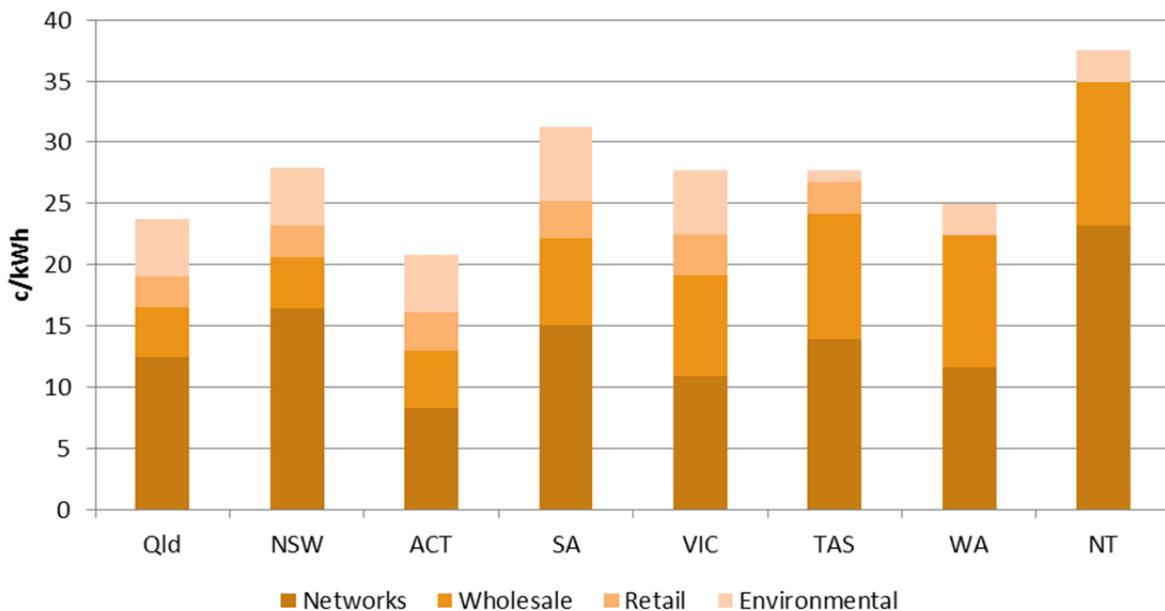
Australia is currently experiencing an unprecedented decline in demand for electricity across the National Electricity Market (NEM), and a flattening of demand in the South West Interconnected System. AEMO has stated that no new capacity is required in any NEM region to maintain supply-adequacy over the next 10 years (AEMO, 2014). Therefore it is expected that investment in new generation will be dominated by renewable sources.

2.1.2.2 Electricity Prices

In Australia, the price of electricity is determined by a number of factors such as transmission and distribution network costs, the wholesale electricity price faced by retailers, and government policies. Recently, a major driver of rising retail electricity prices has been the significant investment in new, and the upgrading of existing, transmission and distribution infrastructure required to support increasing (peak rather than overall) demand for electricity.

The Australian Energy Regulator estimates that transmission and distribution network costs will represent 36-57 per cent of the retail electricity price faced by NEM-connected households in 2012–13, with wholesale electricity prices representing on average a further 21 to 27 per cent (Figure 2). The disperse nature of Australia’s energy infrastructure that seeks to support its relatively small population over vast distances, motivates the focus toward supporting off-grid energy demand with the use of renewables.

Figure 2 Composition of Residential electricity costs in 2012-13



*Environmental component includes green schemes and the carbon tax (which has since been repealed)

Source: (AEMC, 2013)

2.1.3 International remote or off-grid market

Over 1.2 billion people approximately 20 per cent of the world's population currently live without access to electricity worldwide, almost all of whom live in developing countries. This includes 550 million in Africa and over 400 million in India. About 2.8 billion people use solid fuels (wood, charcoal, coal and dung) for cooking and heating (World Bank, Energy).

Without energy, many developing economies cannot grow and poverty cannot be reduced. Energy is an important input to all sectors of the economy, fuelling transport to move goods and people and providing electricity to industry, commerce, agriculture, and important social services such as education and health. Access to electricity is a global challenge, particularly in remote areas which historically have pursued cheaper solutions over more environmentally and socially sustainable options.

Due to the modular nature of many renewable technologies (such as wind and solar photovoltaics) and the recent expansion of these industries with associated reductions in cost, new opportunities for development of off-grid electricity supply are emerging. The international growth markets for renewable generation in remote locations are being experienced in both developed and developing countries such as Arctic Canada, Brazil, Asia and many African countries. Rapidly developing nations such as India and China also have substantial populations in remote areas; in India, around a third of the population relies on off-grid generation systems with further growth expected in this sector due to the instability of the electricity grid. It is recognised that the remote hybrid market is a precursor to the likely uptake of hybrid and renewable enabling technologies in a grid connected application.

Internationally there are four main sub-segments to the remote renewable sector as outlined in table 1 below.

Table 1 Overview of the Global Remote Renewable Sub-segments

| Remote Renewable Sub-Segment | Typical Size Range | Overview | Examples in Australia |
|---------------------------------|--------------------|--|---|
| Remote Community Systems | <2MW | Perhaps the largest number of remote renewable installations today would fall into this category, though data is extremely scarce due to the small scale of such projects and large number of installations. An average community renewable power system has a capacity of 100 kW and is used to displace diesel or other fuel sources. They typically provide power to remote villages, islands, tourist facilities, industrial and military installations, houses, clinics, schools, and stores or an individual dwelling. Although the smallest in scale, the investment required for community power systems per kilowatt is large in comparison with any other sub-segment. | Bushlight is part of the Centre for Appropriate Technology (CAT), an Australian non-profit organisation which works with Indigenous communities throughout regional and off-grid Australia. CAT offers customised renewable systems for rugged, remote applications. Using this concept and through funding from AusAid, CAT developed and took its technology to India in 2009/10 to support a remote community with renewable energy using its understanding from remote Australian installations. |
| Isolated Interconnected Systems | <5MW | Weak islanded grids represent another opportunity for renewables. The lack of options for power and fuel supply to support these remote grids makes renewable energy an attractive option for network support and peak demand management particularly when installed using energy storage technologies such as batteries. Typical applications include water pumping, disinfection, desalination, communication stations, navigational | Powercorp, which was acquired by German transmission and distribution multinational ABB in 2011, adopted its patented flywheel PowerStore system for peak lopping, frequency regulation and integration of intermittent renewable technologies into hybrid applications such as Horizon Power's Marble Bar solar installation in Western Australia. |

| Remote Renewable Sub-Segment | Typical Size Range | Overview | Examples in Australia |
|--------------------------------------|--------------------|---|--|
| | | aids and road signals. | |
| Industrial Remote Mining | <30MW | <p>This sub-segment of the remote renewable market is the least mature, but has a high growth potential due to an improving business case as well as increased interest in shifting to more sustainable energy strategies for sites controlled by large multinationals. Currently, few overseas remote mining operations are deploying renewable energy generation.</p> | <p>Galaxy Resources' Mt Cattlin lithium mine currently uses renewable energy sources for up to 15 per cent of its total power, using solar tracking panels developed by Swan Energy.</p> <p>The mining company intends to also install three wind turbines, each with a 1.2 megawatt capacity, as well as a solar power system with a one megawatt capacity to power the site.</p> |
| Mobile Military or Disaster Recovery | <10MW | <p>This last category of remote renewables is the least developed, but has the most policy and financial support particularly from the U.S. Department of Defence. At present, renewable systems are being deployed in pilot projects in Afghanistan and other remote Defence locations.</p> <p>The requirement to protect or extend fuel use which renewables can provide, is highlighted by the direct relationship between fuel transportation and casualties (Army Technology, 2010) during war.</p> <p>Similar drivers to the defence are the humanitarian services operations where power is often intermittent in regions where disasters have occurred and renewables can provide both a short and long term benefit to the community or region recovering from any catastrophic event.</p> | <p>According to the Australian Defence Force White paper on the Cost of Energy (2013), Defence transport must be converted to run on electricity on solar photovoltaics and wind power to remain viable.</p> <p>Australia's Defence Science and Technology Organisation (DSTO), in collaboration with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) have taken significant strides towards developing a self-powered generating device to assist soldiers in the field.</p> |

3.0 Australian Electricity Markets

3.1 Overview

There are a number of independent electricity grids in Australia, with no electrical interconnection between them:

- **National Electricity Market (NEM)** - The NEM is the largest grid in Australia, spanning the eastern and southern states, providing a fully interconnected network from northern Queensland through New South Wales, the Australian Capital Territory, Victoria, South Australia and Tasmania. The NEM features a sophisticated market operated by the Australian Energy Market Operator (AEMO) that supplies around 86 per cent of the electricity demanded in Australia as shown in Table 2.
- **South West Interconnected System (SWIS)** – The SWIS grid spans the area around Perth in southern Western Australia. The Independent Market Operator of Western Australia (IMO WA) operates the Wholesale Electricity Market (WEM) in the SWIS, supplying approximately 8 per cent of the electrical demand in Australia. The SWIS is not electrically connected to the NEM due to the very large physical distance between these grids and the sparseness of the population in the land in between.
- **Other isolated interconnected systems** – In addition to the NEM and the SWIS, there are multiple independent interconnected systems in locations such as the Pilbara, the Northern Territory and Mt Isa. These isolated interconnected systems are operated by local network providers or local industries (such as the mining operations that they supply) and do not feature sophisticated market structures. Supply in these systems is still considered 'off-grid' by definition. These isolated interconnected systems are presented in section 3.6.

Table 2 Summary of Australia's Energy Markets

| Energy Markets | Capacity | | Consumption | | Emissions |
|----------------------------------|----------|-------|-------------|-------|--------------------------|
| | GW | Share | TWh | Share | t CO ₂ -e/MWh |
| NEM | 49.0 | 83% | 199 | 86% | 0.93 |
| SWIS (WA) | 5.5 | 9% | 17.7 | 8% | 0.82 |
| Off-grid Mining Energy Market | 3.9 | 6% | 12.4* | 5% | 0.61 |
| Off-grid Community Energy Market | 1.0 | 2% | 3.4* | 1% | |

Source: AECOM, AEMO, IMO, Department of Climate Change and BREE

* Excludes NSW, ACT, VIC and external territories of Australia for confidentiality reasons

The establishment of sophisticated markets supplying the majority of electrical load in Australia (via the NEM and the SWIS) has been part of a larger transformation of the Australian energy industry over the last two decades. This has included the removal of regulatory challenges to interstate trade and the disaggregation of public monopolies into separate entities for generation, transmission, distribution and retail. Following disaggregation, competition was introduced into the generation and retail markets. Most of the eastern states have privatised some or all of their electricity supply. The gas industry has undergone similar restructuring allowing competitive energy markets.

The following table provides an overview of the differences between the NEM and SWIS, the two main electricity networks in Australia.

Table 3 Differences between NEM and SWIS (EnergyAction, 2012)

| | NEM | SWIS |
|----------------------------------|--|--|
| Overview | | |
| Coverage Area | NSW, VIC, QLD, SA, ACT, TAS | South West region of WA |
| Energy Generated | 211,000 GWh | 17,500 GWh |
| Number of Generators | 306 Generators | 46 Generators (biggest being Verve Energy (now Synergy)) |
| Number of Retailers | 26 Retailers (Three major – AGL, Origin Energy, EnergyAustralia) | 11 Retailers (Three major – Synergy, Alinta, Perth Energy) |
| Network Details | | |
| Coverage | 800,000 km of power lines | 90,000 km of power lines |
| Network Areas | 13 Distribution Networks | South West Interconnected Network |
| Metering | Contestable Market | Monopoly – Western Power |
| Regulatory Details | | |
| Wholesale Market Operator | Australian Energy Market Operator | Independent Market Operator (IMO WA) |
| Regulatory | Australian Energy Regulatory | Economic Regulation Authority (ERA WA) |
| Contestability | Full Retail Contestability (except <50MWh TAS) | Retail contestability only available for consumers >50 kWh per annum |
| Market Details | | |
| Wholesale Market | AEMO Spot Pool Market | STEM and Reserved Capacity Market |
| Market System | Pool based energy market (Gross pool market) | Pool based with capacity and energy traded separately |
| Spot Market Price Cap | \$12.500 / MWh | \$300/MWh for gas-fired \$700/MWh for liquid fired |
| Long Term Financial Settlements | Future or over-the-counter contracts (AFMA and Futures published on SFE) | Bilateral Contracts (Settled by IMO and confidential) |
| Short Term Financial Settlements | AEMO Spot Pool Price | Short Term Energy Market (STEM) |

3.2 National Electricity Market

The National Electricity Market (NEM) is the wholesale market for the supply of electricity in Queensland, New South Wales, the Australian Capital Territory, Victoria, South Australia and Tasmania. An overview of NEM characteristics is provided in Table 4.

Table 4 NEM Snapshot

| Category | Characteristics |
|----------------------|--|
| Demand | <p>Winter peak demand 2012-13 of 30.5GW (the maximum historical winter demand of 34.4GW occurred in 2008)</p> <p>Summer peak demand 2012-13 of 32.5GW (the maximum historical summer demand of 35.6GW occurred in 2009)</p> <p>Annual electricity consumption of 199TWh (2012-2013)</p> <p>9.3 million customers</p> |
| Supply | <p>Installed generation capacity of 48.2GW (2012-13)</p> <p>317 registered Generators</p> |
| Networks | 13 major distribution networks |
| Greenhouse emissions | <p>319 million tonnes of CO₂-e in 2013 (electricity generation in the NEM)</p> <p>Emissions intensity of electricity generation in the NEM was 0.875 tonnes of carbon emissions per MWh in 2012-2013.</p> <p>Electricity generation is responsible for approximately 35% of Australia's greenhouse gas emissions.</p> |
| Connection Rules | <p>National Electricity Rules (NER) - Available on the Australian Energy Market Commission (AEMC) website:</p> <p>http://www.aemc.gov.au/Electricity/National-Electricity-Rules/Current-Rules.html</p> |

Source: AEMO; ESAA, *State of the Energy Market 2013*, AER, (Department of Energy, 2014)

The NEM operates on the world's longest interconnected power system from Port Douglas in Queensland to Port Lincoln in South Australia – a distance of more than 4,000 kilometres. The total length of distribution infrastructure in the NEM is around 760 000 kilometres—17 times longer than transmission infrastructure. More than AUD \$11 billion of electricity is traded annually in the NEM to meet the demand.

The NEM has been operating since December 1998, with the link to Tasmania established in 2006. Operations today are based on six interconnected regions that largely follow state boundaries. Market operation is governed by the National Electricity Rules (NER) and is managed by the Australian Electricity Market Operator (AEMO).

Figure 3 National Electricity Market overview

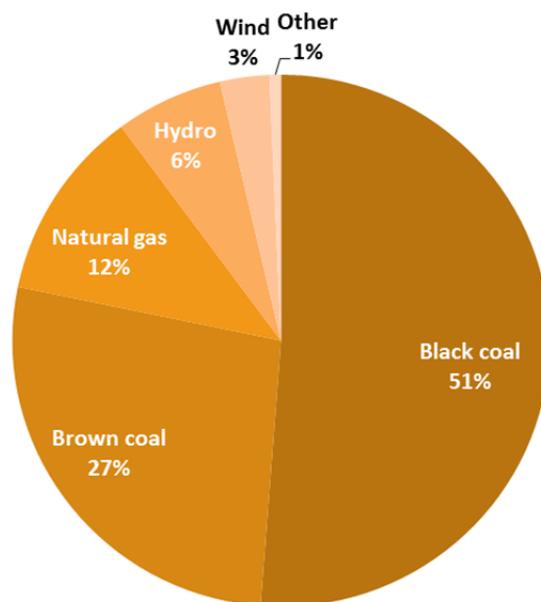


Source: (AER, 2013)

The NEM operates a competitive spot market in which prices adjust in real time to supply and demand conditions through an interconnected synchronous electricity transmission network. Exchanges between electricity producers and electricity consumers are facilitated through an electricity pool where the output from all generators is aggregated and scheduled to meet demand (AEMO, 2010).

The below figure illustrates the generation by fuel type within the NEM which is largely dominated by coal fired generation.

Figure 4 Electricity production in the NEM by fuel type (FY 2012)



Source: (AEMO, 2012)

Despite earlier projections of continuing growth, demand in the NEM has flattened since 2007-08 and declined in recent years (AER, 2013). Future projections continue to anticipate growth albeit slower growth as there remains significant uncertainty around the impacts of declining manufacturing, energy efficiency measures and the continued growth in rooftop solar photovoltaics. This, combined with the uncertainty around national and international carbon actions, means no additional coal-fired plant is expected to be built in the NEM in the coming future. The shift away from investment in coal-fired plants has been occurring over the last 10 years, with the majority of new investments being in gas fired generation and renewables.

Future electricity generation investment in the NEM is likely to be primarily driven by the Renewable Energy Target (RET), with approximately \$18 billion expected to be invested in wind between 2011 and 2018 and \$16 billion in solar photovoltaics (PV) (AER, 2013). Further investment in gas-fired technologies is also anticipated, largely in plant intended to assume a 'peaking' role in the market. Growth in bulk generation from gas is likely to be hampered by challenges in obtaining long term contracts for gas supply, due to competition with the emerging LNG export markets.

The connections process in the NEM is outlined in Chapters 5 and 5A of the NER. These processes are applied somewhat differently by each Network Service Providers in each region, which can create challenges for project developers. Attempts to streamline and improve this process are underway but it remains an area where assistance from local specialists is likely to be of significant benefit to developers.

3.3 South West Interconnected System (SWIS)

The SWIS serves most of WA's population of more than 2 million with approximately half of the total electricity consumed in WA delivered via the SWIS. Some basic characteristics are listed in Table 5.

Table 5 SWIS Snapshot

| Category | Characteristics |
|----------|---|
| Demand | Peak demand of 3.7GW (January 2014) Annual electricity generation of 18.3 TWh (2013-14) 1 million customers |
| Supply | Installed generation capacity of 5.5 GW, including 3 GW of base load capacity 72 registered generation facilities and 25 registered Demand Side Management |

| Category | Characteristics |
|------------------|--|
| | facilities |
| Networks | 1 distribution and transmission network (Western Power) |
| Connection Rules | <p><i>Wholesale Electricity Market (WEM) Rules</i> Available on the Independent Market Operator (IMO) website: http://www.imowa.com.au/market_rules.htm</p> <p><i>Technical Rules</i> Available on the Western Power website: http://www.westernpower.com.au/aboutus/accessArrangement/Technical_Rules.html</p> |

Source: (IMO, 2014)

The transmission and distribution networks in the SWIS are owned and operated by Western Power (see Figure 5). The majority of relevant technical standards for new connections in the SWIS are outlined in Western Power’s Technical Rules.

The Wholesale Electricity Market (WEM) operating in the SWIS is operated by the Independent Market Operator of Western Australia (IMO WA) under the WEM Rules. This market features separate capacity and energy mechanisms.

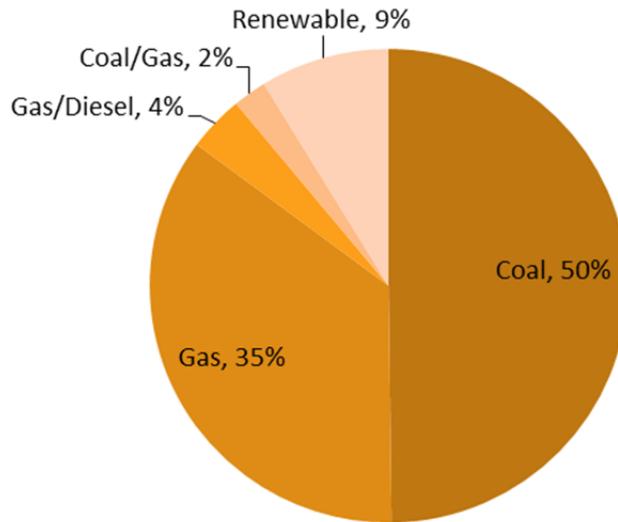
Figure 5 Map of SWIS



Source: Perth Energy

As in the NEM, the majority of electricity production in the SWIS is via coal-fired generation however, in recent years gas-fired and renewable generation have taken a more prominent role. Gas shortages have proven problematic for the SWIS in the past, motivating an interest in fuel diversification and the installation of dual-fuel capable plant.

Figure 6 Proportion of generation in the SWIS by fuel type, 2011



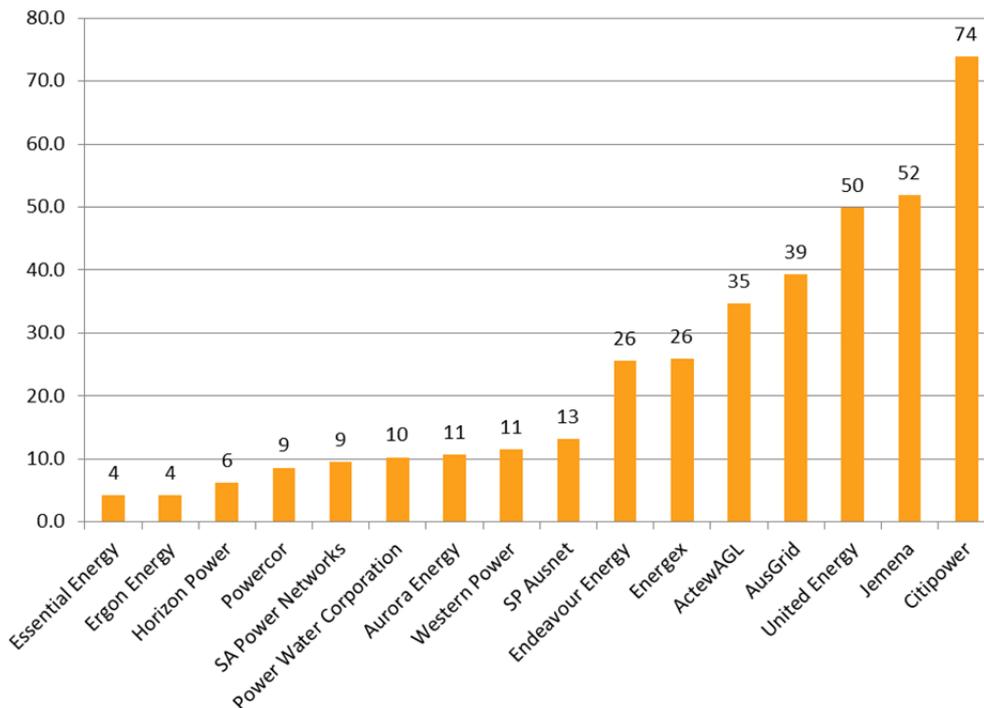
Source: (IMO WA, 2014)

3.4 Australia’s fringe-of-grid market

Fringe-of-grid areas are very remote and serve areas with extremely low population densities. 98 per cent of Australia is supplied electricity using its on-grid networks which service huge geographic areas. The large distances between electricity generators and fringe-of-grid areas leads to large transmission and distribution electrical losses. Distribution Loss Factors (DLF) and Marginal Loss Factors (MLF) can be up to approximately 10% and 14.5% respectively (AEMO, 2013).

Consumers in these fringe-of-grid regions often only pay a subsidised tariff provided to NSP through Community Service Obligation (CSO) payments supplied by State and Territory Governments. Through consultations it was highlighted that there is a growing necessity by State and Territory Governments to minimise ongoing CSO payment or at least obtain greater cost reflective understanding of the cost to supply remote regions of Australia.

Figure 7 NSP Average Network Customer Density



Sources: (AER, 2013), (Western Power, 2014), (Horizon Power, 2014), (Power and Water Corporation, 2013)

Many fringe-of-grid areas also experience regular power interruptions and power quality issues, and the capital and operational costs in these low density areas are significantly higher than in urban areas. Reports such as the Decentralised Energy Roadmap (Intelligent Grid Research Cluster, 2011) highlight the benefits of distributed energy generation to reduce network expenditure. Electricity storage incorporated with renewable systems has the potential to address voltage and current fluctuation problems often experienced on radial and Single Wire Earth Return (SWER) network areas. Ergon Energy trialled the deployment of Grid Utility Storage Solutions (GUSS) on its SWER networks, with GUSS options breaking even in SWER locations and further deployment planned across feasible locations. (Ergon Energy, 2014).

3.5 Australia's Off-grid Electricity Market

As previously mentioned this paper defines 'off-grid' as any isolated or islanded system (including private systems) or interconnected system that is not part of the National Electricity Market or the South West Interconnected Network.

3.5.1 Overview

Only 2 per cent of Australia's population live in the off-grid energy market and the off-grid electricity market currently consumes over 7 per cent of the country's total electricity demand. It is estimated that 15,575 GWh of electricity was produced by off-grid generation in Australia in 2012 (BREE (a), 2013) supplied through a total installed capacity of approximately 5GW. The off-grid energy market sources 78 per cent of its energy from natural gas and the remainder mostly from diesel fuel. It is the most costly supplied electricity. However, it is also the least emission intensive of all of Australia's electricity markets even though only 2 per cent of electricity is currently generated from renewable sources.

Consumers in the off-grid electricity market include agricultural processing facilities, outstations, remote mines, small communities, and remote infrastructure such as telecommunication and desalination facilities.

Much of the off-grid electricity market has experienced an increase in demand in recent years associated largely with the mining industry's expansion. In line with ARENA's RAR Program, this paper investigates two main market sectors:

- **Off-grid Industrial Sector:** The industrial and commercial regional energy market, dominated by the off-grid mining segment and including defence, agricultural and tourist facilities with renewable energy opportunities greater than 1 MW including those connected to off-grid interconnected systems.
- **Off-grid Community Sector:** The community market, which includes small and small off-grid communities, mining towns, and small commercial facilities with renewable energy opportunities between 100kW and 1MW including those connected to off-grid interconnected systems.

The **off-grid industrial sector** consumes approximately 12.4TWh per annum or 79 per cent of the total off-grid electricity produced (excluding NSW, ACT, VIC and external territories of Australia for confidentiality reasons), of which the majority is consumed by the remote mining industry. There has been a recent trend toward higher energy intensity which has risen at an average of 2.3 per cent per annum between 1990 and 2010. Similarly, electricity demand has grown associated with the increasing use of energy for mining exploration activity and the need to exploit deeper and lower grade ores. Australia's mining industry is currently facing rising production costs, global competition and increasing pressure from regulators to improve environmental performance. These factors are motivating many mining companies to focus more on managing operational energy costs. Renewable energy is a viable means of providing both fuel savings and energy security.

The **off-grid community energy sector** is made up of two main sub-sectors: off-grid systems managed by state and territory owned NSP's such as Horizon Power (WA), Ergon Energy (QLD), Power and Water Corporation (NT) and independent off-grid systems managed by the community or an independent power provider.

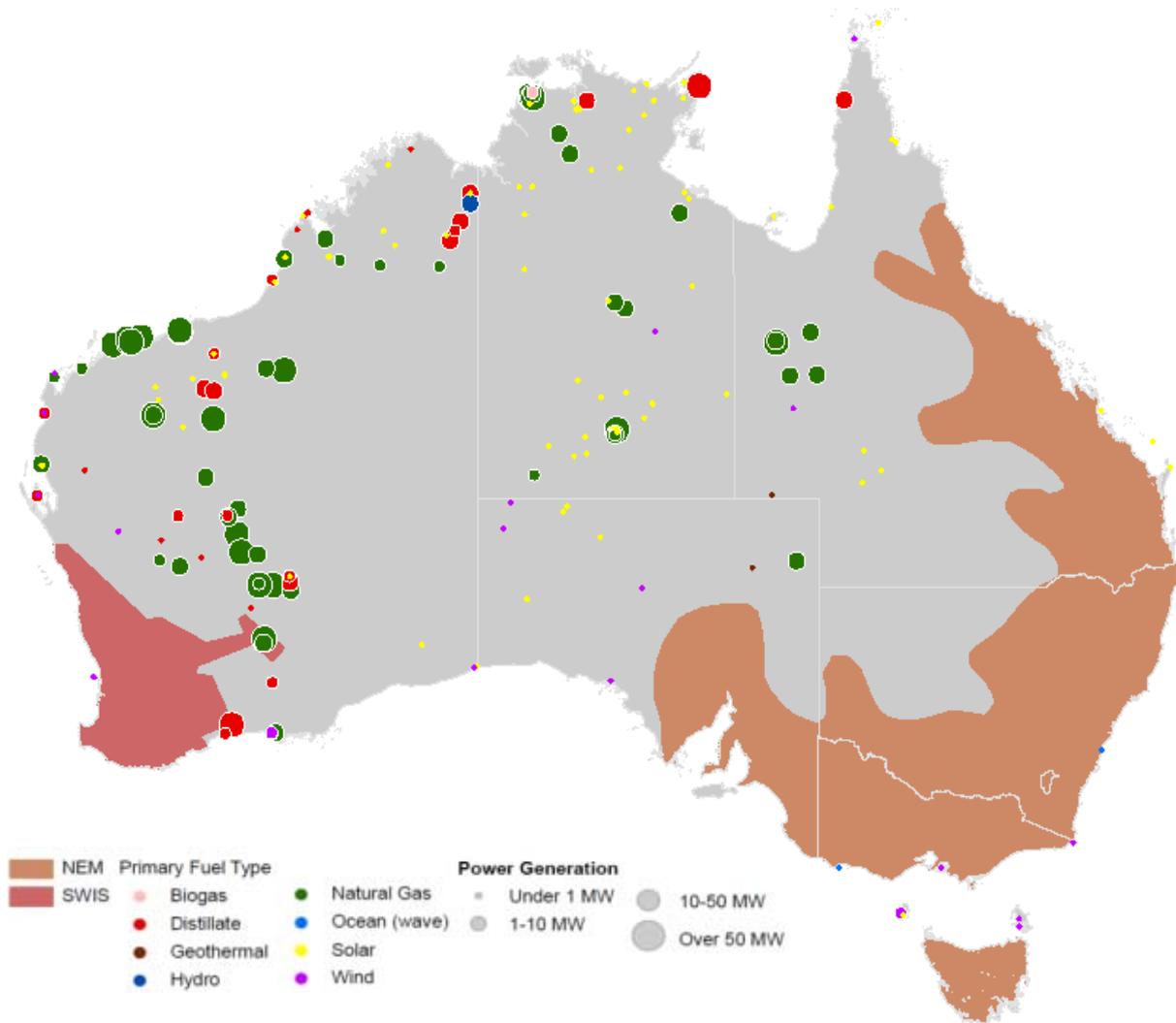
The Northern Territory has the largest electricity off-grid community demand, accounting for 59 per cent of Australia's off-grid community electricity consumption¹. Off-grid communities are supplied power through a

¹ 59% excludes NSW, ACT, Victoria – however, these States/Territories make up very small proportions of the off-grid market

combination of liquid fuel, gas and hybrid renewable plant on reduced tariffs subsidised through Community Service Obligations and consume approximately 3.4TWh per annum or 21 per cent of the total off-grid electricity (excluding NSW, ACT, Victoria and external territories of Australia for confidentiality reasons). Network Service Providers or independent system operators who operate and maintain these off-grid energy systems are likely to seek to minimise the current high costs to supply power to off-grid communities and renewable energy is commonly understood to be part of the solution.

As can be seen from Figure 8, the distribution of existing off-grid generation in Australia is largely constrained to Western Australia, Northern Territory, Queensland and South Australia. These states are therefore the primary focus of this study.

Figure 8 Off-grid generation in off-grid Australia

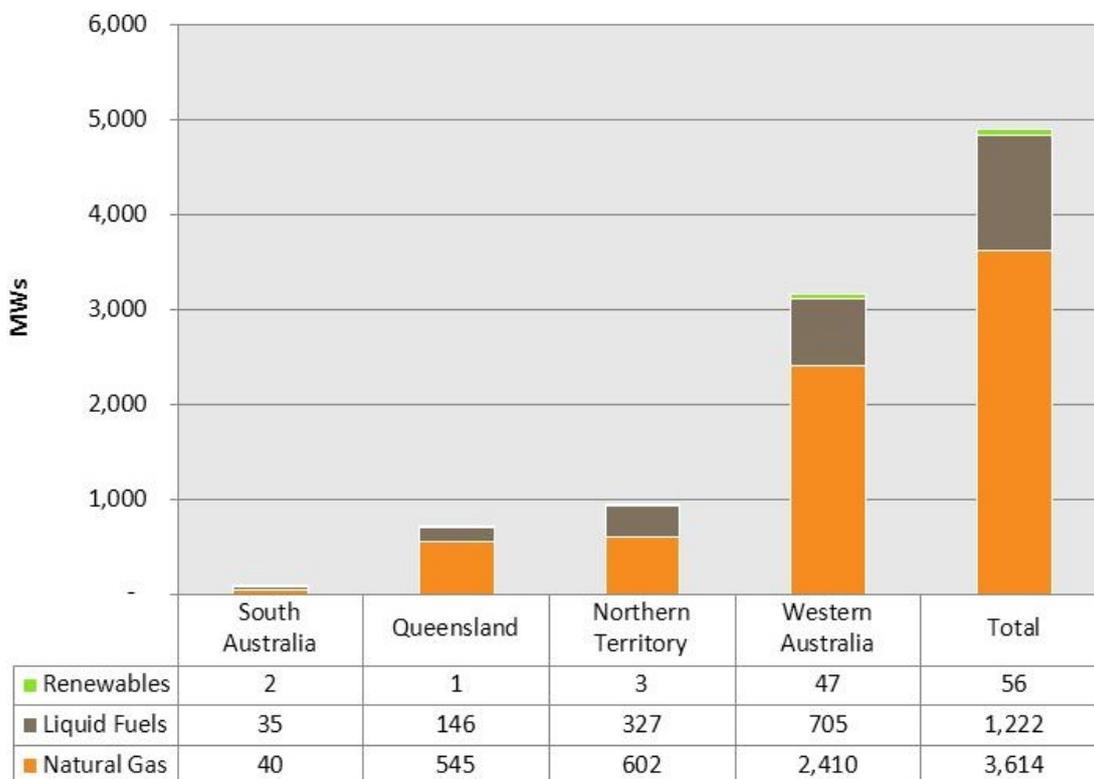


Source: AECOM, based on Geoscience Australia 2006 and 2012 power generation database.

3.5.2 Existing off-grid generation

A summary table of these states is presented in Figure 9 showing the existing distribution of off-grid generation types. It demonstrates that natural gas and liquid fuels dominate off-grid generation. Natural gas includes LNG, CNG and LPG. Liquid fuels include diesel, heavy fuel, kerosene and biodiesel. It is assumed that diesel makes up a significant portion of the liquid fuels category and that biodiesel is unlikely to be a significant portion of the liquid fuels category.

Figure 9 Distribution of Off-Grid Generation by State and Territory



Source: AECOM extrapolated from data obtained from Geoscience Australia and BREE 2013. Note: Data quality is arbitrary and may be inaccurate.

Note that liquid fuels can include biodiesel however a significant proportion of liquid fuels is expected to be diesel.

Off-grid industrial and community sectors are currently supplied with electricity from either off-grid interconnected systems or islanded power stations. There are already a number of electricity generators servicing off-grid communities and the industrial sector including; Ergon Energy, Horizon Power, Verve Energy (now Synergy), Power and Water Corporation (for more detailed discussion of these organisations refer to section 7.0). There are also numerous privately owned and operated off-grid electricity generation systems ranging from single household generators to large scale industrial power stations for mines and processing facilities.

Table 6 summarises the electricity demand of the off-grid industrial and communities sector. The mining sector represents the majority of the off-grid electrical demand in Australia and is likely to be the key driver behind future growth in off-grid electricity demand.

Table 6 Distribution of demand from the off-grid industrial and communities sectors

| State | Community | | Industrial | |
|--------------------|-------------------|-------------|-------------------|-------------|
| | Consumption (GWh) | Share | Consumption (GWh) | Share |
| South Australia | 40 | 17% | 196 | 83% |
| Queensland | 378 | 11% | 3,021 | 89% |
| Northern Territory | 1,927 | 59% | 1,347 | 41% |
| Western Australia | 999 | 11% | 7,881 | 89% |
| Tasmania | 22 | 96% | 1 | 4% |
| Total | 3,366* | 21%* | 12,446* | 79%* |

Source: AECOM extrapolated from data obtained from BREE 2013

*Excludes NSW, VIC, ACT and external territories of Australia for confidentiality reasons

Generation in the off-grid industrial sector is characterised by non-renewable thermal generation facilities fuelled by natural gas or liquid fuels (e.g. diesel, heavy oil). Refer to section 6.0 for more discussion on the off-grid industrial sector.

Existing generation for off-grid communities on islanded systems are predominantly diesel fuelled. Refer to section 7.0 for more discussion on the off-grid communities sector.

Generation associated with off-grid interconnected systems is predominantly fuelled by natural gas as shown in Table 7. A number of off-grid interconnected systems exist in Australia and the dynamics, challenges and opportunities within these systems will often be very different from those not connected to these off-grid interconnected systems. Off-grid interconnected systems are discussed in more detail in section 5.0.

Table 7 shows a breakdown of existing off-grid generation fuel types for each region during 2011-2012 and the distribution of off-grid generation by capacity and total percentage.

Table 7 Capacity and percentage distribution of off-grid generation by region

| Region | Generation by Fuel Type | | | | | | | | | | Total |
|---|-------------------------|--------------|--------------|--------------|-----------|-------------|----------|-------------|------------------|-------------|--------------|
| | Natural Gas | | Liquid Fuels | | Wind | | Solar | | Other Renewables | | |
| | MW | Share | MW | Share | MW | Share | MW | Share | MW | Share | |
| NWIS | 964 | 97.1% | 29 | 2.9% | - | 0.0% | 0.2 | 0.0% | - | 0.0% | 993 |
| Rest of Off-Grid Western Australia | 1,446 | 66.7% | 676 | 31.2% | 9.6 | 0.4% | 0.9 | 0.0% | 36 | 1.7% | 2,169 |
| Darwin to Katherine Interconnected System | 409 | 90.6% | 41 | 9.1% | - | 0.0% | 0.1 | 0.0% | 1.1 | 0.2% | 451 |
| Rest of Northern Territory | 193 | 40.1% | 286 | 59.5% | 0.1 | 0.0% | 1.7 | 0.4% | - | 0.0% | 481 |
| Mount Isa Grid | 415 | 91.4% | 39 | 8.6% | - | 0.0% | - | 0.0% | - | 0.0% | 454 |
| Remainder of Off-Grid Queensland | 130 | 54.6% | 107 | 45.0% | 0.5 | 0.2% | 0.3 | 0.1% | 0.1 | 0.0% | 238 |
| Off-Grid South Australia | 40.0 | 52.3% | 35.0 | 45.8% | 0.3 | 0.4% | 0.2 | 0.3% | 1 | 1.3% | 77 |
| Off-Grid Tasmania | - | 0.0% | 9 | 74.4% | 2.9 | 24.0% | 0.2 | 1.7% | - | 0.0% | 12 |
| Rest of Off-Grid Australia | 17 | 93.9% | - | 0.0% | 1 | 5.5% | 0.1 | 0.6% | - | 0.0% | 18 |
| Total | 3,614 | 73.9% | 1,222 | 25.0% | 14 | 0.3% | 4 | 0.1% | 38 | 0.8% | 4,892 |

Source: AECOM extrapolated from data obtained from Geoscience Australia and BREE 2013. Note: Data quality is arbitrary and may be inaccurate. Liquid fuels can include biodiesel however a significant proportion of liquid fuels is expected to be diesel.

3.5.3 Value proposition for off-grid renewable energy

Australia has a large renewable energy potential, including some of the best wind and solar resources in the world as well as large land areas available to renewables. The highest solar irradiance levels of the country are experienced in the North and Central off-grid regions of Australia.

Approximately 5GW of gas and liquid fuel power plants supply electricity to off-grid communities, infrastructure, mining towns and mines in Australia. Electricity demand in off-grid regions is expected to continue to grow, driven by the rapid development of mines and mining cities. A number of these energy projects are likely to benefit from

off-setting their fuel costs and mitigating their security of supply risks by hybridising the existing plant with renewable energy (as highlighted in section 3.4.4.1).

Wind and solar PV are the two most mature technologies available and are likely to capture the largest share of the off-grid renewable energy potential. It has been estimated that approximately 150 - 200MW of solar PV and wind is already feasible and may only require a minimal subsidy in some locations (as highlighted in section 3.5.4 below).

It is expected that the ARENA RAR program will help the development of the off-grid renewable energy industry and help overcome the challenges in developing and financing these projects. Other government programs which will contribute to the integration of renewables into the off-grid energy mix include the CEFC and others outlined further in section 4.0.

3.5.4 Australia's off-grid renewable market size and distribution

AECOM has estimated the market size potential for integrating renewables into Australia's existing off-grid electricity market through a forecasted high and low penetration potential as shown in Table 8. The establishment of ARENA's RAR and the continuation of the Renewable Energy Target was assumed, in addition to future renewable technology development which will further enable uptake.

AECOM utilised information from Geoscience Australia and the Bureau of Resources and Energy Economics (BREE) to define a primary estimate of the potential market size for off-grid renewable energy especially in hybridised systems. Geoscience Australia has developed two consolidated datasets of Australia's existing generation capacity (one in 2006 and another in 2012). Although some anomalies were identified, these datasets provided a useful approximation of the minimum existing off-grid capacity – the majority of diesel plants with a capacity below 500kW were not presented in Geoscience's dataset. Therefore, where possible, AECOM manually added the community diesel-fired plants owned and operated by the state owned service providers.

Table 8 Estimated off-grid renewable market size by Region (MW)**

| State | Region | Existing Generation | | Renewable Potential | |
|--------------|---|---------------------|--------------|---------------------|------------------|
| | | Liquid Fuels* | Gas | Low Penetration | High Penetration |
| WA | NWIS | 29 | 964 | 27 | 166 |
| | Rest of Off-Grid Western Australia | 676 | 1,446 | 104 | 502 |
| NT | Darwin to Katherine Interconnected System | 41 | 409 | 14 | 82 |
| | Rest of Northern Territory | 286 | 193 | 33 | 145 |
| QLD | Mount Isa Grid | 39 | 415 | 14 | 82 |
| | Remainder of Off-Grid Queensland | 107 | 130 | 14 | 64 |
| SA | Off-Grid South Australia | 35 | 40 | 5 | 20 |
| TAS | Off-Grid Tasmania | 9 | - | 1 | 4 |
| Other | Rest of Off-Grid Australia | - | 17 | 0 | 3 |
| Total | | 1,222 | 3,614 | 150 - 200 | 1,067 |

Source: AECOM extrapolated from data obtained from Geoscience Australia and BREE 2013. Note: Data quality is arbitrary and may be inaccurate.

* Note that liquid fuels can include biodiesel however a significant proportion of liquid fuels is expected to be diesel.

** AECOM acknowledges that the datasets used to define the market size has anomalies and therefore is not complete. As such, the figures presented above table are subject to significant uncertainty and only intended to provide a high-level estimate of the minimum existing diesel and gas capacity and off-grid renewable market potential in the Australia.

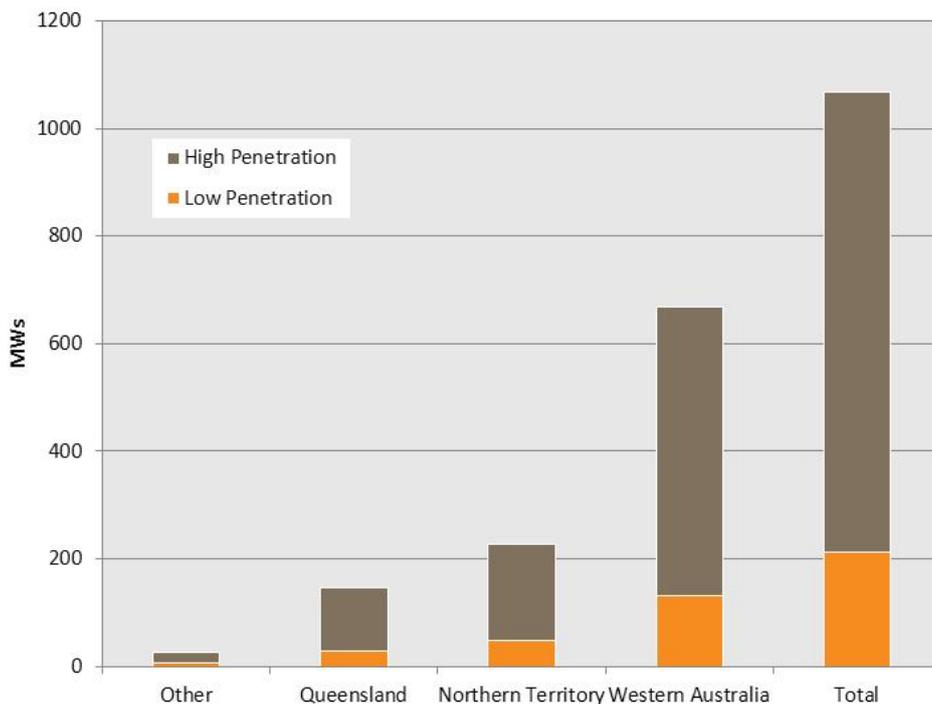
The low penetration case represents a penetration capacity potential of 20 per cent for liquid fuels and 5 per cent for gas-fired existing power stations, with half the project sites assumed to be technically feasible for hybridisation (e.g. site constraints). This represents approximately 4 per cent of the current total off-grid installed capacity.

The high penetration case represents a penetration capacity potential of 50 per cent for liquid fuels and 20 per cent for gas-fired existing power station, with four out of five project sites assumed to be technically feasible for hybridisation. This represents approximately 22 per cent of the current total off-grid installed capacity.

At low penetrations, small-scale wind and solar PV is already viable (assuming the STC upfront discount) in some locations if hybridised with diesel generated electricity as there are minimal additional integration costs. When higher penetrations are targeted, financial support from ARENA or other programs is currently required to make the project commercially viable due to the high cost of integration technologies. Non-financial drivers such as energy security or the desire to reduce greenhouse gas emissions may also come under consideration. In addition, gas is presently cheaper than diesel and, therefore, the business case for integration with gas plants is not as commercially attractive as for diesel. Nonetheless, with ARENA's financial support and an expected increase in gas costs, the business case is expected to improve in the future.

In the longer term, renewable energy penetration is expected to increase as a result of cost reductions in new renewable and enabling technologies (such as energy storage), fuel price volatility and improved access to skilled labour as well as greater confidence in the reliability of integrated hybrid systems.

Figure 10 Estimated off-grid renewable market size by Region (MW)



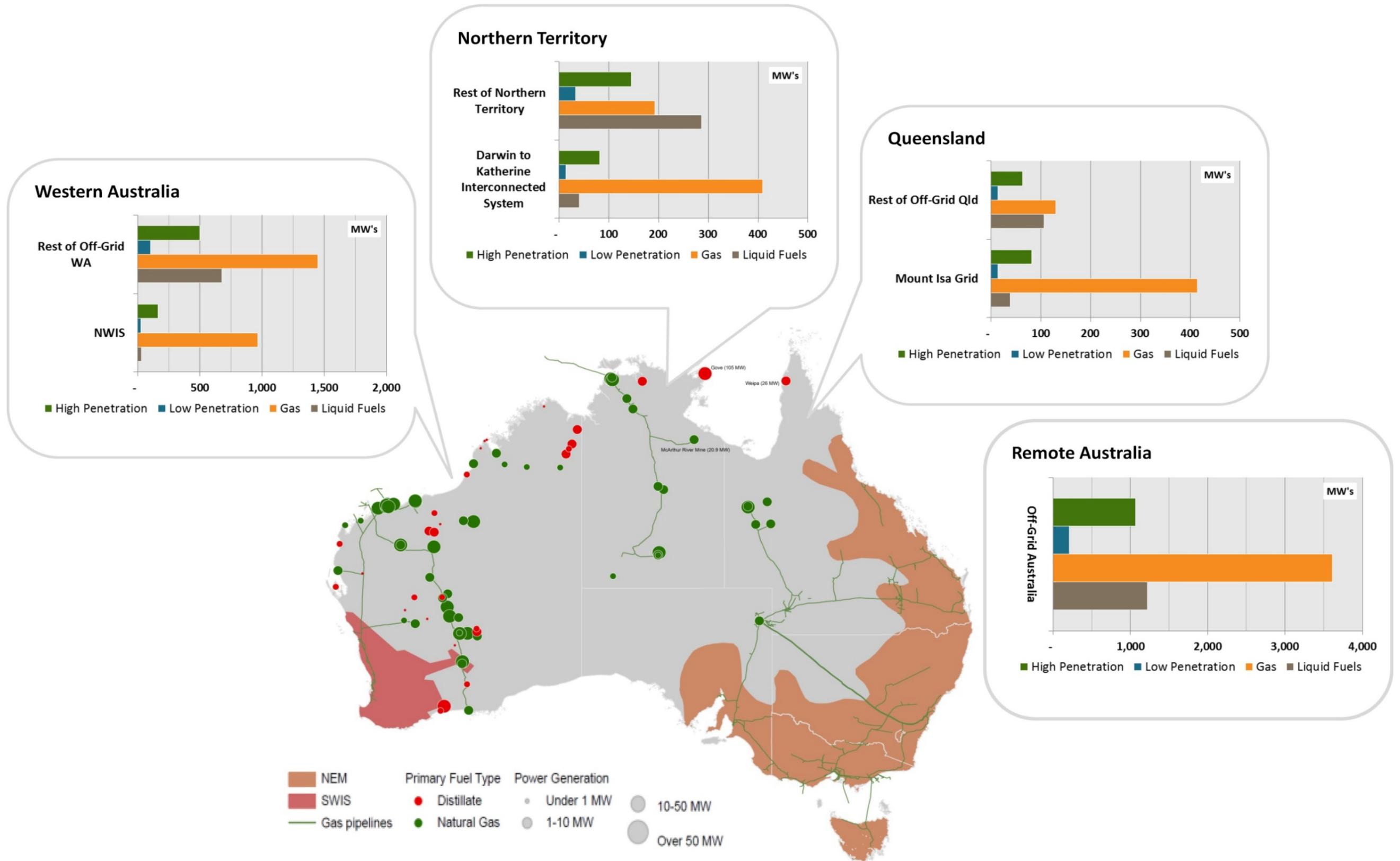
Source: AECOM extrapolated from data obtained from BREE 2013.

Based on these assumptions, the off-grid renewable energy market for the low penetration case is estimated at **approximately 150 - 200 MW**. Using BREE data (BREE, 2012) and accounting for assumed learning curves and technology cost reductions in the past year, an assumed average capital cost of integrating renewables into remote locations of AUD \$3 million per MW was used to estimate a market potential of **approximately \$450 - \$600 million for off-grid renewable energy in the short term**.

In the longer term, the off-grid renewable energy market for the high penetration case could grow an additional **estimated 850 MW**. Assuming the average cost of renewables and energy storage will reduce and based on an assumed average capital cost of integrating renewables into remote locations of AUD \$2 million per MW, this corresponds to a potential additional **\$1.7 billion of investments in the off-grid renewable energy market in the longer term**.

Overall, Australia's off-grid renewable energy market could total an estimated 1 GW and lead to approximately over \$2 billion in investments with a focus being primarily on states such as Western Australia, the Northern Territory and Queensland as shown in Figure 10.

Figure 11 Non-renewable off-grid generation and hybrid potential in Australia



3.5.5 Stakeholders consultations

In 2013, AECOM completed a consultation with more than 30 industry and government stakeholders. A number of common themes emerged from our discussions. ARENA's RAR program has undoubtedly heightened the interest from some segments of the markets, whilst others remain cautiously observing the sector. Table 9 below summarises our discussions.

3.5.5.1 Key observations from stakeholder consultations

Table 9 Key observations from Off-grid renewable market

| | Off-grid Community Market | Off-grid Industrial Market |
|------------------------------|---|---|
| Key Findings | | |
| Project Size | Small (<100kW) | Larger (<10MW) |
| Key Stakeholders | Network Services Providers, State Governments, Regional Service Provider to off-grid communities | Miners, Network Services Providers |
| Market Maturity | Maturing | Varies |
| Configuration | Primarily hybrid systems but varies | |
| Renewable penetration | Typically below 30 per cent of existing capacity, some projects up to 80% | |
| Government Support Programs | <ul style="list-style-type: none"> - ARENA RAR Program (Community Stream) - CEFC - Renewable Energy Target (SRES and LRET) | <ul style="list-style-type: none"> - ARENA RAR Program (Industrial Stream) - CEFC - Renewable Energy Target (SRES and LRET) |
| Observation | | |
| Market Specific Observations | <ul style="list-style-type: none"> - Community service obligations mean the off-grid community sector is already highly subsidised and renewables may provide an incentive to reduce the operating costs associated with existing off-grid generation plant - The Department of Social Services' "Closing the Gap" initiative (formerly Department of Families, Housing, Community Services and Indigenous Affairs) is driving energy load growth in indigenous communities - Regional population growth is generally limited to regions associated with mining activity - In some cases (Islands in particular), the transport of food and other goods to the community is subsidised by the transport of fuel | <ul style="list-style-type: none"> - Lack of confidence in the ability of renewable energy systems to supply electricity in a reliable way - Corporate, emissions and fuel saving drivers are all secondary to power reliability and Occupational Health & Safety - Load profile and energy demand requirements vary from mine to mine. - Limited resources to focus on the integration of renewables - Renewables are not core business |
| Common Observations | <ul style="list-style-type: none"> - Electricity supply solutions in the off-grid applications have traditionally been through the use of diesel and gas-fired generators, which provide reliable and flexible electricity supply - Generally hybrid opportunities exist as a fuel offset exercise, rather than carbon abatement or demand management means - Every project is different. Integration methodologies vary and generally the technical issues aren't well understood | |

| | Off-grid Community Market | Off-grid Industrial Market |
|----------------------------|--|--|
| | <ul style="list-style-type: none"> - Project opportunities tend to be small (<5MW) and are at early stage - The market is only now emerging in Australia representing a limited general understanding of the challenges and opportunities - The market is cautiously excited with respect to ARENA’s RAR Program and first movers will likely have an advantage - As well as unique project opportunities, the major focus will be on integrating wind or solar PV as the technology of choice - Intermittency and reliability concerns exist where the system is isolated (i.e. not interconnected) which limits confidence in adopting higher penetrations - The global and Australian economic downturn has affected many companies attitude to risk, investment and non-core activities - Consulting with key Government, suppliers, end-users and other stakeholders early in the project is essential to success | |
| Challenges | | |
| Market Specific Challenges | <ul style="list-style-type: none"> - Size of individual projects tend to be small which makes it unappealing for a number of developers - Access to capital can be an issue - Projects are usually commercially viable only at low renewable energy penetration, which further limits the opportunity size | <ul style="list-style-type: none"> - Intermittency and reliability concerns limit high penetrations and perceived risks associated with renewables need to be addressed - Energy costs are generally a low priority for miners and rapid production is the key focus - There often remains a disparity between mine life and the renewable plant’s useful life - Split incentives exist which provide disincentives to renewable or energy efficiency uptake - Diesel and gas are well understood while there is limited knowledge and know-how for off-grid renewable energy - Sustainability and cost reductions are generally not the primary driver - Opportunity costs for mining companies of diverting resources from non-core activities are high |
| Common Challenges | <ul style="list-style-type: none"> - Limited economies of scale due to the size and remoteness of most projects - Isolation of project locations can inflate construction and maintenance costs - Commercial models vary and the experience of the financing market in the off-grid renewables sector is limited - Renewables are perceived by some stakeholders as innovative and not mainstream - Some renewable technologies (and enabling technologies) are still at an early stage of commercial development - Limited high quality resource monitoring data available that can be verifiable for long term forecasts, which is required to finance projects - Financing renewable projects must consider the unpredictable renewable resource, which can impact performance and project returns. Many financiers generally understand this for mature technologies such as wind and solar, however other underdeveloped technologies will likely find it difficult to obtain project finance - Renewable energy integration into remote area power systems is not core business for many end users or off-grid interconnected system operators - Reliability in remote locations of renewables that can experience harsh climatic | |

| | Off-grid Community Market | Off-grid Industrial Market |
|--|--|----------------------------|
| | <p>conditions remains a risk</p> <ul style="list-style-type: none"> - Gas, LNG, CNG and grid extensions have and will compete with renewables in the off-grid energy market - Low renewable penetration limitations determined by control logic design products available and existing plant configurations limit investment returns | |

3.5.5.2 Market opportunities

The Australian off-grid renewable energy is an untapped market with large potential. It offers a variety of opportunities for businesses and government for future growth and development. Table 10 below categorises the key opportunities identified through the research and industry consultation conducted.

Table 10 Key opportunities and recommendations for stakeholders

| Opportunities | |
|------------------------------------|---|
| Hybridisation | <p>Hybridised generation systems represent the greatest potential area of growth in the off-grid renewable market.</p> <p>The greatest opportunity for hybridisation exists where fuel costs are high (typically diesel-fired generation) and where there is a fuel supply security risk, which is common in remote locations, which are subject fuel access restrictions as a result of severe weather events.</p> |
| Industrial / Mining Growth Regions | <p>Western Australia's Pilbara, Mid-West and Great Southern Region currently have over 3.1GW of off-grid generation capacity and thereby represent a large proportion of the market</p> |
| System Integration | <p>As the penetration levels of renewables increases in hybridised systems, the integration costs increase. There is a range of energy storage and control technologies available to support reliable operation of variable renewables. However, more system integration experience and expertise is required.</p> |
| Community Growth Regions | <p>The Darwin, Katherine, Alice Springs and Tennant Creek regions all represent an opportunity for greater off-grid renewable development. Similarly mining towns such as Roxby Downs (SA), Weipa (Qld), Karratha (WA), Newman (WA) and others in the Pilbara have shown significant load growth as a result of fly-in-fly-out and permanent regional population expansion.</p> |
| Interconnection | <p>As the population grows and development continues in off-grid mining regions, there is an opportunity to develop the existing interconnected systems and link the adjacent islanded grids. This will also enable larger projects to be developed thereby enabling economies of scales and increasing the incentive to invest.</p> |
| Skill Building | <p>As more renewable plants are constructed in regional Australia there will be a need for skilled labour to design, build, operate and maintain these facilities. Training of resources in close proximity to the installations will be essential.</p> |
| Aggregation of small projects | <p>Many of the project opportunities correspond to small or very small plants. Aggregation of loads or project opportunities in a region will likely bring economies of scale in both construction and operation. The state owned Network Service Providers could provide a natural opportunity for amalgamating a number of community projects. Similarly some regional organisations such as the Pilbara Cities and Regional Development Australia initiatives may support the development of regional renewable precincts.</p> |
| Technology Development | <p>One of the biggest challenges in off-grid applications is the impact of the intermittent nature of many renewable technologies on power reliability. There will be a need for technologies that enable the integration of renewable energy in existing diesel or gas systems in a reliable yet cost effective way.</p> <p>Perhaps the most promising technology is batteries, where significant technology</p> |

Opportunities

improvements and developments are being made. Batteries can provide solutions to short-term and long-term intermittency.

The off-grid market is still relatively immature with a number of challenges discussed throughout this paper. Many of the early projects may have to bear a cost premium associated with the lack of integration experience and track record in Australia. Additionally non-cost barriers are likely to represent extra challenges for first movers. As the industry develops, it will inevitably develop further capacity and costs will decrease. It was clear from the consultations that the success of a few projects will increase confidence and act as a catalyst for future projects.

The territory and state governments currently subsidise the supply of electricity in off-grid locations through Community Service Obligations. Reducing the cost of supplying electricity in off-grid locations will reduce the subsidies required to maintain affordable electricity prices. This opportunity is discussed in depth in Chapter 7.0

4.0 Government Legislation, Policies and Programs

4.1 National energy policy in Australia

Australia's energy policy framework is being developed by the Federal Department of Industry (formerly the Department of Energy, Resources and Tourism) in the Energy White Paper. It will cover the following themes:

- Competitiveness and growth
- International trade
- Energy pricing
- Reducing regulation
- Energy Efficiency
- Renewable and alternative energy

With regard to renewable and alternative energy, the Government intends to consider measures that encourage the deployment of renewable energy in addition to low emission technologies that allow Australia to continue to use its abundant coal and gas resources. The Government will also consider removing any barriers to increases in the use of low emission and alternative transport fuels. (Department of Industry, 2013)

Energy policy reform is also managed via the Council of Australian Governments (COAG), the peak intergovernmental forum in Australia. COAG comprises the prime minister, state premiers, territory chief ministers and the president of the Australian Local Government Association. Its role is to initiate, develop and monitor the implementation of policy reforms that are nationally significant and that require cooperative action by Australian governments. These reforms include energy market reform, which is managed via the Standing Council on Energy and Resources (SCER), formerly the Ministerial Council on Energy (MCE).

4.2 Australia's Direct Action Plan

With the repeal of the *Clean Energy Act 2011*, the Government plans to meet Australia's emissions reduction target through the Direct Action Plan to achieve a reduction in carbon emissions of 5 per cent below 2000 levels by 2020. The Direct Action Plan is comprised of The Emissions Reduction Fund and Solar Towns as described below. This is in addition to pre-existing initiatives that aim to drive innovation and investment in renewable energy such as the Renewable Energy Target, the Clean Energy Finance Corporation (CEFC) and the Australian Renewable Energy Agency (ARENA).

4.2.1 Emissions Reduction Fund

A major part of the Government's Direct Action Plan is the Emissions Reduction Fund. The aim of this initiative is to allow businesses, local governments, community organisations and individuals to complete approved emissions reduction projects and to seek funding from the Government for those projects through a reverse auction or other purchasing process.

It was designed by the Department of the Environment and legislation on this fund has yet to be passed. The principles of the fund are:

- Lowest cost emissions reductions – to identify and purchase emissions reductions at the lowest cost;
- Genuine emissions reductions – to purchase emissions reductions that make a real and additional contribution to reducing Australia's greenhouse gas emissions;
- Streamlined administration – to be easy for businesses to participate.

4.2.2 Solar Towns

The Government's has allocated \$2.1 million over three years from 2014-15 to support community groups, such as sports clubs, seniors' clubs and scout centres, to support the installation of solar photovoltaic and solar hot water systems in the electorates of Corangamite, Bendigo and McEwen in Victoria, Moreton and Bonner in Queensland and Lyons in Tasmania. Grants will also be available to community groups in the City of Monash in Victoria and the Port Adelaide/Wakefield/Makin area in South Australia. (Australian Government, 2014)

4.3 Other major initiatives

Other initiatives, including the Renewable Energy Target (RET), the Clean Energy Finance Corporation (CEFC) and the Australian Renewable Energy Agency (ARENA) have been developed to complement the RET scheme. The RET, ARENA and CEFC have been designed to support new technologies through the innovation and commercialisation chain.

4.3.1 The Renewable Energy Target (RET)

Australia has a Renewable Energy Target (RET) of 20 per cent by 2020, implemented via a renewable certificates mechanism. The Clean Energy Regulator oversees the implementation of the RET scheme while the Department of Environment (formerly the Department of Climate Change and Energy Efficiency) manages national policy and the legal framework.

Since 2011 the RET has operated in two parts:

- 1) **Large-scale Renewable Energy Target (LRET)** – encourages the development and implementation of large-scale renewable energy projects such as wind farms. Large renewable generators produce Large-scale Generation Certificates (LGCs).
- 2) **Small-scale Renewable Energy Scheme (SRES)** – supports the installation of small-scale systems including solar systems which are typically under 100kW for small-scale solar PV panels or 6.4kW for hydro and 10kW for wind and also includes solar water heaters (Department of Climate Change and Energy Efficiency, 2013). Small renewable generators produce Small-scale Technology Certificates (STCs).

Most renewable energy systems are eligible to create LGCs or STCs corresponding to the amount of MWh produced, regardless of whether they are grid-connected or off-grid. Combined, the two parts are intended to deliver in excess of 45,000 GWh of renewable energy in 2020 (Department of Climate Change and Energy Efficiency, 2013).

The RET policy legislates obligations on electricity retailers and other liable entities to source a proportion of their electricity from renewable energy sources. The Renewable Power Percentage (RPP) of liable entities increases each year to 2020 and then remains constant to 2030. Liable entities have to procure and surrender certificates (LGCs and STCs) from the market to meet their obligations.

The LRET is the key driver for the development of wind farms in Australia, which are meeting the majority of LGC requirements since they are currently the cheapest form of renewable energy. Looking forward, the market price for LGCs is broadly expected to represent the premium paid for renewable energy compared to the average wholesale price for electricity in the NEM. The estimated volume weighted average market price for a LGC was AU\$38.69/MWh in 2013.

Small-scale systems are eligible to receive all STCs for renewable energy deemed to be created over the life of the plant upon installation of the system. This provides a reduction in the capital investment required and minimises administrative overheads.

The Federal Government has recently conducted a review of the Renewable Energy Target. The outcome of the review is not expected until 2015.

4.3.2 Australian Renewable Energy Agency (ARENA)

ARENA was established in 2012 as an independent agency with the primary objectives to improve the competitiveness of renewable energy technologies and increase the supply of renewable energy in Australia (ARENA, 2013). ARENA's \$2.5 billion funding is legislated until 2020, providing improved long term funding and policy certainty for industry.

ARENA's Regional Australia Renewables (RAR) program is directly relevant to the themes of this paper and it is discussed in detail in section 4.3.4.

4.3.3 The Clean Energy Finance Corporation (CEFC)

The CEFC has been established by the Australian Government to invest up to \$10 billion over five years starting from 2013-2014 in the commercialisation and deployment of renewable energy, energy efficiency and low-pollution technologies. The CEFC will not provide grants; instead it will invest through a variety of funding tools

including loans and equity investment. The CEFC has been collaborating with banks and other financing institutions to provide co-funded loans. The focus has primarily been on loans above \$50m, however financial institutions have recently expressed an appetite for aggregating smaller projects.

4.3.4 ARENA's Regional Australia Renewables (RAR) program

One key driver promoting the off-grid clean energy market's growth is the Australian Renewable Energy Agency's (ARENA) Regional Australia's Renewables (RAR) Program. The program intends to provide up to AUD \$400 million funding to build 150MW of installed off-grid and fringe-of-grid renewables by 2018. Expressions of interest were sought from interested parties between June 2013 and December 2013 with the intention to commit all funding within 2-3 years of June 2013.

The RAR program is split into two separate programs: the RAR – Industry program (I-RAR) and the RAR – Community and Regional Renewable Energy program (CARRE). These two programs cover two sectors:

- **Industrial and mining sector**, supporting demonstration projects greater than 1MW with an aim to prove the potential and value proposition of renewables in this sector including two or more projects greater than 10MW in scale.
- **Communities sector**, which includes interconnected systems supported via Network Service Providers (NSP) or operated and managed by an independent system operator. Most renewable project opportunities in this sectors range between 100kW and a few megawatts.

Interconnected systems such as the NWIS, Darwin-Katherine, Mount Isa and others, are considered to be off-grid systems and renewable energy projects in these locations were eligible for the ARENA's RAR program.

In addition to the overarching RAR program objectives detailed in the Preamble of this report, the CARRE program has further objectives of its own. The CARRE program objectives are to:

- demonstrate technical viability and system reliability of high penetration renewable energy systems in islanded and mini-grids;
- facilitate the further development of supporting technologies and systems that will improve renewable energy reliability and commercial success, such as system integration and stabilisation and storage, through demonstration and deployment ;
- demonstrate the commercial viability of innovative business models, including ownership models, for renewable energy systems in these locations; and
- develop and share knowledge and experience in implementing, operating and maintaining renewable energy systems among regional energy suppliers and distributors and commercial and community customers.

4.4 Other support programs

The table below provides an overview of other programs supporting the development of regional renewable projects in Australia.

Table 11 Remote energy programs

| Program | Details |
|--|---|
| Community Service Obligations <i>State and Territory Governments</i> | <p>Electricity supply is considered an essential service and the National Framework for Energy Community Services Obligations (CSO) is aimed at providing equity in electricity pricing across Australia (MCE, 2008).</p> <p>CSOs are targeted at regional areas of Australia's electricity requirements.</p> <p>It is typically delivered by state-owned service providers or independent regional service providers that gain funding from the state government. It is done under different programs such as the Remote Area Essential Services Program (RAESP) in Western Australia, or the Remote Areas Energy Supplies scheme (RAES) in South Australia.</p> |
| Diesel Fuel Rebate Scheme | <p>Under the Diesel Fuel Rebate Scheme, the Australian Government provides a rebate of the excise and customs duty paid on diesel by various parties, including mining, agriculture and some remote residential uses.</p> |

| Program | Details |
|--|--|
| <i>Australian Taxation Office</i> | The primary purpose of the scheme is to maintain competitiveness in key export industries, such as mining and agriculture, in a manner consistent with the Government's broader fiscal objectives. |
| R&D Tax Incentive <i>AusIndustry</i> | The Research & Development (R&D) Tax Incentive is targeted at assisting businesses offset some of the costs of doing R&D. It is a broad-based entitlement program which means that it is open to firms of all sizes in all sectors who are conducting eligible R&D, including in the energy sector. |
| Small-scale Renewable Energy Scheme <i>Clean Energy Regulator</i> | Under the Small Renewable Energy Scheme, renewable solar PV projects under 100kW can generate STCs upfront, which assists with upfront capital costs. Other renewable energy technologies can be eligible as described in Error! Reference source not found. A number of conditions applied, which are described in the RET website (http://ret.cleanenergyregulator.gov.au/Solar-Panels/Solar-Credits/Solar-Credits) |
| Renewable Energy Venture Capital Fund <i>Southern Cross Venture Partners</i> | Renewable Energy Venture Capital Fund is a 13 year venture capital fund of \$100 million managed by Southern Cross Venture Partners. This investment was matched by Softbank China Venture Capital creating a \$200 million Southern Cross Renewable Energy Fund. The primary objectives of the fund are to: <ul style="list-style-type: none"> - Increase the number of Australian renewable energy and enabling technology companies that are successful in Australian and overseas markets; - Foster the skills and management capability of Australian renewable energy and enabling technology companies by providing active investment management; and Leverage additional investment in Australian renewable energy technology and enabling technology companies from the private sector, including from international sources. |
| Remote Indigenous Energy Program (REIP) <i>Department of Social Services</i> Funding has closed | REIP was part of the Australian Government's Clean Energy Future Package with AUD \$40 million pledged over four years. The program was to build upon the work undertaken by Bushlight over the last ten years. REIP was to provide funding for the deployment of fit-for-purpose renewable energy systems in up to 50 smaller remote Indigenous communities across Australia. REIP was planned to target communities with a maximum population of 50 people and no more than 20 dwellings. REIP was to act to replace the entire diesel generation system in these communities with a solar installation REIP was also to provide energy efficiency education and training in basic system maintenance to community members and repairs and maintenance to existing systems (Department of Families, Housing, Community Services and Indigenous Affairs, 2013). |
| Bushlight <i>The Centre for Appropriate Technology (CAT)</i> The program is no longer funded | The program started in 2002 and is no longer funded. Between 1997 and 1999, the Australian Cooperative Research Centre for Renewable Energy and the Centre for Appropriate Technology conducted an audit of renewable energy systems in remote areas. This research project led to the development of Bushlight in 2002. Bushlight was a program delivered by the Centre for Appropriate Technology (CAT). The program focused on the design, installation and maintenance of small renewable energy systems for remote households and communities. The program was primarily funded by the Australian Government through the Department of Families, Housing, Community Services and Indigenous Affairs. Bushlight also received funding from a range of other sources, including fee-for-service work for discrete projects. The latest project, in May 2013, was with Tjuwanpa Outstation Resource Centre to share knowledge and conduct training on renewable energy systems near Hermannsburg, West of Alice Springs. |

| Program | Details |
|--|--|
| | <p><i>“Since 2002 the Australian Government has provided about \$57 million to the Bushlight program, delivered by the Centre for Appropriate Technology to install more than 140 renewable energy systems in more than 120 remote Indigenous communities. Bushlight also provides maintenance services and community training supporting renewable energy systems in a further 100 communities.” (Department of Families, Housing, Community Services and Indigenous Affairs, 2013)</i></p> |
| <p>Renewable Remote Power Generation Program</p> <p><i>Closed in 2009</i></p> | <p>The program was operational between 2001 and 2009. It provided rebates of up to \$500,000 for households, communities, not-for-profit, business, government and other organisations, to support the installation of renewable generation systems in off-grid areas. Other sub-programs existed, including the Remote Area Power Supply Program, the Renewable Energy Water Pumping Program, the Regional Energy Efficiency Program, the Rural Renewable Energy Program, Large individual projects off-grid and Industry support projects.</p> |

5.0 Off-grid Interconnected Systems

Many areas defined as ‘off-grid’ in this study are in fact interconnected electricity networks or ‘grids’. These grids are much smaller than the NEM and SWIS which make up the area defined as ‘on-grid’ in Australia. Nevertheless, some such as the NWIS and Darwin-Katherine interconnected systems are thousands of kilometres long and are by no means geographically small by world standards. Gas-fired generation makes up the vast majority of generation within these isolated interconnected systems.

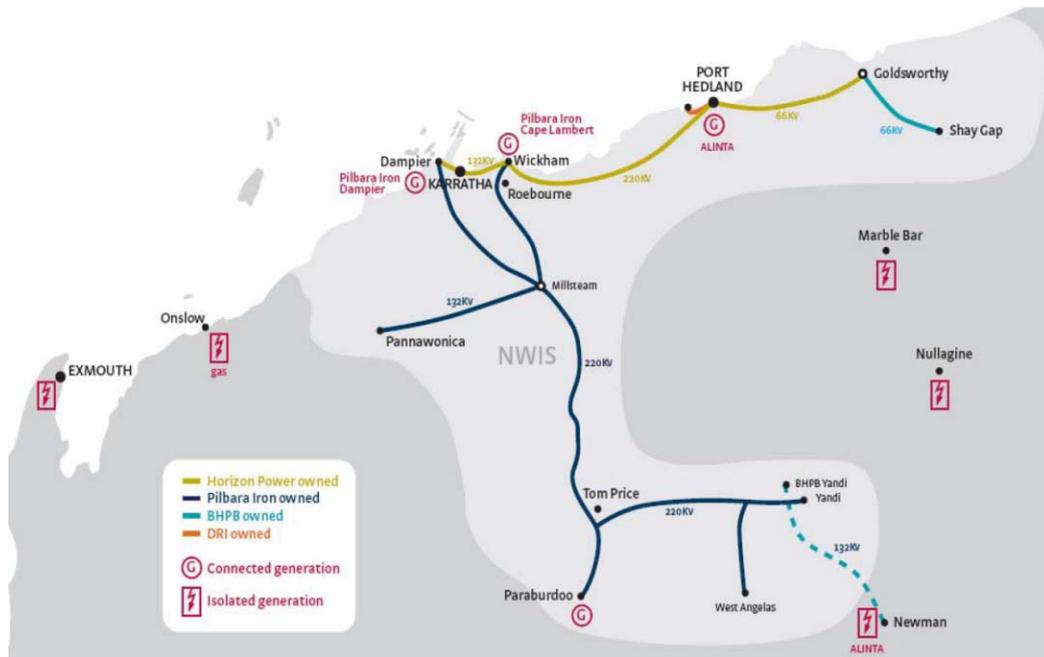
5.1 Western Australia

Thirty eight networks including two interconnected networks are operated and managed by Horizon Power to supply electricity to communities and industries in Western Australia. The North West Interconnected System (NWIS) is the second largest interconnected system in Western Australia after the SWIS (refer to section 3.3), supplying electricity to mines and the Pilbara. The NWIS has a generation capacity of 400 MW which is mainly fuelled by natural gas (Energy Action, 2012). While not connected electrically, the SWIS and the NWIS are connected through gas pipelines.

The NWIS evolved from islanded generation and transmission systems installed in the 1970s to provide electricity for iron ore mines. These islanded systems were interconnected in 1985 to form the NWIS. Five parties are involved in the ownership and operation of the NWIS: Horizon Power, Rio Tinto, ATCO Australia, Alinta Energy and BHP Billiton. Connections to this network proceed under the processes defined by Horizon Power.

Horizon Power reported that 548 GWh were generated in the NWIS in 2012-13 (Horizon Power, 2012-13).

Figure 12 North West Interconnected System (NWIS)



Source: (Horizon Power, 2009)

Horizon Energy also operates the much smaller East Kimberly Interconnected System which supplies electricity to Kununurra and Wyndham from Pacific Hydro’s 30 MW Ord River Hydroelectric Power Station located 80 kilometres south of Kununurra.

5.2 Northern Territory

The Northern Territory features three regulated systems: Darwin-Katherine, Alice Springs and Tennant Creek. These supply electricity to over 75,000 customers.

The three regulated systems as well as the power systems of several smaller townships are operated by Power and Water Corporation (PWC).

Table 12 Electricity generation in 2011 in the NT regulated markets

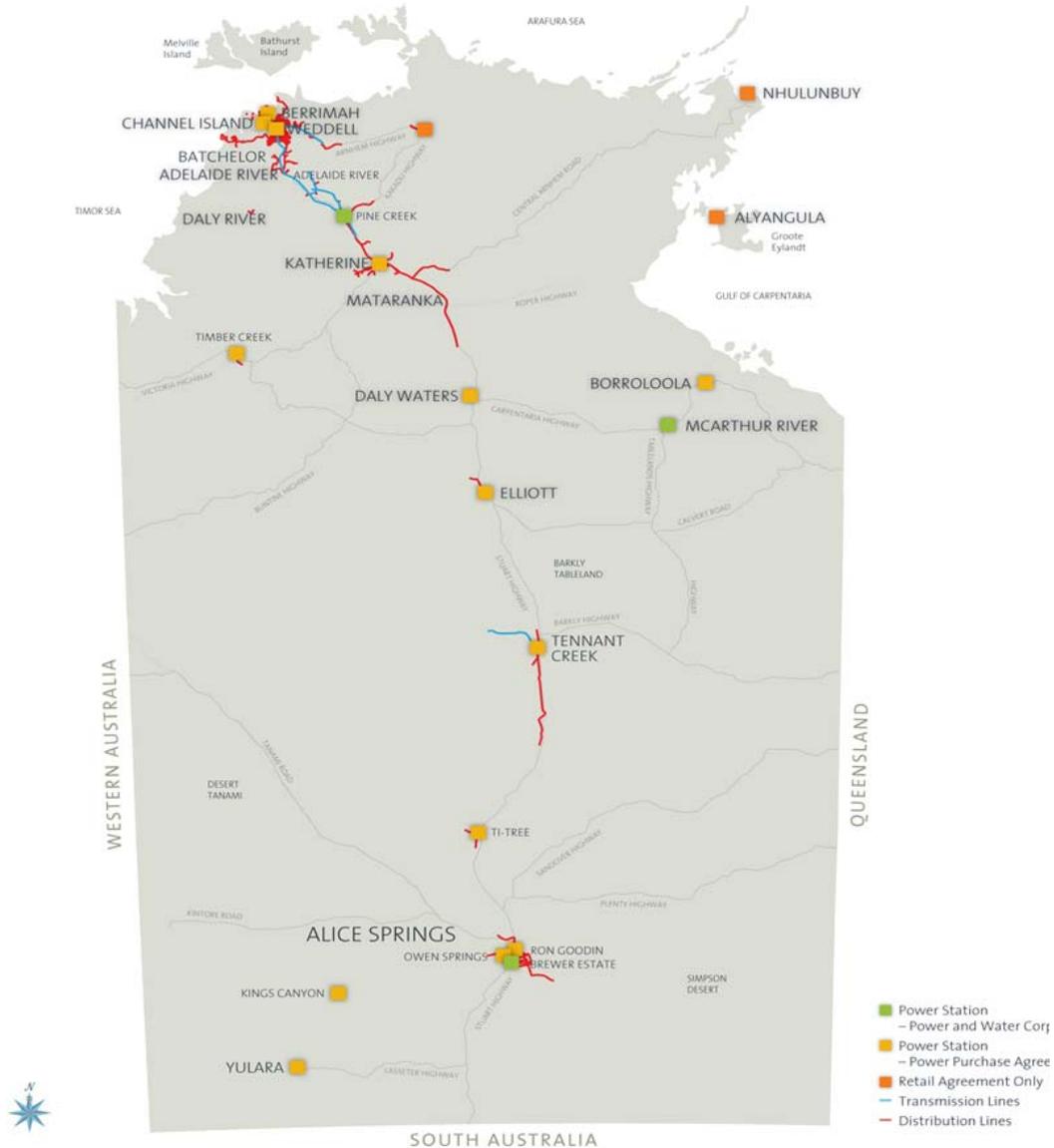
| | Capacity | Demand | Network length | NT Consumption |
|------------------|----------|--------|----------------|----------------|
| | MW | GWh | km | Share |
| Darwin-Katherine | 433 | 1,545 | 4,829 | 46% |
| Tennant Creek | 17 | 31 | 385 | 1% |
| Alice Springs | 73 | 187 | 607 | 6% |

Source: (Northern Territory Government, 2011)

PWC is a vertically integrated power utility managing generation, transmission, distribution and retail. There are four other generation companies that operate within the PWC managed networks, namely NGT, Cosmos Power and LMS Generation whose generation is connected to the Darwin-Katherine system, and Central Energy Power which generates in the Alice Springs system.

The 322MW Channel Island Power Station near Darwin is the largest power station in the Northern Territory and is connected to the Darwin-Katherine network. Figure 13 highlights all PWC's power stations (excluding minor off-grid stations operated by Indigenous Essential Services). It must be noted that six power stations (Borroloola, Elliott, Daly Waters, Timber Creek, Ti Tree and Kings Canyon) located in remote towns are owned and managed by PWC but are not connected to a regulated market. More than 90 per cent of the electricity generated within the three PWC regulated markets come from natural gas, while generation in the six islanded towns is largely diesel-fuelled.

Figure 13 Power Water Corporation interconnected systems and power stations



Source: (Power Water Corporation, 2013)

5.3 Queensland

The Mount Isa-Cloncurry supply network in North West Minerals Province is Queensland’s only regulated off-grid interconnected system. It is operated by Ergon Energy and supplies over 10,500 customers in Mt Isa, Cloncurry and parts of Burke and Boulia. The major focus for the region is mining and minerals processing activities, with a particular focus on base metals. The region also has a well-established pastoral industry and is becoming an increasing focus for tourism. Mount Isa, the major city in the region, serves as a transport hub and as a base for much of the economic and social activity in the region.

The preliminary conclusion of the North West Queensland Energy Demand Working Group in 2008 was that there is significant potential future energy demand in North West Queensland. To date, the 305 MW gas-fired Mica Creek Power Station owned and operated by Stanwell Corporation supplies electricity to Mount Isa-Cloncurry network. Some of the mines also supply their own power – Glencore Xstrata owns two gas-fired power plants (32MW and 45MW), Incitec Pivot owns 42MW gas-fired power plant to supply Phosphate Hill mine and Energy Development owns and operates a 38MW plant, which supplies power to BHP Billiton Base Metals. In addition, the 242MW Diamantina Power Station is currently under construction to supply power to Glencore Xstrata Mount Isa Mines through to 2030.

5.4 Renewable energy opportunities in off-grid interconnected systems

5.4.1 Large shopping centres and warehouses

Shopping centres and warehouses consume large amounts of power and will often have large roof space available to install solar energy. Their electricity demand profile matches solar PV generation well, which enables the deployment of “behind-the-meter” solar systems. This effectively means that solar power offsets contracted electricity prices as opposed to generation cost only, which makes solar PV significantly more cost competitive.

According to stakeholders consulted in the Northern Territory, there has been a noticeable change of mindset with regards to renewable energy. Only half a decade ago, businesses did not show any interest in solar energy and did not believe it could be a cost competitive solution. Today, a number of large users including shopping centres and warehouses are looking at solar as a promising solution to cut their electricity cost.

Smaller businesses will usually not have the capital to invest in solar projects, but are more likely to adopt solar leasing agreements. Larger businesses will have easier access to capital and typically want to own the solar system, but will usually need a third party to manage the project on their behalf.

Cold thermal storage has been identified as an add-on opportunity in regions such as the Northern Territory and the Pilbara. It provides cost effective storage and enables higher solar penetration. It provides a good match of the demand profile of large shopping centres in tropical regions, as half their energy demand is for cooling. The technology has been successfully deployed on the Charles Darwin University campus in Darwin.

Table 13 Key stakeholders and challenges of large shopping centres and warehouses

| Key Stakeholders | Challenges |
|--|---|
| Large shopping centres with major retailers including: Target, Coles, Woolworth, Federation Centres, Bunnings. | Energy is still a secondary concern for most businesses. Little time is available to investigate renewable energy opportunities. The high capital cost is a significant challenge. |

5.4.2 Behind-the-meter installations on hospitals, schools, airports

Some parties that are increasingly considering solar as a ‘behind the meter’ solution to offset their electricity demand include hospitals, schools and airport. In certain cases, the marketing advantage of integrating renewables can be another important driver.

5.5 Challenges to renewable energy in the off-grid interconnected systems

The main challenges to the uptake of renewables in off-grid interconnected systems identified in the research and stakeholder consultations are project economics, competing subsidies and split incentives.

5.5.1 Economics

The interconnected systems are primarily supplied by gas-fired generation, which reduces the competitiveness of renewable energy.

5.5.2 Opposing subsidies

Off-grid energy supply subsidies such as the Community Service Obligations (CSO) imposed on Network Service Providers of off-grid interconnected systems and Fuel Tax Credits, together add complexity to the true cost of supplying energy to remote locations. An overview of some of the subsidies provided to remote grid operators are set out below for the financial year 2012/13:

Table 14 CSO Subsidy Overview

| Organisation | CSO Subsidy 2012/13 | Further Details |
|--------------|---------------------|---|
| Ergon Energy | \$400 million | Funded by Queensland Government. Queensland State Treasurer Tim Nicholls was reported in May 2013 to say that the by 2014/15, “the cost [of CSO’s] is estimated to increase to more than \$700 million”. In 2009-10 this subsidy amounted to \$250M for Far North |

| Organisation | CSO Subsidy 2012/13 | Further Details |
|---------------------------|---------------------|--|
| | | Queensland (Cairns and Far North Environment Centre, 2011). |
| Horizon Power | \$181 million | Funded by the WA Government from the network charges to Western Power's wholesale distribution customers. |
| Power & Water Corporation | \$63 million | Funded by the NT Government. AEMC estimates that NT householders pay around 24 to 26 per cent less than the cost reflective price of electricity. (AEMC, 2012) |

Cost reflective pricing may be important to promote more efficient use of energy and improve the utilisation of infrastructure thereby lowering overall supply costs for all consumers. Renewable energy will likely require further future Government support if fossil fuels continue to be subsidised by these programs.

5.5.3 Split incentives

As highlighted previously, interconnected systems cover the industry and community segments. These systems are much larger than off-grid communities and are operated by either Power and Water Corporation (PWC) or Horizon Power. Mining companies that connect to them can be required to contribute to the investment in new capacity or pay a relatively higher electricity rate compared to other customers. There is often a lack of clarity around which party/parties could benefit from renewable energy and therefore who should invest in renewable energy.

5.6 Off-grid interconnected systems case studies

Some examples of renewable energy projects that have been developed in recent few years are set out in Table 15.

Table 15 Off-grid interconnected systems case studies

| Alice Springs' Solar City | Desert Knowledge Australia Solar Centre |
|--|---|
| <p>Alice Solar City is a \$37 million project designed to explore how a combination of options including energy efficiency measures for homes and businesses, solar technologies, cost reflective pricing and community education can encourage the residents of Alice Springs to use electricity more efficiently.</p> <p>The project was launched in 2008, when there were only 2 solar systems in Alice Spring. By 2013, 316 solar PV systems, 908 solar hot water systems and 608 smart meters had been installed on homes and businesses.</p> | <p>The Desert Knowledge Australia Solar Centre (DKASC) is a demonstration facility in Alice Springs, which involves 28 different solar panels. The site is open to visitors and its website (http://www.dkasolarcentre.com.au/) offers a range of information on the installed technology and the real time and historical performances of the different solar systems. The objective of the project is to support the deployment of solar in regional locations through demonstrating solar technology performance in arid conditions.</p> |
| Uterne Solar Farm | Other renewable energy projects |
| <p>The 1MW tracking system was built in 2011 in Alice Springs. It was built by SunPower with funding from the Alice Solar City initiative. At the time of construction, the system was the largest tracking array in Australia. It covers over three hectares and consists of 3,048 solar modules installed across 254 tracking arrays. The solar farm is expected to produce about 1 per cent of Alice Springs' electricity a year and can meet 2 per cent of peak demand on a sunny day.</p> | <p>Crowne Plaza solar system: 305kW Fixed flat plat PV system at Crown Plaza, Alice Springs</p> <p>Alice Springs Airport: 235kWp Tracking concentrated PV, Alice Springs Airport</p> <p>Shoal Bay landfill: 1.1MW of landfill gas from Shoal Bay landfill</p> |

6.0 Off-grid Industrial Market

6.1 Mining sector

6.1.1 State of the market

Electricity consumption in the off-grid industrial market is largely dominated by the demand from the mining sector. The mining industry experienced unprecedented growth over the last decade and currently represents approximately 5 per cent of Australia's energy demand.

Mining investment has boomed in recent years, rising from 1 per cent of nominal output 10 years ago to 4 per cent at the end of the last decade. In 2012-13, the mining sector accounted for approximately 10 per cent of Australia's GDP, employed over 260,000 people and invested AUD\$7.1 billion in minerals and petroleum exploration.

In the year to April 2013, production capacities increased by 100 million tonnes for iron ore, 22 million tonnes for coal, 4.3 million tonnes for LNG and 2 million tonnes for alumina.

During 1989-90 to 2010-11, energy consumption in the mining sector increased by an average growth rate of 6.3 per cent a year due to a strong increase of mining activity and depletion effects. In 2012-13, energy consumption in the mining sector grew by 9 per cent, reflecting a transition from investment to production phase of the mining boom (BREE, 2013).

Ranked number one in the world for mining investment, Australia is a politically and economically stable economy rich in resources (Behre Dolbear Group, 2012). Australia holds the world's largest reserves of brown coal, mineral sands, nickel, lead, silver, uranium, iron ore and zinc. Table 16 shows Australia dominates mineral production and resources with estimates that current rates of mining production can be sustained for many decades.

Table 16 World ranking of Australia's mineral production and resources for 2009 (Source: (Geoscience Australia, 2012), (Austrade, 2014))

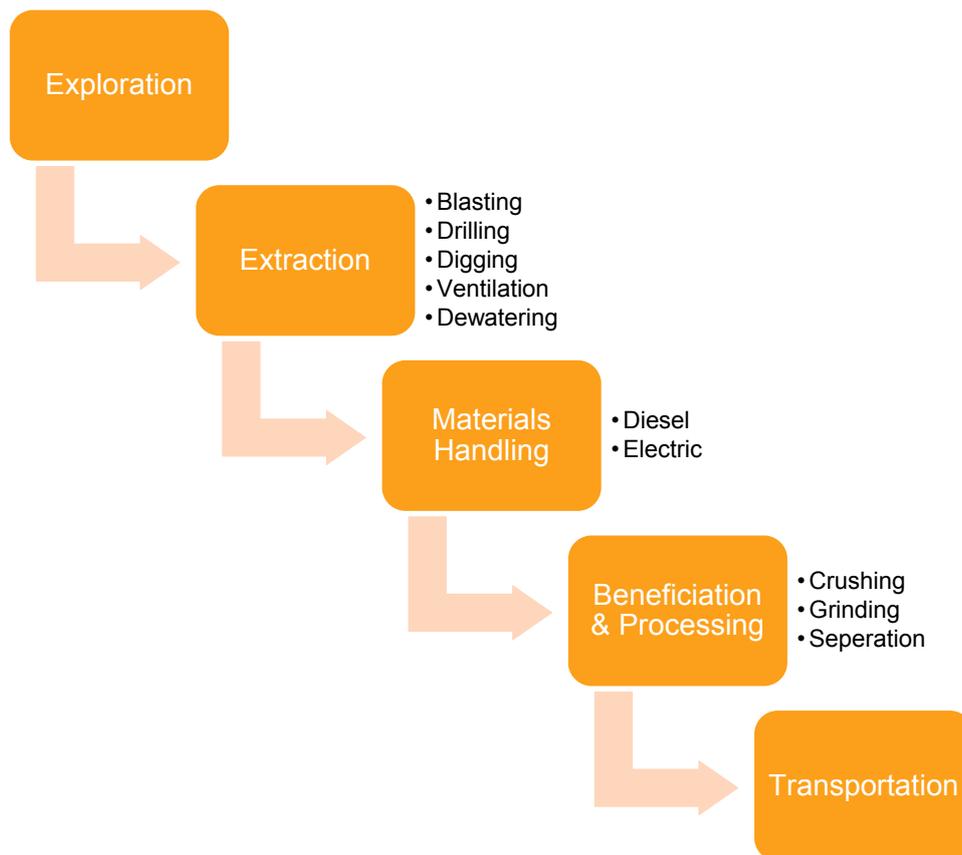
| Commodity | Production Rank | Resource Rank | Energy Intensity |
|--------------------------------------|-----------------|------------------------|------------------|
| Base Metals | | | |
| Lead | 2 | 1 | High |
| Nickel | 4 | 1 | |
| Copper | 5 | 2 | |
| Zinc | 2 | 1 | |
| Manganese Ore | 2 | 4 | |
| Precious Metals & Diamond | | | |
| Diamond | 5 | 3 (industrial diamond) | High |
| Silver | 5 | 1 | |
| Gold | 2 | 1 | |
| Coals | | | |
| Black Coal | 4 | 5 | Moderate - High |
| Brown Coal | 5 | 1 | |
| Mineral Sands | | | |
| Rutile | 1 | 1 | High |
| Zircon | 1 | 1 | |
| Other | | | |
| Iron Ore | 1 | 1 | High |

| Commodity | Production Rank | Resource Rank | Energy Intensity |
|-----------|-----------------|---------------|------------------|
| Bauxite | 1 | 2 | |
| Lithium | 2 | 3 | |
| Niobium | Not Known | 2 | |
| Tantalum | Not Known | 2 | |
| Uranium | 3 | 1 | |

The mining industry is a major contributor to Australia’s economic prosperity, contributing close to 60 per cent of the annual value of total goods exports (\$176 billion) in 2012-13 and generating \$12.7 billion in new private capital expenditure, an increase of 15.5% compared to the previous year (Austrade, 2013). This is supported by free trade agreements in the global marketplace for the exportation of goods on a commercial basis to Australia’s major mineral export markets including Japan, China, Korea and India.

In existing mines, energy can correspond to a large share of a mine’s operational cost with crushing, grinding and hauling ores the top three operational costs of a mine (Bloomberg, 2012). The most energy intensive mining processes are illustrated below:

Figure 14 Energy intensive processes during the mining production chain



6.1.2 Market outlook

The rapid growth of the mining sector weakened during 2012-13, creating a significant impact on the Australian economy. Australia’s mining industry is facing rising production costs and global competition, declining grades of ores that are increasingly complex to process, and increasing pressure from regulators to improve environmental performance. As a result, the mining industry has reduced new investments and put many large projects planned on hold.

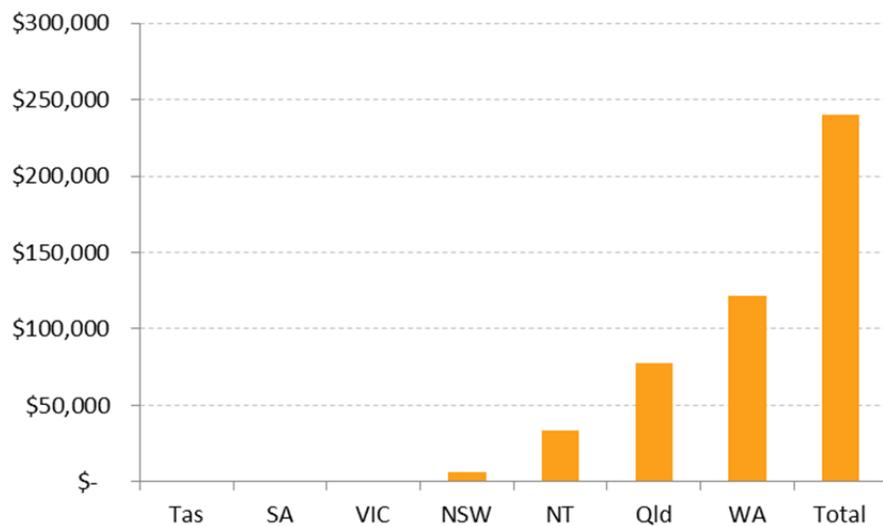
Despite the recent slowdown of mining investments, Australia still features a large pipeline of projects. Significant opportunities still exist for off-grid renewable investment in the Australian resources and energy sectors, particularly in reducing costs even though there remain challenges in realising these opportunities.

As of October 2013, there were 63 mining projects in Australia at the committed stage (lifetime CAPEX value of \$240 billion) and 162 projects at the Feasibility Stage (lifetime CAPEX value of \$208 billion) (BREE, 2014). Liquefied natural gas (LNG), gas and oil projects are dominating Australia's investment program with AUD \$195 billion in committed investments (81 per cent of committed investments) (BREE, 2013).

Table 17 Summary of Mining projects in the investment pipeline, October 2013

| | Publicly Announced | | Feasibility Stage | | Committed | | Completed | |
|---------------------------------------|--------------------|------------------|-------------------|------------------|-----------------|------------------|-----------------|------------------|
| | No. of Projects | Range AUD \$b | No. of Projects | Value AUD \$b | No. of Projects | Value AUD \$b | No. of Projects | Value AUD \$b |
| Aluminium, Bauxite, Alumina | 3 | 1 - 2 | 3 | 2.0 | | | | |
| Coal | 19 | 16.9 – 19.6 | 50 | 54.1 | 15 | 11.4 | 5 | 5.1 |
| Copper | 5 | 10.2 – 11.4 | 9 | 3.2 | 2 | 0.3 | | |
| Gold | 9 | 1.1 – 1.8 | 10 | 2.1 | 4 | 0.5 | 2 | 0.9 |
| Infrastructure | 10 | 14.8 – 23.5 | 17 | 28.2 | 11 | 12.0 | 4 | 8.7 |
| Iron ore | 19 | 35.8 – 55.8 | 22 | 39.6 | 9 | 17.3 | 1 | 5.2 |
| Lead, Zinc, Silver | 2 | 0.1 – 0.5 | 3 | 0.5 | 4 | 1.9 | | |
| LNG, Gas, Oil | 9 | 24.5 – 26.8 | 9 | 62.7 | 14 | 195.0 | 5 | 10.2 |
| Nickel | 4 | 2.0 – 4.0 | 7 | 5.9 | | | | |
| Uranium | 5 | 1.4 – 2.4 | 2 | 0.6 | 1 | 0.1 | | |
| Other Commodities | 7 | 2.0 – 4.0 | 30 | 9.6 | 3 | 1.5 | 1 | 0.3 |
| Total | 92 | 110 – 152 | 162 | 208 | 63 | 240 | 18 | 30 |
| Approximate breakdown by state | | | | | | | | |
| Western Australia | 39 | 56.0 – 86.0 | 50 | 72.3 | 24 | 121.8 | 8 | 20.5 |
| Queensland | 24 | 20.6 – 27.4 | 64 | 99.2 | 19 | 77.4 | 4 | 4.8 |
| Northern Territory & South Australia | 13 | 1.1 – 13.9 | 11 | 7.7 | 4 | 33.6 | 2 | 0.5 |
| NSW | 11 | 5.6 – 7.3 | 25 | 12.9 | 15 | 6.4 | 2 | 1.3 |
| Victoria and Tasmania | 2 | 1.6 – 2.1 | 10 | 2.3 | 1 | 1.0 | 1 | 2.6 |

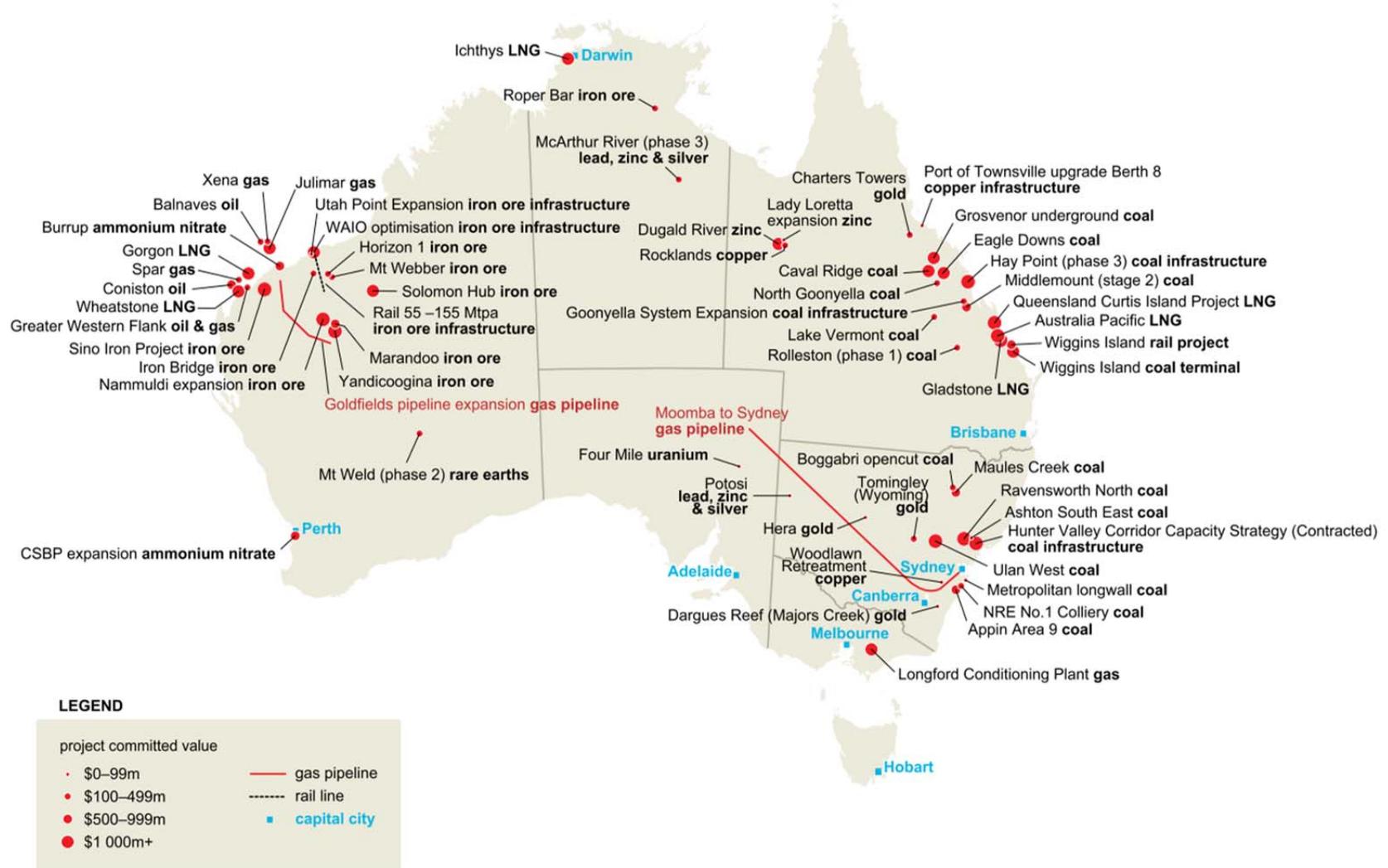
Source: (BREE, 2013)

Figure 15 Committed mining investment for projects by Region

Source: (BREE, 2013)

The majority of the mining projects in development are located in Western Australia and Queensland. Twenty-four projects valued at a total of \$122 billion are committed in WA. In the six months to October 2013, eight mining projects were completed in WA, with an aggregated value of \$20.6 billion. Over the last decade, the Pilbara region of WA has become a regional hub for oil and gas and iron ore projects resulting in an important growth in population and energy demand in the region.

Figure 16 Advanced minerals and energy projects – October 2013



Source: (BREE, 2013)

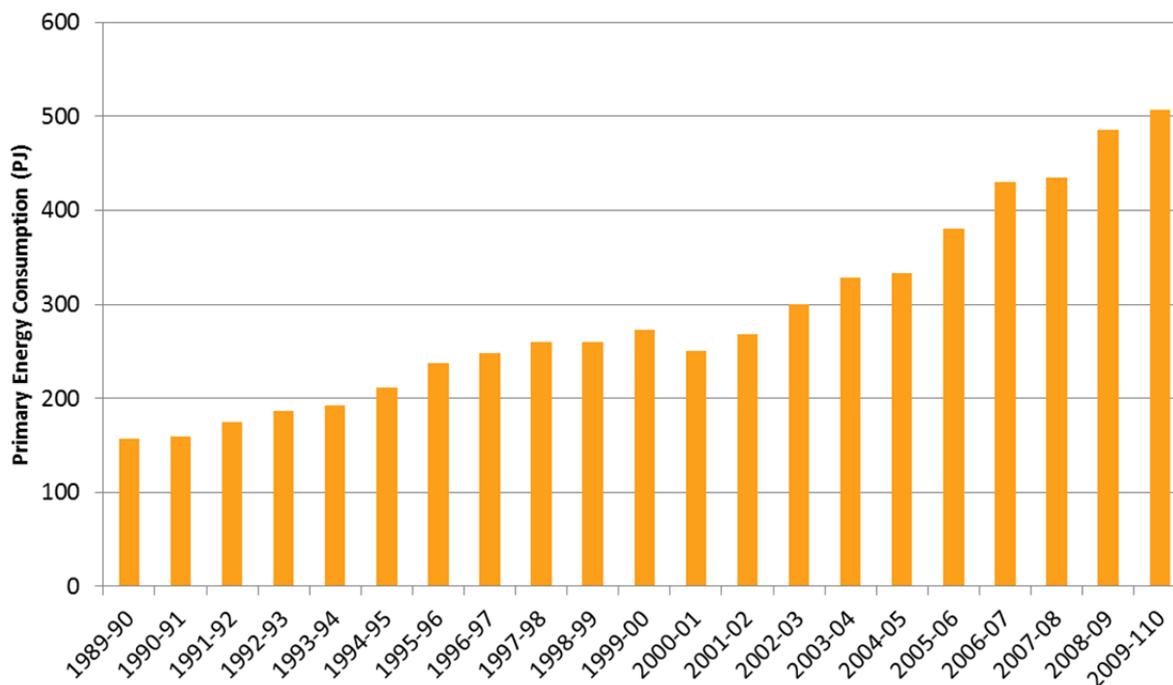
6.1.3 Energy demand in the mining sector

Mining operations require energy in a variety of forms and for a variety of usages including excavation, grinding, haulage, ventilation, and dewatering as well as for supporting infrastructure and services. Comminution or grinding is the largest energy consumer of a mine site requiring up to over 100kWh per ton depending on the degree of grinding. (Wang, Fengnian, & Manlapig, 2011)

As illustrated in Figure 17, the energy consumption of the mining sector tripled over the period from 1990 to 2010, corresponding to an average 5.7 per cent average annual growth rate (BREE, 2012). By 2012, the off-grid mining sector accounted for 12.4 TWh of Australia's electricity consumption.

The future mining investments discussed in section 6.1.2 suggest that this trend is likely to continue over a number of years. In particular, the three segments dominating the investment plan are; oil and gas, iron ore and coal and these also are the three largest energy consumers within the mining industry. Mining regions such as the Pilbara and Midwest are expected to see their electricity demand soar over the next decade.

Figure 17 Primary energy consumption in the mining sector²



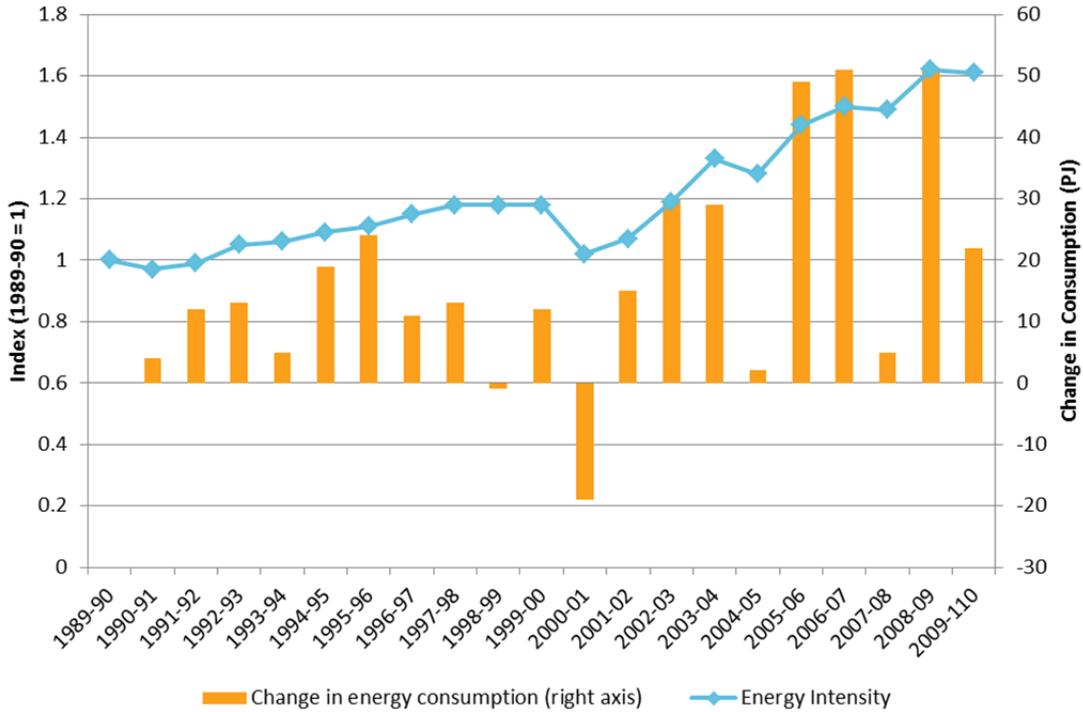
Source: (BREE, 2012)

The rising energy consumption from the mining sector is the result of an intensification of the mining activity combined with an increase of the energy intensity of the mining sector.

As illustrated in Figure 18 the energy intensity of the industry has risen at an average 2.3 per cent rate per annum between 1990 and 2010.

² Note: The graph shows the net primary energy consumption of (or net primary energy supply to) the mining sector. The final energy consumption is the net primary energy supply less energy consumed or lost in conversion, transmission and distribution. In 2009-10, the final energy consumption of the mining sector amounted 340PJ (out of 509PJ of primary energy supply shown in the graph).

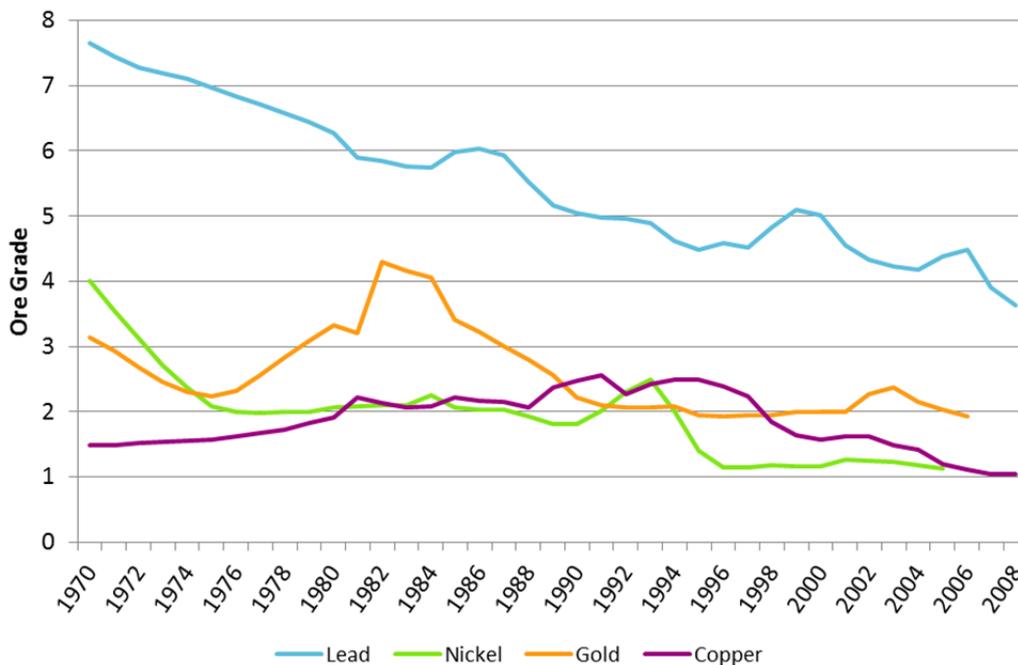
Figure 18 Trends of intensity and yearly change in energy consumption in the mining sector



Source: (BREE, 2012)

Figure 19 shows that the trend toward higher energy intensity correlates with an increase in the use of energy for exploration activity and the need to exploit deeper and lower grade ores — particularly base metals such as copper, nickel, lead and zinc. In addition, the sharp rise in production of relatively energy-intensive liquefied natural gas (LNG) may have contributed to the increase in energy intensity in the sector in recent years. The rising commodity prices have also incentivised mining companies to focus on faster mining output rather than managing operational energy costs.

Figure 19 Average ore grades over time



Source: (CRCORE, n.d.)

As highlighted in section 6.1.2, the Pilbara region of Western Australia is a growing region for gas and iron ore. For example Chevron's Wheatstone gas project and related developments at Onslow are forecasting that demand will triple by 2016/17, which means a new 9MW power station will be required. In the Pilbara region the energy demand from the mining sector is expected to increase by 12,000 GWh by 2015. A majority of it is likely to be gas-fired self-generation. For the Mid-West region of Western Australia, an additional 2,100 GWh per year of new generation will be required by 2018, of which around 77% will be off-grid. (CME, 2013)

As for other remote renewable energy opportunities within mines, the below three mines use off-grid diesel generation systems as their prime power source. With the potential for sites to benefit from off-setting their fuel costs and mitigating their security of supply risks, renewable energy hybridisation could be considered.

Table 18 South Australian mines using off-grid diesel generation systems

| Site | Location | Organisation | Plant size (kW) |
|----------------------|----------|------------------------|-----------------|
| Jacinth Ambrosia | Yalata | Iluka Resources | 6,800 |
| Challenger Gold Mine | - | Kingsgate Consolidated | 5,000 |
| Beverly | Beverly | Heathgate Resources | 6,000 |

Source: (GovtSA, 2014)

6.2 Renewable energy in the mining sector considerations

There are a number of challenges that limit the development of renewable energy in the mining sector; some of which are presented in Table 19 below.

Table 19 Challenges and opportunities in the mining sector

| Challenges | Opportunities |
|--|--|
| <p>Intermittency and reliability – Mine sites require very high levels of reliability. An electricity outage can cost millions of dollars per day in lost revenue from loss of production, and outages can be extended further due to the slow time to restart processing and ramp up to full capacity. Maintaining constant and reliable electricity supply can also be important from a safety perspective.</p> <p>Solar PV and wind are intermittent by nature, and therefore can't ramp-up rapidly.</p> <p>There is general lack of confidence from the mining industry that renewable energy can be integrated reliably to their generation system.</p> | <p>Solar PV and wind hybrid systems can be designed to meet the reliability requirements of the mining sector.</p> <p>Renewables can be used to offset diesel or gas usage, rather than to replace capacity in the system.</p> <p>At low levels of penetration, intermittent renewable ramping will remain within the load following capability of the diesel units. At higher levels of penetration short term intermittency can be addressed by the use of flywheels and batteries to allow the existing power generation units to match.</p> <p>To examine the business case, the appropriate cost comparison is the operating cost of diesel generation (mostly composed of fuel costs) against the levelised cost of integrated solar generation (including control and integration costs). At low levels of solar penetration, solar energy still presents a positive business case in most parts of Australia. See section 8.0 below for further details.</p> |
| <p>Split incentives – One party may install the generator while another bears the ongoing fuel costs.</p> <p>This is the case in some interconnected systems operated by Horizon Power, where the mining companies have obligations to pay for an agreed power plant capacity but do not pay the subsequent operational diesel costs.</p> <p>A similar situation happens when mining companies procure their electricity from Independent Power Producer (IPP), who build, own, operate and maintain the power system on their behalf. The miner might pay a fixed electricity rate over a contract term and free issues diesel to the IPP. Take-or-pay terms are also a common feature of PPA contracts, which can complicate matters.</p> | <p>Where the parties have a close commercial relationship, there are opportunities to agree on contractual terms, which represent a win-win situation.</p> <p>Where electricity is generated using diesel, the party responsible for the ongoing fuel cost may want to invest into the integration of solar into the system.</p> |
| <p>Low priority – Energy costs tend to be a low priority for the miners whose primary focus is on rapid production expansion over capital cost savings. There is also a historical perception of low energy prices.</p> | <p>As costs increase, there is likely to be a growing focus on energy costs by the mining industry. The current economic environment and moderation of the mining investment may also push some of the mining companies to look at alternative ways to save energy and costs; while minimising the risks associated with fuel price volatility.</p> <p>In light of ARENA's RAR program, there is a role for government organisations and private companies to highlight to the mining industry the economic benefits of renewable energy.</p> |

| | |
|---|---|
| <p>Short project timeframes – Renewable energy projects generally rely upon long operating lifetimes to achieve cost effectiveness. By contrast, certain mining projects may not last for that duration, or may have an uncertain lifetime.</p> | <p>The cost effectiveness of renewables to displace diesel or gas operation will depend upon the lifetime of the project, with longer lifetimes allowing cost recovery at lower delivered diesel or gas prices. Higher delivered diesel or gas prices or additional project support from organisations such as ARENA could justify the integration of PV particularly into projects with shorter lifetimes. ARENA is focusing on mining projects with a 5 year minimum lifetime.</p> <p>Portable systems are now available on the market, and these may prove suitable for some applications. This would allow a PV system to be integrated into the power system at a mine site, and then moved at the end of the mine operations to another site.</p> <p>In some cases there is an opportunity to develop a renewable energy project for a mine located close to a remote community. As the mine operation stops, renewable electricity can be used for the communities in the vicinity.</p> |
| <p>Technology maturity – While grid connected wind and solar PV are mature technologies, there are few examples of large off-grid projects. First-of-a-kind projects are generally considered high risk, which increases the costs of financing and can make businesses require evidence of large returns before they are prepared to proceed.</p> | <p>Although there are limited examples in Australia's mining sector, successful examples of remote towns being powered by solar or wind hybrid systems do exist and a few off-grid case studies are provided throughout this paper. Internationally more demonstrated examples are available (including specifically in the mining sector).</p> <p>ARENA's RAR program will likely assist in developing a track record of successful off-grid renewable energy projects. This is fundamental to give the mining industry confidence that off-grid solar or wind can be integrated to a diesel or gas system in a reliable way. These projects should follow detailed engineering studies to minimise the risk of failure, which could cause long-lasting reputation damage to the industry. Projects with a high risk profile (such as mining projects) should start with lower a penetration of renewable energy, while a few show-case projects with high penetration of renewable energy could be developed in remote communities that present a lower risk profile.</p> |
| <p>Labour costs – The remote location of many mines means that labour costs are typically very high. The proximity of the mining industry itself also tends to increase the cost of labour.</p> | <p>The increased labour costs in remote locations should be taken into account. This is particularly important during the construction phase when skilled labour requirements are highest. Ongoing operations and maintenance costs can be maintained at a low level with remote monitoring. An on-site presence is likely to be required for security and basic cleaning, but skilled maintenance can be called upon as required.</p> <p>It is very important that the systems deployed on mining sites are designed to be robust and reliable to minimise maintenance cost.</p> |

| | |
|--|---|
| <p>Cyclone risk – Some areas, such as coastal sites in the Pilbara, are vulnerable to extreme cyclonic winds and rain.</p> | <p>In these areas, wind and PV installations must be designed to withstand cyclone conditions. The mounting and anchoring can be designed to withstand greater loads, or it may prove feasible to install adjustable solar systems or wind turbines that are designed to be laid flat when a cyclone is anticipated at the site. This is the case in Coral Bay (see section 7.1.4). For larger sites, cyclone-proof wind turbines are available in the market.</p> <p>These systems are more expensive but many are still likely to be competitive with diesel costs. These projects may also seek funding from ARENA's RAR programs.</p> |
| <p>Competition from gas – Gas generation is substantially cheaper than diesel generation and so it presents a far less attractive business case for integrating renewables. In particular, where gas is available from a pipeline; renewable energy cannot compete against gas-fired power.</p> <p>In remote locations, where there is no accessible gas pipeline, Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG) or even gas pipeline expansions are regularly considered in parallel with renewable energy options. The preferred option depends on a number of site specific factors.</p> | <p>Gas prices are subject to fluctuation and renewable energy can be seen as a hedge against the risk of high gas prices.</p> <p>Some mines use trucked gas, which can be very expensive depending on the distance it is trucked, opening an opportunity for renewable hybridisation.</p> <p>Renewable energy's environmental benefits outweigh those of gas.</p> |

6.3 Independent Power Producers

In the off-grid industrial sector, it is commonplace to procure electricity from Independent Power Producers (IPPs). IPPs build, own and operate power plants on behalf of an energy user. The project is typically reliant on the terms and conditions of a Power Purchase Agreement (PPA), which guarantees a revenue stream for the IPP. Payment to the IPP might be based on a combination of one or more of fuel consumption, electricity output, fixed charges and take-or-pay arrangements.

The off-grid generation portfolios of two major IPPs operating in the off-grid market of Australia are provided below.

6.3.1 Energy Development Ltd

Energy Developments Ltd (EDL) develops, owns and operates electricity generation facilities in remote off-grid communities and for remote off-grid industrial users throughout Australia. Generated electricity is either sold to retailers such as Horizon Power, Ergon Energy or Power and Water Corporation or directly to industrial users (e.g. mines). Energy Developments Ltd owns 743 MW of generating assets in Australia including a number of off-grid energy generation facilities located in Queensland, Northern Territory, Western Australia and South Australia. These generation facilities are either LNG, gas or diesel fuelled and have generation capacities of 1 MW to 40 MW each.

Table 20 EDL's remote power stations

| Power Station | Installed Capacity (MW) |
|----------------|-------------------------|
| WKPP | 70 |
| Cannington | 40 |
| Pine Creek | 35 |
| Sunrise Dam | 28 |
| McArthur River | 24 |
| Wodgina | 14 |
| Darlot | 12 |
| Other | 57 |
| Total | 280 |

Source: (EDL, 2012)

Figure 20 Energy Developments Ltd power stations



6.3.2 Pacific Energy

Pacific Energy acquired Kalgoorlie Power Systems (KPS) in May 2009. Pacific Energy owns and maintains a portfolio of approximately 210MW of gas and diesel fuelled electricity generation, supplying power to Australia's resource sector in Western Australia, Northern Territory and South Australia and 6MW of hydro generation located in Victoria supplying the National Electricity Market. Figure 21 describes some locations of Pacific Power's portfolio, which is predominantly for off-grid industrial electricity users.

Figure 21 Pacific Energy power generation facilities



Source: (Pacific Energy, 2014)

6.4 Off-grid industrial case studies

An overview of renewable energy projects that have been recently developed in the off-grid industrial sector are described in Table 21.

Table 21 Case studies in the mining sector

| 66kW hybrid system for BHP | Galaxy Resources Mount Cattlin mine |
|--|--|
| BHP installed a 66kW hybrid diesel/battery storage/ photovoltaic system to supply electricity to a remote communications tower critical for mining operations. Commissioned in November 2012, it is designed to provide 100 per cent renewable energy for 5 days without requiring the diesel generators to run. | Galaxy Resources have installed 14 dual tracking solar panels and two wind turbines at Mt Cattlin lithium mine and processing plant. The plant produces 226MWh per year of renewable energy and supplements the 5MW diesel generator (approximately one sixth of the total load). (Galaxy Resources, 2013) |
| Rio Tinto Weipa bauxite mine | |
| 6.7MW of solar power and energy storage will be developed on the Weipa bauxite mine in Queensland. It is expected to reduce daytime diesel demand from the mine's 26MW diesel generator by up to 20 per cent. ARENA has committed \$10.3 million to the two phases of the project. | |

6.5 Other off-grid Industrial applications

Other off-grid industrial applications for renewables cover a wide range of applications including:

Table 22 Off-grid industrial opportunities

| Category | Example | Opportunity | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------------|----------------------------|---|---|-----------------|-------------|------|----|-----|----------------------------|------|------|------------|------|------|-------------------|------|------|-----------------|-----|-----|-----------------|-----|-----|--------------|--------------|-----------|
| Off-grid Industry | Meat processing facilities | Off-grid meat processing facilities use over 66 per cent of their energy through the operation of processing equipment, boiler losses and refrigeration (NFEE, 2004). The thermal loads provide an opportunity for implementing solar thermal and cold stores provide an opportunity for demand management. Data commissioned by BREE in 2013 indicates there is an estimated 62MW of installed capacity supplying approximately 196GWh to the off-grid agricultural sector, see table below. | | | | | | | | | | | | | | | | | | | | | | | | |
| | | <table border="1"> <thead> <tr> <th>Estimated Agricultural Electricity Demand</th> <th>Consumption GWh</th> <th>Capacity MW</th> </tr> </thead> <tbody> <tr> <td>DKIS</td> <td>17</td> <td>5.4</td> </tr> <tr> <td>Rest of Northern Territory</td> <td>68.1</td> <td>21.6</td> </tr> <tr> <td>Queensland</td> <td>69.8</td> <td>22.1</td> </tr> <tr> <td>Western Australia</td> <td>35.7</td> <td>11.3</td> </tr> <tr> <td>South Australia</td> <td>2.8</td> <td>0.9</td> </tr> <tr> <td>New South Wales</td> <td>2.3</td> <td>0.7</td> </tr> <tr> <td>Total</td> <td>195.7</td> <td>62</td> </tr> </tbody> </table> | Estimated Agricultural Electricity Demand | Consumption GWh | Capacity MW | DKIS | 17 | 5.4 | Rest of Northern Territory | 68.1 | 21.6 | Queensland | 69.8 | 22.1 | Western Australia | 35.7 | 11.3 | South Australia | 2.8 | 0.9 | New South Wales | 2.3 | 0.7 | Total | 195.7 | 62 |
| | | Estimated Agricultural Electricity Demand | Consumption GWh | Capacity MW | | | | | | | | | | | | | | | | | | | | | | |
| | | DKIS | 17 | 5.4 | | | | | | | | | | | | | | | | | | | | | | |
| | | Rest of Northern Territory | 68.1 | 21.6 | | | | | | | | | | | | | | | | | | | | | | |
| | | Queensland | 69.8 | 22.1 | | | | | | | | | | | | | | | | | | | | | | |
| | | Western Australia | 35.7 | 11.3 | | | | | | | | | | | | | | | | | | | | | | |
| | | South Australia | 2.8 | 0.9 | | | | | | | | | | | | | | | | | | | | | | |
| | | New South Wales | 2.3 | 0.7 | | | | | | | | | | | | | | | | | | | | | | |
| Total | 195.7 | 62 | | | | | | | | | | | | | | | | | | | | | | | | |
| Off-grid Infrastructure | Communications | Powering mobile and IT communications infrastructure is particularly challenging in remote areas with limited mains grid power. Often these off-grid mobile towers are powered by diesel generators. There is a great potential to increase the use of renewable energy in this sector, which accounted for only | | | | | | | | | | | | | | | | | | | | | | | | |

| Category | Example | Opportunity |
|----------|--------------------------|--|
| | | 0.11 per cent in 2010 (Green Telecom Networks, 2010). |
| | Desalination | <p>Most desalination plants consume a large amount of energy, therefore finding methods of using renewable energy to power the desalination process is desirable. Solar collectors or wind turbines can be used to provide heat or electrical energy required to operate a standard reverse osmosis, electro-dialysis, or distillation desalination plant.</p> <p>Renewable energy systems can easily be oversized and paired with water storage (which is cheaper than energy storage) to facilitate 100% renewable energy, with diesel operating as a backup only. This works by powering the desalination plant with renewable power (only) such that it provides sufficient water despite intermittency issues. The water tank acts as a buffer between the intermittent production of water and the demand for water.</p> |
| | Pumping and Irrigation | <p>There are more than 10,000 solar powered surface and bore water pumps in use around the world today (TRL Solar, 2013). Solar is already widely used on farms and outback stations in Australia to supply bore and surface sourced water to livestock. In remote regions there is an opportunity to further adapt renewables for pumping water from wells and rivers to communities for domestic consumption and irrigation of crops. Once a very expensive technology, prices have dropped in recent years.</p> <p>A typical solar powered pumping system consists of a solar panel array that powers an electric motor, which powers a bore or surface pump. The water is often pumped from the ground or stream into a storage tank that provides a gravity feed, so energy storage is not needed for these systems. PV powered pumping systems are a cost-effective alternative to agricultural wind turbines for remote area water supply. (Energy Matters)</p> |
| Tourism | Resorts, Hotels, Islands | Interest in Renewable Energy Technology is high within the tourism sector; primarily for cost savings, ethical reasons and social responsibility as opposed to benchmarking, marketing or as a potentially more reliable energy source. |

6.5.1 Non-Mining Industrial renewable energy opportunities

Square Kilometre Array

The Square Kilometre Array (SKA) project is a global project to build the world's largest radio telescope in Mileura (WA). The project is led by the SKA Organisation and involves a number of organisations from different countries including the CSIRO.

In December 2011 Horizon Power received \$15.5 million in funding to construct a 1MW power station to support the Australian Square Kilometre Array Pathfinder Project (ASKAP), a pilot project for the SKA project. The ASKAP represents approximately 1 per cent of SKA project development. The generation system will be a renewable hybrid system and will be designed to be "radio-quiet".

Table 23 Key stakeholders and considerations of the Square Kilometre Array

| Key Stakeholders | Considerations |
|------------------------|--|
| Horizon Power CSIRO | Technically challenging project. The system must be "radio-quiet" and extremely reliable |

Algae project in the Pilbara

As part of its vision to create an attractive region, the Pilbara Cities Office is encouraging industry diversification across the region. In 2012, the Office commissioned a study to assess the opportunities for the development of an algae-based industry in the Pilbara. Algae can be used to produce a number of renewable, carbon neutral biofuels including biodiesel, methane, ethanol and jet fuel. The study highlights that the Pilbara's climate and access to seawater and carbon dioxide make it an ideal region for the development of an algae industry. (WorleyParsons, 2012)

There is already a developing algae industry in the region and a growing interest in these technologies. Recent projects include Aurora Algae's demonstration project in Karratha and their commercial scale farm in the Maitland area (in development). Sapphire Energy and Murdoch University research funded by Rio Tinto are also involved in this new industry.

Table 24 Key stakeholders and considerations of Pilbara algae project

| Key Stakeholders | Considerations |
|---|--|
| Rio Tinto and Murdoch University Aurora Algae Sapphire Energy Pilbara Cities | Industry relatively immature Little skilled workforce in this space Development Approval difficult to obtain |

7.0 Off-grid Communities Market

Over two-thirds of the total Australian population reside in major cities in comparison to just 2.3 per cent (half a million people) who live in remote areas of Australia (ABS, 2013). The remote population has experienced a modest 8.25 per cent growth rate over the ten years to 2011, with some regions (Victoria, NSW and Tasmania) experiencing negative growth over this period. The off-grid community energy sector is currently supplied primarily through state and territory owned NSP's such as Horizon Power (WA), Ergon Energy (QLD) and Power Water Corporation (NT).

This paper focuses on Western Australia, Queensland, Northern Territory and South Australia which together make up approximately 80 per cent of the Australian remote population and offer the greatest potential opportunity for off-grid and fringe-of-grid renewable energy. This is highlighted in Figure 22.

Figure 22 Remote and very remote populations in each State (as per the Australian Statistical Geography Standard categories)



Source: (ABS, 2013)

The off-grid community energy market is a combination of islanded micro grid systems supporting communities and mining towns. In off-grid community markets, States and Territories pay a Community Service Obligation (CSO) to energy suppliers to subsidise the cost of energy to consumers. Electricity supply is considered an essential service and the National Framework for Energy Services Obligations is aimed at providing equity in electricity pricing across Australia (MCE, 2008). The actual costs of providing electricity services to customers in remote and regional areas is substantially higher than providing the same services in metropolitan areas due to higher fuel costs, lower economies of scale and lower customer density. All regional and remote customers in a particular class (i.e. residential and small business) receive the benefits of the CSO. The CSO is not means tested and varies across the states and territories. They include a combination of concessional tariffs, grants and rebates.

Table 25 Approximate* Community Service Obligation payments to selected utilities for regulation of remote electricity users

| Utility | CSO Payment (2012-13) |
|---|-----------------------|
| Western Australia (Horizon Power) | \$154 million |
| Ergon (Queensland) | \$620 million |
| Power and Water Corporation (Territory) | \$76 million |

*figures may include contribution to water and sewage services

Source: (Horizon Power, 2013), (Queensland Treasury, 2013), (Power and Water Corporation, 2013)

Growth in Mining Towns

Over the 12 years up to 2012 employment in the mining industry has tripled in Australia, peaking at 276,300 people employed which has consequentially driven strong population growth in mining towns where 'fly-in, fly-out' and 'drive-in, drive-out' workers reside (ABS, 2013).

Figure 23 The ten strongest growth mining cities



Source: (ABS, 2013)

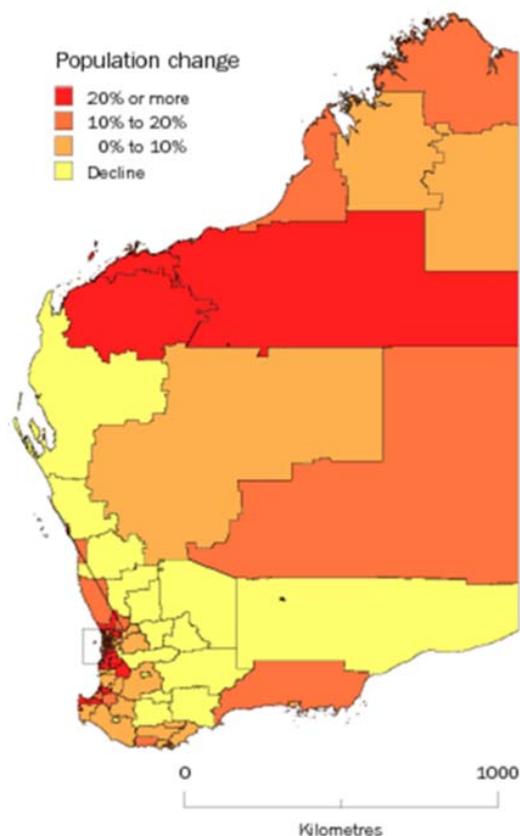
Apart from Weipa in far North Queensland and Roxby Downs in South Australia, the 10 mining towns with the strongest growth between 2006 and 2011 are all located in either the Bowen Basin in Central-eastern Queensland or in the Pilbara region (see Figure 23). These mining towns have experienced a population growth between 18 per cent and over 51 per cent over the five years to 2011 (ABS, 2013). The large influx of people to these once rural towns is creating a need for new infrastructure. Most mining towns are investing heavily to improve their supply of affordable and accessible essential services such as electricity and water.

7.1 Western Australia

In recent years Western Australia has experienced an unprecedented population growth driven by a rapid development of the mining industry. WA's population increased by 24 per cent to 2.35 million in the ten years to 2011 and is expected to double in the next 30 to 40 years (ABS, 2011). The Western Australian Government and private companies are supporting this growth with multi-billion dollar infrastructure projects and services.

With 1.83 million people, the population of greater Perth represents 78 per cent of the state's population and experienced a 26 per cent growth over the ten years to 2011. The Pilbara recorded a 59 per cent population growth (23,300 people) over the same period, the state's fastest population increase.

Figure 24 Population change in WA between 2001 and 2011

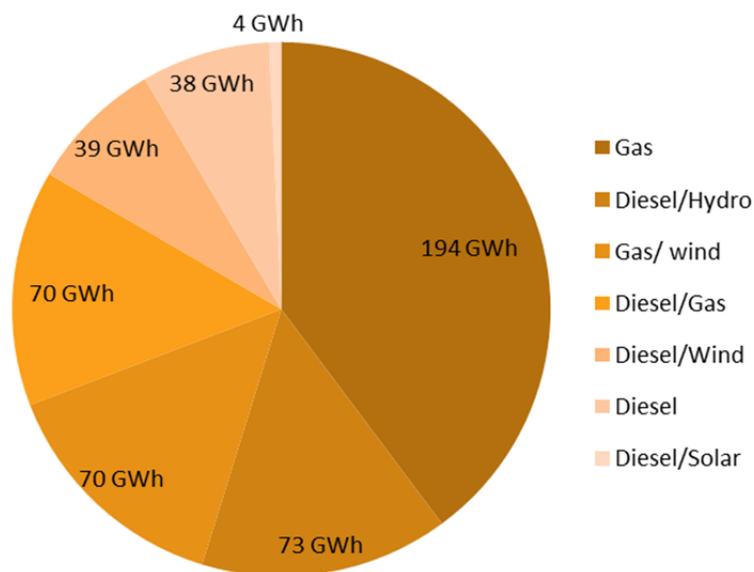


Source: (ABS, 2011)

7.1.1 Remote communities

Horizon Power supplies electricity to 36 isolated communities through Western Australia (see Figure 26 in section 7.1.2). As highlighted in Figure 25 below, diesel and gas are the primary energy sources.

Figure 25 Electricity supply in Horizon Power remote communities (in GWh)



Source: AECOM based on horizon power annual report and website

Seven out of the nine remote grids supplying a load above 10GWh are partly or fully supplied by gas-fired plants. The majority of the smaller remote loads involve diesel generators.

Table 26 List of remote communities serviced by Horizon Power

| Communities | Electricity consumption (MWh) | Current Energy source |
|-----------------------|-------------------------------|-----------------------|
| Ardyaloon | 1,697 | Diesel |
| Beagle Bay | 1,578 | Diesel |
| Bidyadanga | 2,708 | Diesel |
| Broome | 130,238 | Gas |
| Camballin/ Looma | 2,691 | Diesel |
| Carnarvon | 49,044 | Gas |
| Coral Bay | 3,079 | Diesel/Wind |
| Cue | 2,015 | Diesel |
| Denham | 5,528 | Diesel/Wind |
| Derby | 36,196 | Diesel/Gas |
| Djarindjin/ Lombadina | 1,613 | Diesel |
| Esperance | 70,257 | Gas/Wind |
| Exmouth | 24,992 | Diesel/Wind |
| Fitzroy Crossing | 14,100 | Diesel/Gas |
| Gascoyne Junction | 631 | Diesel |
| Halls Creek | 11,221 | Diesel/Gas |
| Hopetoun | 5,853 | Diesel/Wind |
| Kununurra | 63,764 | Diesel/Hydro |

| Communities | Electricity consumption (MWh) | Current Energy source |
|--------------|-------------------------------|-----------------------|
| Kalumburu | 540 | Diesel |
| Lake Argyle | 222 | Hydro |
| Laverton | 4,598 | Diesel |
| Leonora | 10,881 | Gas |
| Marble Bar | 2,365 | Diesel/Solar |
| Meekatharra | 7,402 | Diesel |
| Menzies | 706 | Diesel |
| Mount Magnet | 4,103 | Gas |
| Norseman | 4,148 | Diesel |
| Nullagine | 1,171 | Diesel/Solar |
| Onslow | 8,159 | Diesel/Gas |
| Sandstone | 709 | Diesel |
| Warmun | 2,927 | Diesel |
| Wiluna | 2,851 | Diesel |
| Wyndham | 9,080 | Diesel/Hydro |
| Yalgoo | 943 | Diesel |

Source: AECOM; (Horizon Power, 2012-13)

7.1.2 Key stakeholders

Horizon Power is Western Australia's primary regional and remote electricity provider servicing both communities and major industrial users. Horizon Power manages two interconnected electricity networks, the North West Interconnected System (NWIS) in the Pilbara and the East Kimberly Interconnected System, as well as 36 non-interconnected or islanded systems in regional towns and remote communities.

Horizon Power services the biggest area with the least amount of customers in the world with just one customer for 53.5 square kilometres.

Horizon Power's generation portfolio is predominantly gas and diesel-fired, however wind, solar and hydro generation facilities also feature. Horizon Power has recently commissioned two solar diesel hybrid power stations in the remote Western Australian communities of Marble Bar and Nullagine.

Figure 26 Horizon Power's power stations



Source: Horizon Power website

Verve Energy (now Synergy) is a major supplier of electricity within the SWIS, however they also own and operate a number of remote off-grid generation facilities in Western Australia including renewable energy assets integrated with Horizon Power diesel and gas generation systems at Hopetoun, Coral Bay, Denham, Esperance and Bremer Bay.

The **Department of Aboriginal Affairs** (DAA) of Western Australia is responsible for advising Government on the adequacy, implementation and coordination of services to Aboriginal people in Western Australia. Amongst other tasks, the DAA works with Aboriginal Australians to improve the delivery of services in remote communities.

7.1.3 Renewable energy opportunities

Pilbara Cities

The Pilbara is located between the Kimberley and the Tropic of Capricorn. It is home to approximately 60,000 people over approximately 508,000 square kilometres. The Pilbara region is rich in minerals and hydrocarbons, becoming an important mining and export region of Australia. The Pilbara population has experienced strong growth over the past few years, which is expected to continue, needing infrastructure development, including in the power sector.

In 2013 there are \$100 billion worth of committed projects in the Pilbara and over 7,000 new dwellings required by 2015.

Some of the Pilbara's fastest growing centres including Karratha and Port Hedland, which are envisioned as cities of 50,000 people each by 2035, Newman with a forecast population of 15,000 people and Tom Price and Onslow.

Since 2009 approximately \$1.2 billion in State Government Royalties for Regions funding has been committed to transform the Pilbara through the Pilbara Cities program. Pilbara Cities was established in April 2010 to help develop the necessary infrastructures associated with significant growth in the region. Pilbara Cities Office (PCO) was created to ensure the royalties are used in line with the government, industry, business and community objectives.

A number of projects are already in development in Karratha, Port Headland, Onslow and Newman.

Additional generation capacity will be required in the NWIS as well as in some regional centres including Onslow and Newman to meet the region's growing demand.

A few projects recently developed or in development include the following:

- BHP building a 178 MW gas plant in Newman
- Rio Tinto is planning for 120 MW open cycle gas turbines
- CITIC Pacific recently built a 450 MW combined cycle gas-fired power station
- Onslow Power Station – Chevron is to build a new gas power station in Onslow to meet the demand from the forecast population growth. A 1 MW generator was installed at the end of 2013 and Horizon and Chevron are working together towards a plan of installing 9MW by 2016 (Horizon Power, 2012).
- The 18MW Mungullah gas power station was completed at the end of 2013 near Carnarvon
- In South Headland, a new 67MW power station will provide power until a new long-term 110MW power station is completed, which is planned for 2017. (Horizon Power, 2014)

Horizon Power is forecasting the generation in the Pilbara to grow substantially over the coming decade. For example, demand is expected to triple in Onslow by 2016-17 as a result of Chevron's Wheatstone project. To meet the short term growing demand, the utility is planning to build new power stations and to secure additional capacity through the renewal of power purchase agreement (PPA) such as the PPA with Alinta in Port Hedland (Horizon Power, 2012). In parallel, Horizon Power is working with the State Government to define the best approach to optimised power development in the Pilbara in the long term.

In its 2009 submission to the Energy White Paper, Horizon Power stated: "The Pilbara, Mid-West, and even the south coast of Western Australia could become renewable energy centres. The Pilbara is unique in that it is close to wind, wave and geothermal resources and to 90 per cent of Australia's known oil and gas resources, has coastal access that could facilitate large-scale combined cycle power generation and, importantly, has a world-class solar resource." (Horizon Power, 2009)

There are significant opportunities to collaborate with Pilbara Cities, Horizon Power and the mining sector to integrate renewable energy into the short and long term strategy of the region. The renewable energy project development would likely consist in hybridisation of new or existing generation systems in the Pilbara with wind or solar.

Key challenges renewable energy projects in the Pilbara Cities must overcome include the extreme climate and regulatory environment. The Pilbara's climate is both arid and tropical, which experiences high temperatures and low irregular rainfall following the summer cyclones. Cyclones and flooding are major hazards in the Pilbara with periods of torrential rainfall between November and May and approximately seven cyclones every ten years. During the summer months, maximum temperatures exceed 32 °C almost every day, and temperatures in excess of 45 °C are not uncommon. Land owner and environmental approvals may be challenging and should be considered early in the project

Carnarvon

The population growth in Carnarvon is driving increasing electricity demand. Horizon Power recently built the \$73 million Mungullah Power Station (18 MW) to replace the existing power station and meet the long term electricity needs of the community and businesses.

The power station is comprised of five diesel generators and five gas generators. The gas is supplied via the Dampier to Bunbury Gas Pipeline Carnarvon Lateral and has become the primary fuel source due to its cheaper price.

There may be an opportunity to integrate up to 3.6MW of renewables at Carnarvon (based on a 20 per cent penetration of renewable energy in the 18MW power station), however the cheaper gas-fired generation may makes this location less attractive than similar diesel-powered communities.

Kimberley Indigenous communities

A number of Kimberley Indigenous communities, serviced by Horizon Power or other regional service providers, need important upgrades of their power supply systems.

Every year a few communities benefit from the Horizon Power Aboriginal and Remote Community Power Station Project (ARCPSP) funded by the Australian and State Governments. The program is designed to improve the power supply to remote Indigenous communities.

Two recent projects, the Kalumburu and Yungngora power systems, were funded under ARCPSP via Horizon Power. In 2012, the utility upgraded the electrical networks of Yungngora and Kalumburu and new diesel power stations were completed at Kalumburu and Yungngora in 2013 (Horizon Power, 2012).

The Remote Area Essential Service Program is also available to assist in the improvement of power supply for remote communities. Kimberley Regional Service Providers (discussed further in section 7.5.2) have been involved in a number of projects under their Remote Area Essential Service Program contract.

The large remoteness and dispersed nature of the communities presents a number of logistical and scale challenges for renewables deployment. The cost of construction and maintenance is also exceptionally high in remote areas. As such the hybrid the systems deployed must be robust and reliable.

7.1.4 Case Studies

Table 27 Case studies in Western Australia

Marble Bar

The Marble Bar community is located in the Pilbara in Western Australia. The town's power system is managed by Horizon Power, which operates a hybrid system comprised of a 1.28MW diesel plant (four 320 kW units) and a 302 kW solar tracking system.

The total integrated system (including the diesel units) was commissioned in May 2010 at a capital cost of \$16 million. The facility was awarded a \$4.9 capital grant under the Federal Government Remote Renewable Power Generation Program (this grant was shared with the Nullagine project described in the following section).

The town sources 30 per cent of energy from the solar units, with an instantaneous peak of up to 92 per cent from solar. 65 per cent of daytime energy is supplied by solar (Horizon Power, 2012).

A single 500kW fly-wheel energy storage system is included in the system to manage power quality and system stability.

The system enabled the average duration of power outages to be reduced from 38 minutes in 2009-10 to 8 minutes in 2010-11 (Horizon Power, 2012).

Nullagine

The Nullagine community is located in Western Australia, and features a peak demand of 0.4MW. The power supply is managed by Horizon Power. They operate 0.96MW of diesel capacity supplemented by 203kW of solar capacity (900 panels). The solar system supplies 30 per cent to 40 per cent of the town's energy demand.

The total integrated system (including the diesel units) cost \$14 million to install in October 2010. The facility shared with the Marble Bar project a \$4.9 capital grant from the Federal Government.

As with the Marble Bar system, the solar-diesel hybrid installed at Nullagine has operated reliably and enabled a reduction in the average interruption time 110 minutes in 2009-10 to no interruption in 2010/11 (Horizon Power, 2012).

Coral Bay

The Coral Bay community is located in the Pilbara, in Western Australia. The community features a peak demand of 600kW, and a minimum demand of 200kW (ABB, 2012).

The town's electricity system is managed by Horizon Energy. It comprises 7 x 320kW low load diesel generators integrated with Verve Energy (now Synergy) renewable assets including three 275 kW wind turbines and a 500kW inverter coupled flywheel (Ecogeneration, 2008).

The total integrated system (including the diesel units) cost \$12 million to install in 2007. The facility was supported by a 50 per cent capital grant under the Federal Government's Remote Renewable Power Generation Program for the renewable component (Evans & Peck, 2011).

The town sources 45 per cent of energy from the wind turbines. Wind generation routinely exceeds 90 per cent of the town's requirements.

The wind turbines are designed to be tilted down in the event of extreme wind events, such as an approaching cyclone. The low load diesel generators can be run for sustained periods at loads as low as 5 per cent and provide voltage and frequency regulation.

The system is control by a renewable micro-grid controller.

The wind energy input saves approximately 500kL of diesel per year, which formed the basis for the project business case. In addition, the flywheel energy storage reduced the need to run an extra diesel unit for spinning reserve, allowing additional maintenance cost savings.

Leinster mining township

BHP-Billiton Nickel West division installed solar PV to the rooftops of the Leinster township which supports the nickel mine. 195 1.5kWp CIS thin film technology solar panels were installed with full web-based remote power system monitoring in 2011 for a capex of \$1.5 million.

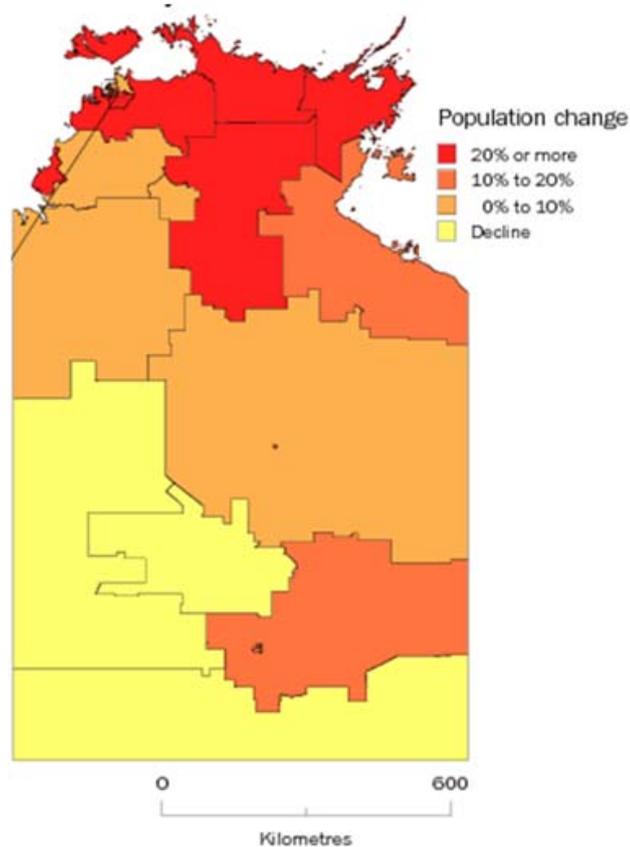
7.2 Northern Territory

With a population of approximately 235,000 people (ABS, 2012), the Northern Territory represents 1 per cent of Australia's population and has the lowest population density of any state or territory. Approximately 56 per cent of the population lives in Darwin and another quarter live in five regional centres: Alice Springs, Katherine, Tennant Creek, Jabiru and Nhulunbuy. The remaining population lives in remote communities.

Between 2001 and 2011, the Northern Territory experienced the third fastest population growth after Western Australian and Queensland (ABS, 2011). Figure 27 geographically depicts the population change over the ten years to 2011. Greater Darwin experienced the largest population increase, while the remote north areas of the Territory recorded the fastest population growth.

Approximately 30 per cent of the Northern Territory's people are indigenous, compared with 2.5 per cent nationally. Over 550 Indigenous communities and outstations are not connected to the main grids.

Figure 27 Population change in the Northern territory between 2001 and 2011



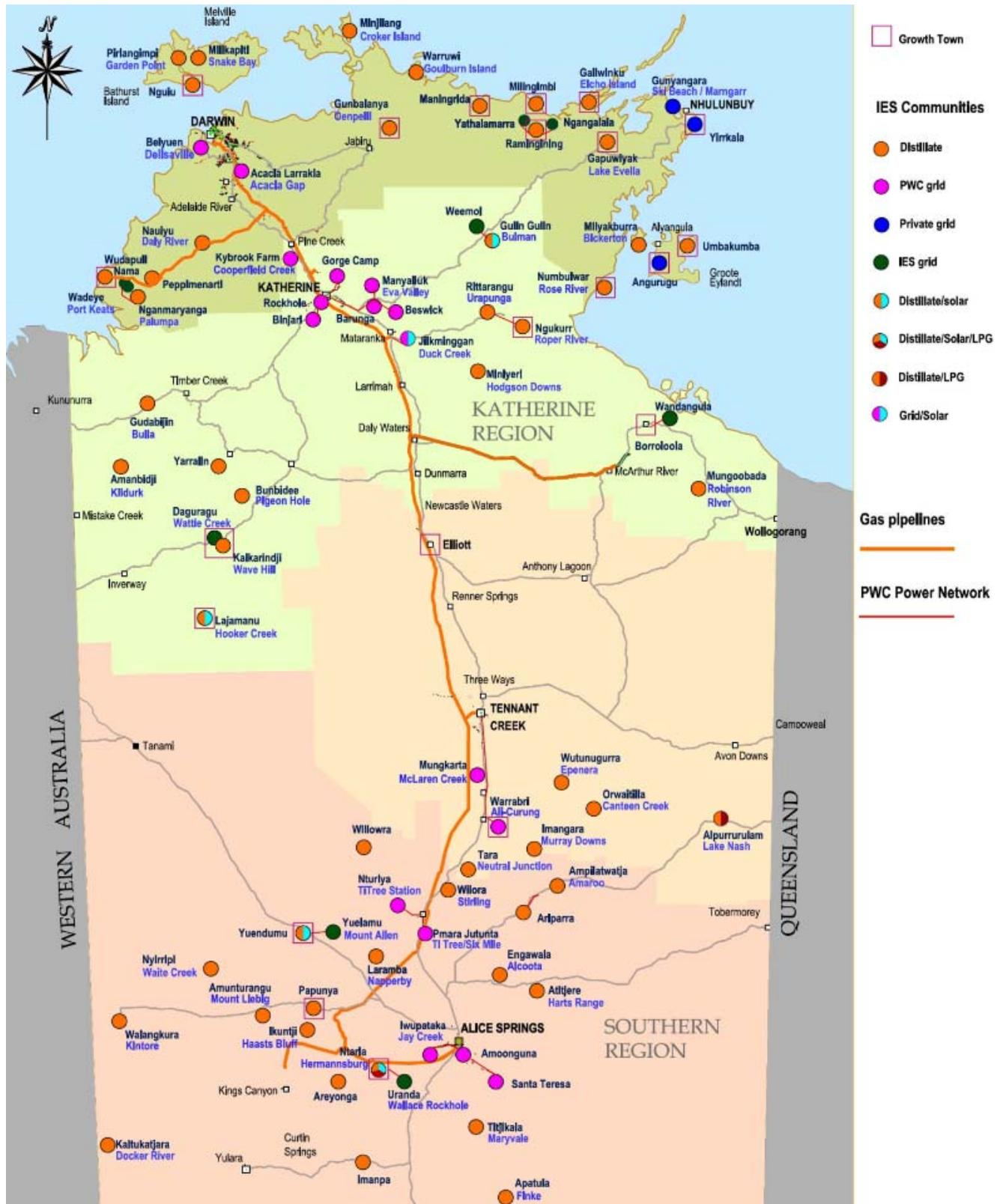
Source: (ABS, 2011)

7.2.1 Territory growth towns and remote communities

Power and Water Corporation (PWC) supplies electricity to the Territory's major interconnected network as well as to six main communities (refer to section 5.2). PWC owns an aggregated generation capacity of 559MW (with an additional 57MW under independent Power Purchase agreements) and supplied approximately 2,000 GWh of electricity in 2012-13.

Indigenous Essential Services (IES; a subsidiary of PWC) supplies electricity to 20 Territory Growth Towns (TGTs) and 52 remote indigenous communities. The supply of electricity to these remote communities is very costly and largely subsidised by the Northern Territory Government.

Figure 28 Energy sources used by IES to supply electricity to Indigenous communities



Source: (Green Energy Task Force, 2011)

Territory Growth Towns

Between 2006 and 2011, the 20 Territory Growth Towns experienced an 11 per cent Indigenous population growth, approximately double the growth rate of the Indigenous population of the Northern Territory (NT). These Territory Growth Towns have been identified by the Northern Territory and Australian Governments as a target for investment to enhance services, infrastructure and facilities.

As highlighted in the table below, the majority of the Territory Growth Towns are supplied electricity from diesel generators. Fourteen towns are using solely diesel generators, which have together produced over 57,600 MWh in 2011. To put this figure into perspective, approximately 35MW of solar PV is necessary to produce the equivalent amount of electricity. In reality, replacing all diesel systems with solar would likely require a larger solar capacity and very expensive energy storage.

Table 28 Territory Growth Town electricity supply status (2011)

| Territory Growth Towns | 2011 electricity consumption (MWh) | Current Energy source |
|-------------------------------|---|------------------------------|
| Serviced by PWC | | |
| Borroloola | 4,190 | Diesel |
| Elliott | 1,710 | Gas |
| Serviced by IES | | |
| Ali Curung | 1,620 | Gas |
| Angurugu | 3,990 | BHP/GEMCO mine |
| Deguragu- | 990 | Kalkarindji grid |
| Galiwinku | 6,140 | Diesel |
| Gapuwiyak | 2,630 | Diesel |
| Gunbalanya (Oenpelli) | 4,320 | Diesel |
| Hermannsburg | 3,020 | Diesel/ solar/ LPG |
| Kalkarindji | 2,320 | Diesel |
| Lajamanu | 2,900 | Diesel/ solar |
| Maningrida | 8,310 | Diesel |
| Milingimbi | 3,330 | Diesel |
| Nguiu | 6,200 | Diesel |
| Ngukurr | 4,100 | Diesel |
| Numbulwar | 2,760 | Diesel |
| Papunya | 1,570 | Diesel |
| Ramingining | 2,970 | Diesel |
| Umbakumba | 2,080 | Diesel |
| Wadeye | 6,700 | Diesel |
| Yirrkala | 3,300 | Rio Tinto Power station |
| Yuendumu | 3,400 | Diesel/ solar |

Source: (Green Energy Task Force, 2011)

7.2.2 Key stakeholders

Power and Water Corporation (PWC) provides electricity, water and wastewater services to customers across the Territory. PWC has a total generation capacity of 615 MW (558MW Generation owned with 57MW under power purchase agreements with independent power producers), most of which is connected to the Darwin-Katherine interconnected system. PWC also own and operate a number of smaller remote off-grid gas or diesel-fired power stations.

Power and Water Corporation's wholly owned subsidiary **Indigenous Essential Services (IES)** delivers electricity, water and wastewater services to remote Indigenous communities. IES owns and operates 200 generators across 52 diesel-fired power stations totalling 73 MW installed capacity and over 1,000km of transmission lines. IES are exploring options to offset high diesel fuel, transportation and storage costs including the use of solar and wind generation to augment diesel generators. IES uses solar/diesel hybrid generation in eight mini-grids that power eleven remote indigenous communities.

The **Centre for Appropriate Technology (CAT)** is a non-governmental organisation that works with remote communities to secure sustainable livelihoods through access to appropriate technology. CAT was established in 1980 and is incorporated under the Northern Territory Associations Act. CAT is governed by an Indigenous board and established the Bushlight program in 2002 to increase access to renewable energy in small Indigenous communities. Bushlight has installed over 140 stand-alone solar and solar-diesel systems in remote communities and they have over 260 systems on their repair and maintenance program.

The **NT Cattlemen's Association (NTCA)** is the peak cattle industry body in the Northern Territory and is actively involved in supporting the deployment of renewable energy on the Territory's cattle stations.

7.2.3 Renewable energy opportunities

Indigenous Essential Services communities

The vast majority of Territory Growth Towns (TGTs) and the 52 remote communities served by IES use diesel generation as their primary electricity source. Although individual power demand of each town is small, the aggregated capacity represents a reasonable opportunity to use renewable energy (likely solar energy) to offset part of the diesel consumption.

In 2012, approximately 30 million litres of diesel was transported to remote power stations (PWC, 2012). IES is exploring renewable energy options to offset diesel fuel, transportation and storage costs. Six remote indigenous communities already have solar augmenting diesel generation with a total installed capacity of 800 kW with further sites in planning stages (Indigenous Essential Services, 2011).

There is an opportunity to work with PWC or IES to develop renewable energy projects for the remote communities they supply.

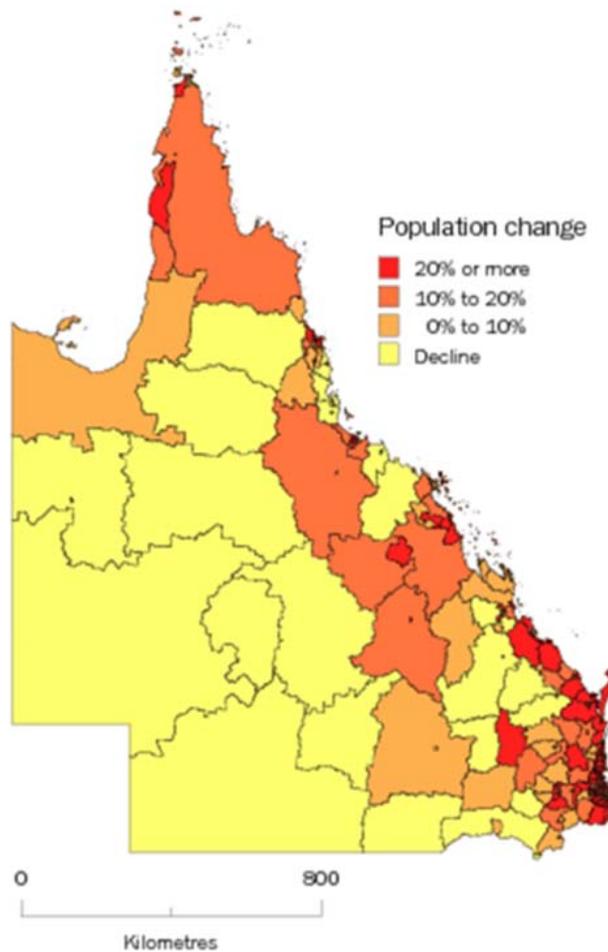
IES has an installed diesel capacity is approximately 74MW and the demand was 110GWh in 2011. In late 2009, the Green Energy Taskforce developed a roadmap for the development of renewable energy in the Northern Territory, which recommended the initial development of 10MW of solar power over three to four years to offset diesel in remote communities. In a second stage, the roadmap suggested a 100 per cent substitution of diesel generation with renewable energy and low emission fuel.

The large number of small, remote and dispersed communities managed by IES presents a number of logistical and scale challenges for renewables deployment. The cost of construction and maintenance is also exceptionally high in remote areas. As such the hybrid the systems must be robust and reliable.

7.3 Queensland

With 4.4 million people, Queensland's population grew by 23 per cent between 2001 and 2011. The majority of the population is concentrated in South East Queensland, which experienced significant growth over this period. The population increase in far North Queensland and Mackay was primarily driven by the development of the mining industry in these areas. Except for the Far North Queensland region, most of regional Queensland experienced a decrease in population over the ten years to 2011.

Figure 29 Population change in Queensland between 2001 and 2011



Source: (ABS, 2011)

7.3.1 Remote communities

Ergon Energy designs, installs, owns and operates power systems in 33 remote communities across the state of Queensland (see section 7.3). When developing a remote energy project, Ergon Energy is required to assess the benefits and limitations of different types of power systems. Some of the key requirements for the design of the remote station are that it must be designed as an unmanned, secure and reliable system. These remote off-grid power stations range from 165 kW to 9.55 MW installed capacity. All of Ergon Energy’s remote power stations use diesel as their primary fuel. As highlighted in Table 29, three of the power stations are augmented with renewable energy supplies including geothermal at Birdsville, wind at Thursday Island and solar at Windorah.

Table 29 Ergon Energy community asset portfolio (December 2012)

| | Number of systems by size (2011-12) | | | |
|------------------------------|-------------------------------------|---------------|----------------|---------------------|
| | 30 - 100kW | 100kW - 500kW | 500kW - 1MW | 1MW - 10MW |
| Diesel | 1 | 19 | 6 | 3 |
| Hybrid (Diesel / Solar) | | 1 (Windorah) | | 1 (Doomadgee)* |
| Hybrid (Diesel / Wind) | | | | 1 (Thursday Island) |
| Hybrid (Diesel / Geothermal) | | | 1 (Birdsville) | |
| TOTAL | 1 | 20 | 7 | 5 |

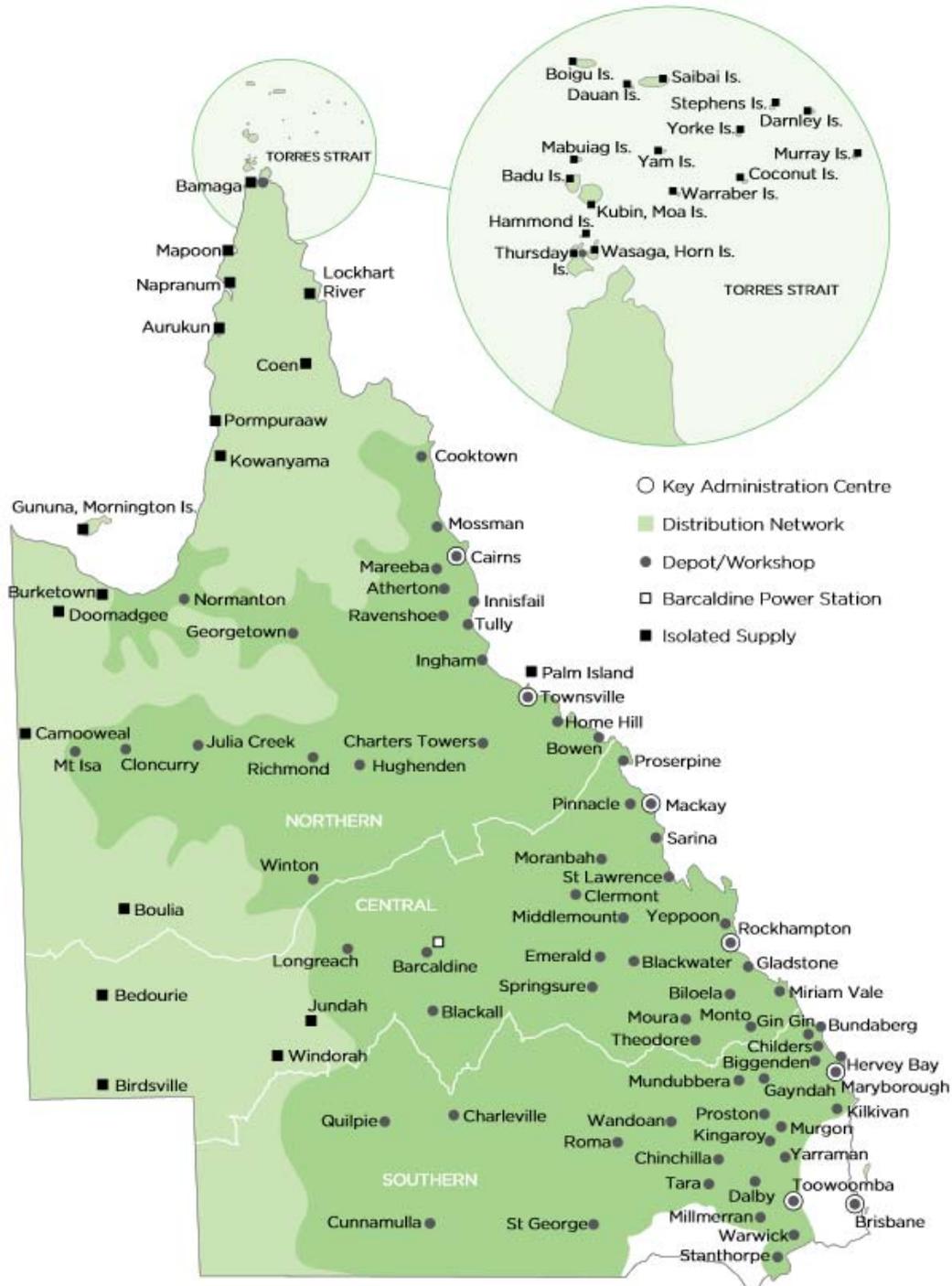
* Doomadgee Solar Farm is currently under construction and will be commissioned in 2013

Source: Ergon Energy

7.3.2 Key stakeholders

Ergon Energy is one of Queensland’s two primary electricity providers operating within the NEM (the other being Energex). Ergon Energy also owns and operates 33 remote off-grid power stations throughout western Queensland, the Gulf of Carpentaria, Cape York, Torres Strait, Palm and Mornington Islands. These remote off-grid power stations range from 165 kW to 9.55 MW installed capacity. All of Ergon Energy’s remote power stations use diesel fuel. Three of the power stations are augmented with renewable energy supplies including geothermal at Birdsville, wind at Thursday Island and solar at Windorah.

Figure 30 Ergon Energy Network



Source: (Ergon Energy, 2013)

7.3.3 Renewable Energy opportunities

Ergon Energy remote communities

There is an opportunity to work with Ergon Energy to develop renewable energy projects to offset diesel consumption in remote communities. According to Ergon Energy, small penetrations of renewable energy are already commercially viable. Ergon Energy already has a few operating renewable energy projects (described in section 7.3.4) and is currently assessing wind, solar and geothermal opportunities in a number of locations:

Birdsville New Geothermal Power Station - Ergon Energy is currently investigating options to increase the electricity production from the geothermal resource at Birdsville. It is expected that a significant part of the cost will be in the integration of geothermal system to the existing diesel system.

Thursday Island Upgrade Wind Turbines – The wind system on Thursday Island is at the end of its life. Ergon Energy has initiated a feasibility study to assess the viability of increasing the wind farm capacity.

Doomadgee solar farm stage II – Ergon Energy is assessing the option to increase the penetration of renewable energy in Doomadgee. The system would require integration and stability devices resulting in the need for additional funding to make it commercially viable.

Moa Island and Badu Island wind projects – Ergon Energy is investigating the possibility to install wind systems on the two islands, in the Torres Straits. The projects are at an early stage of their development and no wind monitoring equipment has been installed to date.

Gununa, Mornington Island and Bamaga Solar Farms – Ergon Energy is investigating the possibility to install solar systems in Gununa and Bamaga and on Mornington Island. The projects are at an early development stage.

Fringe-of-grid systems – Queensland has an extensive fringe-of-grid area with low population density and long distribution lines with large loss factors and expensive augmentation costs. There is a significant technical benefit to the fringe-of-grid systems if appropriate funding and revenue streams can be found.

The small scale, remoteness and dispersed nature of the opportunities presents a number of logistical and scale challenges for renewables deployment. The cost of construction and maintenance is also exceptionally high in remote areas. As such the hybrid the systems must be robust and reliable.

7.3.4 Case studies

Table 30 Case studies of Ergon Energy remote communities

| Windorah Solar Farm | Doomadgee Solar Farm |
|---|--|
| <p>The Windorah solar farm was installed in 2009. It consists of five 26kW solar concentrated dishes integrated to the diesel power station, which has been configured to run at low loads enabling up to 80 per cent instantaneous penetration of renewable energy. Battery storage is used to smooth the output of the solar system. The solar system supplies 17 per cent of Windorah's energy needs.</p> <p>The project is to displace 300 tons of greenhouse gas emissions by reducing the consumption of diesel by up to 100,000 litres per year (Ergon Energy, 2012).</p> <p>The project's capital cost amounted to \$4.6 million.</p> | <p>The 264kW Doomadgee solar farm is due to be commissioned in early 2013 in Doomadgee (North West Queensland).</p> <p>According to Ergon Energy, the solar plant should save around 115,000 litres of diesel each year. It will have a winter penetration of 50 per cent without storage and provide 8 per cent of the total energy needs of community.</p> <p><i>"The solar farm will also help ensure reliable supply of power during the wet season when vehicle access to the community is cut off – sometimes for up to six months – hampering diesel fuel deliveries."</i> (Ergon Energy, 2012)</p> |
| Wind at work on Thursday Island | Ergon Energy's geothermal power station |
| <p>Thursday Island has 4,000 residents and is not connected to the NEM. Ergon Energy built a \$2.5 million wind farm (450kW) integrated to the diesel generation system of Thursday Island, in the Torres Strait.</p> <p>The wind farm supplies 5 per cent to 10 per cent of the</p> | <p>Ergon Energy's geothermal project uses near-boiling water from the 1.3km deep Great Artesian Basin.</p> <p>The project is located in Birdsville, about 1,600km west of Brisbane, on the edge of the Simpson Desert.</p> <p>The project provides approximately 30 per cent of Birdsville's electricity needs and reduces diesel</p> |

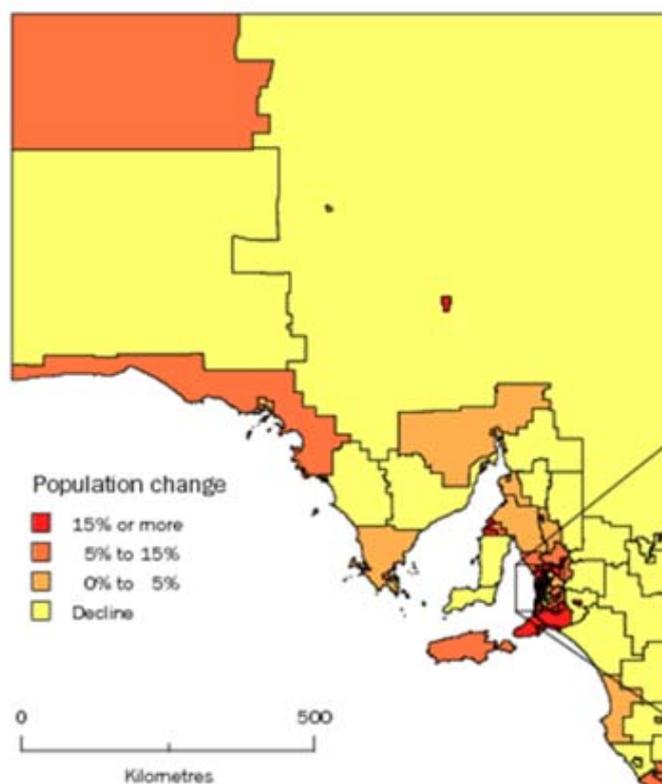
island's electricity needs and saves approximately 300,000 to 600,000 litres of diesel annually. (Ergon Energy, 2012)

consumption by 130,000 litres a year.

7.4 South Australia

The South Australian population increased by 8.4 per cent to 1.64 million in the ten years to 2011. This was the slowest growth of all states and territories and the large majority of this population growth occurred in the Adelaide region.

Figure 31 Population change in SA between 2001 and 2011



Source: (ABS, 2011)

7.4.1 Remote communities

The South Australian Government supplies electricity to remote communities in South Australia

The Indigenous communities located in the north west of the state are home to approximately 1,000 people spread over 210,000 square kilometres. The annual electricity consumption of these communities is no more than 10GWh and is supplied by three systems:

- Anangu Pitjantjatjara Yankunytjatjara – 14 communities, supplied by a 3.3MW central power station in Umuwa. The electricity is transported to the communities via a 400km 33kV line.
- Aboriginal Lands Trust, which supplies Yalta
- Maralinga Tjarutja, which supplies Oak Valley

Outside of Indigenous land, approximately 2,600 people live in 13 remote towns, which together consume approximately 15 GWh annually. Ten of the towns are serviced by the South Australian Government, who owns and operates diesel generators with a combined production of approximately 3GWh.

Independent owner-operators supply electricity to the three remaining communities, with electricity subsidies from the government.

- Andamooka – 2-3GWh pa
- Coober Pedy – 11-12GWh pa supplied by 4MW of diesel
- Yunta – 2-3GWh pa

All small domestic customers have subsidised electricity and pay no more than 10 per cent above the on-grid regulated standing contract tariff.

7.4.2 Key stakeholders

The South Australian Government runs the Remote Areas Energy Supplies Scheme (RAES), which supplies electricity to 13 remote towns and a further 16 remote Aboriginal communities and homelands. RAES' generation facilities are stand-alone diesel and LPG generators with the exception of one which is a solar-diesel hybrid system.

7.4.3 Renewable energy opportunities

South Australian Government remote communities

As in other states, there is an opportunity to deploy renewable energy to offset South Australian remote community diesel usage. There is an opportunity to amalgamate small projects through the South Australian government.

The size of the aggregated capacity would remain relatively modest but could enable considerable fuel savings.

Other diesel generation in South Australia

The Government of South Australia commissioned a study in October 2013 to map out all the diesel generators above 100kW in the state. The intention was to size the potential market for renewable energy. The information was gathered through a survey sent to a number of stakeholders. The information sought included capacity installed, number of engines installed and age of the assets. This database will provide a better understanding of the size of the market in South Australia and there are intentions to update the database in 2015.

Table 31 summarises the off-grid and mini-grid diesel generation systems in South Australia.

Table 31 Diesel generation systems in South Australia

| Diesel generation system | Number of Plant | Plant per organisation Average | Size of plant Average | Plant Size Range (kVA) | Average Generators per plant | Number of generators per plant |
|--------------------------|-----------------|--------------------------------|-----------------------|------------------------|------------------------------|--------------------------------|
| Off-grid | 49 | 1.63 | 1,389 | 0.3 – 20,000 | 1.63 | 1 – 5 |
| Mini-grid | 53 | 1 | 797 | 16 – 4,000 | 2.53 | 1 – 8 |

The database can be found in the following link:

<http://www.renewablessa.sa.gov.au/investor-information/diesel-generators-directory>

The study also conducted economic modelling of different power system configurations including:

- fuel-saving PV: where the solar is sized to provide 30 to 35% of the minimum midday demand and integrated with a continuously operating diesel plant
- primary PV: PV-battery-diesel system where the solar is sized to meet most of the total load during the day and the battery bank meeting the load during the night. The diesel generator is back-up power supply with around 10% contribution to annual load.

The conservative results based on a set of assumptions indicated that:

- for loads above 700kWh per day, the fuel-saving PV systems had the lowest lifecycle costs
- for loads up to 350kWh per day, the primary PV system had the lowest lifecycle costs

7.5 Independent remote networks

A number of community systems are ran independently from the main state Network Service Providers. Examples of these communities include: some remote islands that are managed by an independent board, outstations and

homelands that are typically run by the community itself and some independent remote communities or groups of communities. These are presented in further details in the following sections.

7.5.1 Islands

Australia has more than 8,000 islands ranging from the tropics to parts of Antarctica.

Diesel based power generation is generally the prime power supply to islands, leaving them vulnerable to volatile oil prices, expensive transportation costs and the effects of fossil fuels on the local environment (including spill risk). Many islands' economics rely heavily on tourism, and expensive electricity decreases the affordability of the island as a destination as the high electricity costs filter through to higher service costs.

The benefits of implementing renewables can include:

- reducing energy costs and increasing profitability
- attracting eco-friendly tourists willing to pay a premium for sustainable tourism experiences
- reducing air and water pollution
- increasing employment opportunities for the installation, operation and maintenance of renewable systems.

However some challenges unique to islands should be considered, such as:

- the island's long term vulnerability to climate change including sea-level rise and greater frequency of extreme weather events
- land value
- aesthetic impacts.

Case studies

Some flagship case studies demonstrating the integration of renewables on islands are described in Table 32 below. A number of islands are and have investigated the use of renewables including King Island, Lord Howe Island, Flinders Island and Rottneest Island.

This growing knowledge and experience in integrating renewables on Australian islands has potential to be applied on South Pacific islands, where a number of aid programs are focusing support on transitioning power supplies to more renewable sources such as the Tokelau Renewable Energy Project which has received funding support from New Zealand's Aid Programme.

Table 32 Case studies for integration of renewables on islands

| Island renewables | |
|-------------------|--|
| King Island | <p>The recently completed King Island Renewable Energy Integration Project (KIREIP) aims to utilise renewable energy to meet 65% of the islands energy needs. The KIREIP project integrates 390kW solar PV and 2450kW wind capacity into the 6MW diesel engine plant. (Hydro Tasmania, 2014)</p> <p>The high penetration renewables project focuses on the integration of enabling and storage technologies, including a 3MW/1.6MWh (i.e. 45 minutes storage) Ecoult UltraBattery (a lead acid battery / ultracapacitor hybrid), demand management and smart grid technology and a diesel-UPS fly-wheel. (Hydro Tasmania, 2014)</p> <p>In an earlier project, a vanadium redox battery was installed in 2003; however, it was decommissioned after encountering technical issues (Hydro Tasmania, 2014).</p> |
| Rottneest Island | <p>A wind turbine-diesel hybrid system was installed on Rottneest Island in 2004 to reduce the island's reliance on diesel. The hybrid system comprised of a 600kW wind turbine and two 320kW low load diesel generators, which were integrated into the existing diesel system. The wind turbine produces around 35% of the Islands' power needs helps save approximately 430 000 litres of diesel per year (Rottneest Island Island Authority, 2014).</p> |

7.5.1 Outstations and homelands

In Australian sub-tropical areas and in arid inland regions, cattle are bred on large stations. The Northern Territory produces over 600,000 cattle a year with a number of pastoral stations dispersed over half the Territory. The pastoral industry is the Northern Territory’s third largest GDP earner, generating over \$400 million directly into the Northern Territory’s economy (Northern Territory Cattlemen’s Association, 2009). Approximately 9,000 people live in more than 500 small, remote and dispersed communities across the Northern Territory, known as homelands or outstations. Similarly, a number of stations can be found across Queensland, South Australia and Western Australia.

Cattle outstations usually have a small electricity load supplied by diesel generators. These are not serviced by Power and Water Corporation or Indigenous Essential Services. They are delivered through a range of service and electricity providers, with financial assistance through grants from Department of Housing, Local Government and Regional Services (DHLGRS).

In 2010, the Northern Territory Cattlemen’s Association (NCTA) investigated opportunities for cattle stations to convert to renewable power. Although the findings of the project highlighted a number of challenges to make these projects cost effective, a few cattle stations have converted to renewable energy and provided positive feedback on the NTCA website. The individual systems are typically very small but, aggregated, they can represent an opportunity.

Some renewable energy projects that have been developed in the Northern Territory’s remote communities over the last few years are listed in Table 33.

Table 33 NT remote communities renewable energy examples

| Indigenous community renewable energy projects | |
|--|---|
| Gulin Gulin (Bulman) | 55kW system commissioned in November 2002 |
| Gudabijin | 4.6kW system upgrade commissioned in 2009 |
| Lajamanu | 290kW solar system (12 dishes) commissioned in 2006 |
| Yuendumu | 240kW solar system (10 dishes) commissioned in 2006 |
| Ntaria | 192kW solar system (8 dishes) commissioned in 2005 |

7.5.2 Aboriginal communities in Western Australia, not serviced by Horizon Power

A number of small, very remote communities and outstations in the Kimberly and very remote areas in the Western Desert are not serviced by Horizon Power. The Remote Area Essential Services Program (RAESP) created in 1997 is a program managed by the WA Department of Housing to support the supply of essential services (including power) to some of these communities. In 2006, thirty-four regional providers were servicing 121 communities.

A key stakeholder is the Kimberley Regional Service Providers (KRSP), which provides a range of services including maintenance, repair and capital works to communities in the Kimberley. As part of their Remote Area Essential Service Program (RAESP) contract with the WA Department of Housing, they have been working for 54 remote communities to provide capital and maintenance works on their power and water systems.

Case study - the Shire of Ngaanyatjarraku

Based on the traditional lands of Ngaanyatjarra people, the Shire of Ngaanyatjarraku is home to approximately 1,840 people, in nine communities (see Table 34). The Shire covers over 150,000 square kilometres and is arguably the most isolated in WA. Its largest community, Warburton, is over 1,500 kilometres from Perth (by road) and 750 kilometres from Alice Springs (by air). The Shire provides all essential services (including diesel-fuelled electricity supply) to its Indigenous communities.

Table 34 Communities in the Shire of Ngaanyatjarraku

| Ngaanyatjarra communities | Estimated population |
|---------------------------|----------------------|
| Warburton | 720 |
| Blackstone | 202 |

| Ngaanyatjarra communities | Estimated population |
|---------------------------|----------------------|
| Warakurna | 194 |
| Wanam | 161 |
| Jameson | 140 |
| Tjukurla | 94 |
| Patjarr | 59 |
| Tjirrkarli | 55 |
| Kanpa | 43 |

Source: (Shire of Ngaanyatjarraku, 2012)

7.6 Summary of key opportunity areas

With fast growing mining towns and over a thousand small remote communities and outstations across Australia, the community segment represents a relatively untapped renewable energy market. Most communities supply their electricity from expensive diesel fuelled power systems. Depending on remoteness and size of the community, the diesel prices to communities vary from approximately \$1.10/L to \$1.70/L after rebates. This corresponds to a fuel cost between \$300/MWh and \$450/MWh generation.

By contrast, the Levelised Cost of Electricity of solar PV in remote location such as the Pilbara can be expected to be approximately \$230/MWh³ for projects with a low penetration of renewable energy. This cost increases with higher penetration of renewable energy into the system. However, ARENA's RAR program should provide financial support to enable renewable energy systems to remain competitive, even at higher penetration levels.

The key opportunities identified in the off-grid community market are:

- islands that are not connected to mainland electricity supply.
- growing mining towns, where renewable energy projects can be developed in collaboration with mining companies and/or state owned service providers and other organisation such as the Pilbara Cities Office.
- fringe-of-grid opportunities where there are large distribution loss factors, expensive augmentation which can be addressed with embedded generation.
- aggregation of small communities through the state owned service provider – Horizon Power, Ergon, Power and Water Corporation, South Australian Government.
- Aggregation of small Aboriginal communities or outstations through regional service providers or independently.

In some cases, renewable energy also enables an increase in the reliability of the remote system. It can continue to generate power when diesel supply has been lost (e.g. due to floods, insufficient diesel storage on site, or other reasons). This is not an unusual situation in some very remote communities – a \$1.3 million project was recently completed to extend the fuel storage capacity at Maningrida (NT) to mitigate supply risks.

³ Based upon the Australian Energy Technology Assessment, BREE, 2012. This does not include costs associated with integration into an off-grid system, which increase rapidly with medium to high solar penetration.

7.7 Challenges to renewable energy in the community market

Table 35 Challenges and solutions to renewable energy in the community market

| Challenges | Solutions |
|---|---|
| <p>Small and dispersed – Apart from the major mining towns, most Australian remote communities are small, with populations sometimes less than 100 people and rarely over a couple of thousand.</p> <p>These communities are also very dispersed and remote, often located hundreds of kilometres from the closest regional town.</p> <p>The remoteness increases the cost of renewable energy projects. The small size of the renewable energy opportunities also makes them less attractive or unattractive to developers and investors.</p> | <p>The higher cost of renewable energy projects in very remote places must be balanced with the higher cost of diesel in these same places.</p> <p>The opportunities lie in aggregating a number of renewable energy project opportunities together.</p> |
| <p>Capacity constraints even in regional cities – Although many regional towns are experiencing energy load growth, much of the demand remains relatively low. A range of financial incentives have already caused an unprecedented number of renewable energy installations within some regions. In 2011, Horizon Power enforced a maximum size limitation on renewable energy systems in Exmouth, Carnarvon and Broome as a result of the fluctuations and impacts of changing renewable output affecting system stability.</p> <p>Generally many of the renewable energy opportunities in off-grid towns will be below a few megawatts in capacity due to the energy demand and system capacity constraints outlined above. For developers in this market the saturation point for renewables limits their return on investment. Also the fixed cost of establishing a remote renewable project is diluted by the smaller installations and therefore dictates developers to focus on large projects.</p> | <p>Further research is required into the reliability impacts of higher penetrations of renewables onto off-grid interconnected systems, including control systems to help network operators manage their systems more effectively and the use of energy storage devices.</p> <p>As highlighted previously stand-alone projects – even in regional towns – are unlikely to attract major developer. Aggregation of projects will likely be needed.</p> |
| <p>Land access rights - Sites where project developments are proposed need to consider who owns and occupies the land in order to gain land access rights. Without these rights, fines can be incurred.</p> | <p>Most councils or state departments will have a process for seeking and obtaining land access rights. This will need to be obtained prior to entering the site.</p> <p>Written permission to enter Aboriginal land is required by the Commonwealth.</p> |
| <p>Community acceptance – Projects in remote areas are likely to affect a community especially an Aboriginal or Torres Strait Island community. Community acceptance should not be overlooked as strong opposition can cause major delays or even lead to the project being abandoned.</p> | <p>Community consultation is an important step that needs to start at the beginning of project development and throughout the project life. Generally, experienced stakeholder consultation consultants are required.</p> <p>For Aboriginal and Torres Strait Island community consultation, this needs to be managed in a culturally respectful way with the community and generally requires an archaeologist and anthropologist with experience working with Aboriginal or Torres Strait Island communities.</p> |

| Challenges | Solutions |
|--|---|
| <p>Aboriginal Cultural Heritage – Project sites may contain Aboriginal cultural heritage sites, which are generally protected sites. If destroyed, it can lead to the Aboriginal community litigating the project owner. This can cause major delays or even lead to the project being abandoned.</p> | <p>This needs to be managed in a culturally respectful way with the community and generally requires an archaeologist and anthropologist with experience working with Aboriginal or Torres Strait Island communities. Depending on the state legislation, it may require conducting a survey to identify sites of significance, consultation, developing a management plan and permission to implement the management plan.</p> |
| <p>Capital cost – Renewable energy is capital cost intensive. The state owned Network Service Providers or Independent Power Providers who service the remote communities are often capital constraint. The large investment required is a key barrier to renewable energy.</p> | <p>Costs will naturally reduce as technologies improve (particularly in solar and energy storage technologies). ARENA and the CEFC could have a critical role in removing this barrier.</p> <p>There is a potential role for new business models such as renewable energy leasing from parties that have access to capital.</p> |
| <p>Competing subsidies – As per section 5.5.2, the Community Service Obligation places obligations on the state and territory governments to provide services at a subsidised rate to remote communities. As such, remote communities do not experience the actual cost of supplying electricity to the remote regions. It plays a critical role in ensuring adequate provision of an uncompromised essential services such as electricity to remote communities and industry. However, it also means the financial benefit of remote renewable energy projects will largely be gained by the state or territory governments and the remote community end-users have limited financial incentives to deploy renewable energy.</p> | <p>Recent consultations indicated that Power and Water Corporation, Horizon Power, Ergon Energy and the South Australian Government are all interested in cost effective renewable energy options to offset diesel in remote communities.</p> <p>ARENA could support community projects developed through the state or territory owned Network Service Providers.</p> <p>Many State Governments intend to lower the CSO contribution.</p> |
| <p>Reliability and economics – There is a significant cost premium from associated with the remoteness of these communities and their small size.</p> <p>Larger renewable energy systems enable small economies of scale. However, the higher renewable energy penetration imposes additional integration costs (control systems and storage).</p> <p>Bringing skilled labour to solve any failure of the system is disproportionately expensive in these small remote communities. Any unplanned maintenance can quickly offset all savings enabled by the renewable energy system.</p> | <p>ARENA may provide some critical financial support. It could also provide the industry an opportunity to demonstrate that small reliable and robust systems can be deployed in remote location.</p> <p>ARENA could also provide insights and learnings from funded projects that might minimise future project risk.</p> |

| Challenges | Solutions |
|---|---|
| <p>Competition by CNG, LNG and grid extension – Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG) or even grid extensions are in competition with renewable energy options. Grid extension has been considered an option for Mount Isa and the South Australian remote communities close to the NEM for example.</p> | <p>Although grid extensions may be in competition with renewable energy hybrid projects it will enable renewable resources that are largely untapped to be developed as standalone large scale renewable energy projects.</p> <p>CNG and LNG may represent a tougher competition, particularly, where the diesel engines are at the end of their life and need to be replaced. Installing a gas turbine will enable operational cost reduction while having a lower capital cost than a diesel-renewable hybrid system. However, gas prices are subject to fluctuation and renewable energy can be seen as a hedge against the risk of high gas.</p> <p>ARENA's RAR program could also enable renewable energy to be in a better position to compete against a gas alternative.</p> |
| <p>Labour costs – As highlighted above, there is a major cost premium due to the remoteness. Skilled labour costs are typically very high, particularly in mining towns.</p> | <p>The increased labour costs in remote locations should be taken into account. To prevent impacts of high labour cost, the systems must be designed to be “robust and reliable”, with remote monitoring and modularised construction which will likely compress construction schedules.</p> |

8.0 Renewable Hybrid Considerations

8.1 Financial drivers

The development of the mining industry growth in Australia has brought significant new power generation growth in remote regions of Australia. In some regions, such as the Pilbara, significant new power generation capacity is needed to meet the demand of mines and the growing population of mining towns.

The principal benefit of off-grid renewable energy is to defray the risk of increasing fuel prices. There is currently over 1.2GW of diesel generation capacity installed in remote Australia which supplies electricity to mines and communities. These costs are expected to rise over time and are vulnerable to price shock events or supply chain interruptions in international markets.

Mature renewable energy technologies (such as wind or solar PV) are already competitive with diesel in systems featuring a low penetration of renewable energy. When including the Federal Government's \$0.38/L Fuel Tax Credit, long term contracting and the buying power of a large mining company most large mine sites are likely to be paying in the vicinity of \$0.90 to \$1.10/L for diesel fuel (or \$26/GJ), while communities can pay up to \$1.70/L for diesel or more. This equates to \$240 to \$300/MWh for diesel cost only for larger mines and up to \$450/MWh for communities and smaller industrial loads (depending upon the efficiency of the diesel unit). By contrast, the Levelised Cost of Electricity of a medium size solar PV plant in remote locations such as the Pilbara is approximately \$226/MWh⁴ (without grants or rebates). Therefore, for low penetrations of solar PV, there is a genuine business case for utilising solar PV to offset diesel.

The main challenge to date is the fact that low-penetration renewable hybrid energy projects are generally too small to make a significant difference to the fuel usage. As such, most mining companies and network service operators have not found the savings worth the investment. As the penetration of renewable energy increases, additional enabling technology must be used to ensure the stability of the electricity system. These include communication and controls, storage, load management technology among others, which on average significantly increase the cost of the hybrid project. In addition, the limited experience within Australia and generally smaller project scales, typically dictate further cost premiums from the construction contractors and financiers. The RAR program is intending to support the development of a number of off-grid projects that will demonstrate the feasibility of off-grid systems and is expected to act as catalysts for future projects.

All sites will have different characteristics. In particular, the case for solar PV hybrid systems often depends largely upon the delivered cost of diesel fuel at each site – the higher the cost of diesel, the more potential to save money by integrating solar PV.

The viability of exploring renewables as a future fuel security and fuel price off-set opportunity has now become a more attractive proposition in off-grid Australia. The modular nature of many renewable technologies (such as wind and solar PV) and the cost reductions gained through recent expansion of these industries, means new opportunities are emerging for developing off-grid clean electricity sources. It was identified through industry consultations that some mining companies are currently investigating renewable energy options as a way to reduce their energy costs, while reducing exposure to fuel price fluctuation risks and reducing carbon emissions. Projects under consideration are focusing on offsetting diesel fuelled generation due to its higher relative costs when compared to gas.

In the medium to longer term, a large increase in gas prices and price volatility is expected in Australia's domestic gas markets as local producers begin to service the demands of local Asian markets through export LNG. This will likely further extend the viability of integrating renewables into gas fuelled systems, particularly as further technology cost reductions are expected and energy storage devices evolve. It provides a comparison of the costs of energy from diesel and solar PV assuming that all existing generation assets would remain on site to provide adequate reliability. As such, it is a comparison between the short run marginal cost (SRMC) of diesel and the full levelised cost of energy (LCOE) from solar PV including capital and operating costs. It shows that the cost of solar PV has become competitive with the operating cost of diesel in recent years without rebates. Although note that diesel costs and solar PV system costs vary substantially for each project.

⁴ Based upon the Australian Energy Technology Assessment, BREE, 2012. This does not include costs associated with integration into an off-grid system, which increase rapidly with medium to high solar penetration.

Figure 32 Solar PV cost comparison with diesel fuel-only costs (includes Fuel Tax Credit, excludes large consumer buying power; assumes low penetration solar systems)

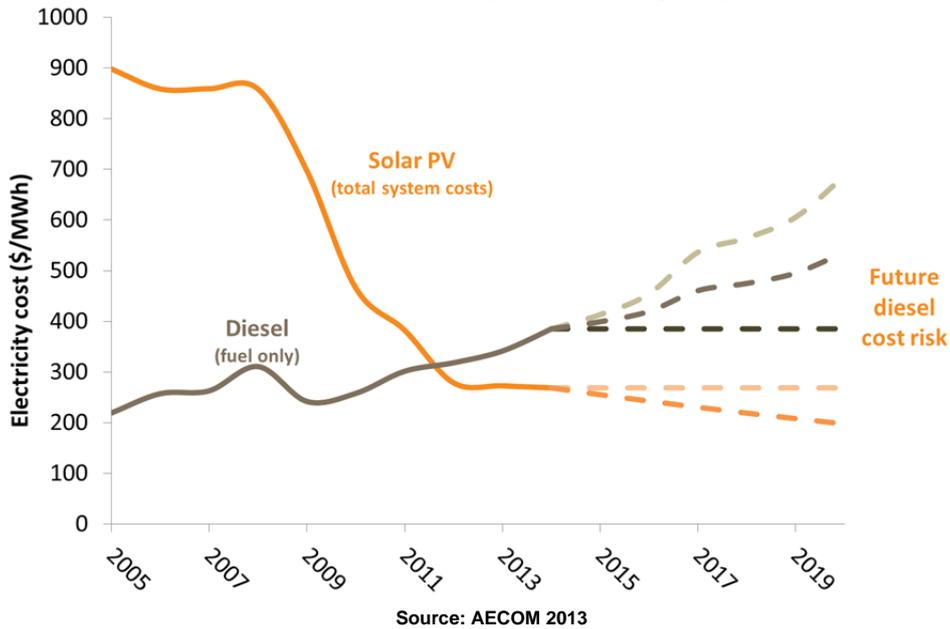


Figure 33 below provides a comparison of the cost of solar PV with diesel generation as a function of PV capital costs. For a given site, the delivered diesel price paid at the site is read on the y-axis and the expected renewable energy project life is read on the x-axis. If the project site in one of the orange areas there is a business case for the integration of renewable energy (the LCOE of renewable energy is lower than the SRMC of diesel). Whilst projects in the grey zone are unlikely to cost effectively integrate renewable energy, however they may still seek to invest in renewable integration to reduce the risk of fossil fuel price volatility and exposure to international price volatility events. Overall, it shows that in some cases there is a business case for integrating renewable energy into remote electricity systems where diesel costs are high and project lifetimes are suitably long.

Figure 33 Break-point analysis of the cost of solar PV with diesel generation, as a function of PV capital costs.

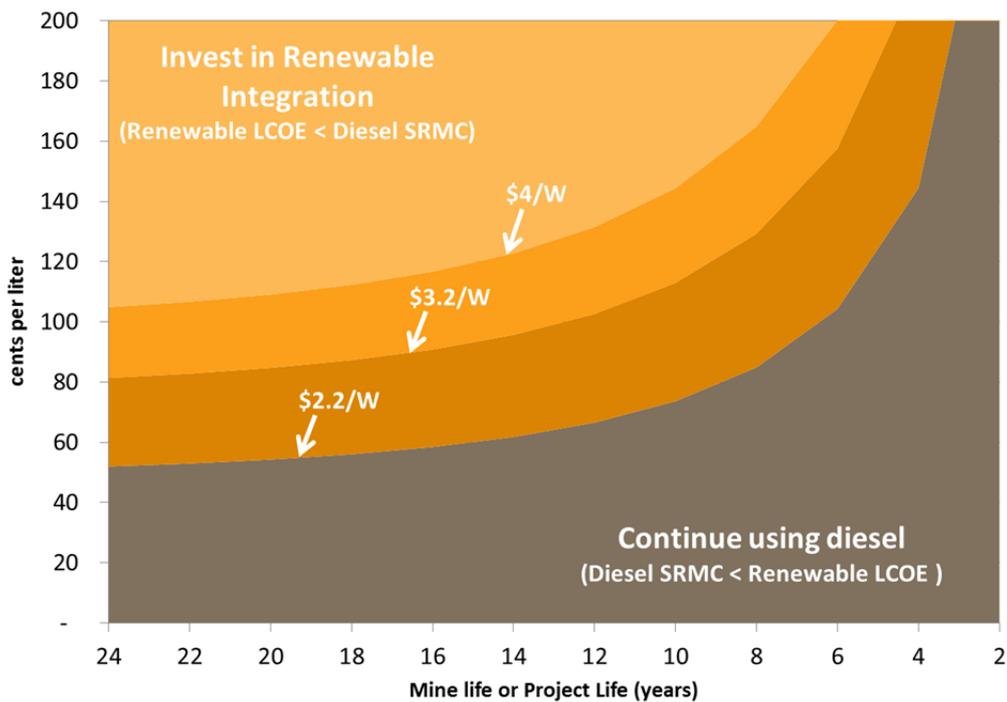


Figure 33 also presents a series of three alternative capital cost assumptions for an associated renewable energy infrastructure, represented in \$/MW. Off-grid renewable capital costs are impacted by the site location, site conditions, access to labour and construction materials and other specific opportunities and constraints.

8.2 Feasibility assessment guide

This chapter provides an overview of the technical and commercial considerations that should be addressed when conceptualising, developing and delivering a remote renewable hybrid project. It must be noted that every project is unique and developers should seek project-specific advice from independent or qualified professionals. For simplicity, either solar PV or wind is assumed as the renewable electricity generation means as these are the most common and commercially feasible technologies at the present time.

8.2.1 Existing system assessment

Before attempting to assess the feasibility of an off-grid renewable energy project and to define an appropriate concept design, it is important to understand the capabilities and limitations of the existing remote electrical system and the constraints associated with the site. All relevant information will be gathered and analysed with particular attention given to the following:

- **Load** - detailed information on the load across the electrical system will be critical. This includes load profile and load steps and the impact of potential private solar systems. This may require additional power monitoring to be installed in strategic locations within the distribution network.
- **Network configuration and parameters** - The network configuration and key network parameters (including voltage, frequency, fault currents etc.) must be well understood.
- **Existing diesel plant performance data** - Including a detailed generation output, ideally with less than one minute, time stamped generation data for the existing plant for at least 12 months.
- **Updated resource assessment data** - Wind and solar resource assessments are an important part of the technical feasibility study and will rely on the quality of the monitored data.
- **Financial information** - Detailed operation and maintenance costs for the diesel power station and network, information on electricity tariffs, equipment costs etc.
- **Site characteristics** - including topology, geotechnical information, environmental features, surroundings and shading elements (air services tower and vegetation), available land area and rooftops etc.

8.2.2 Optimisation

Once data has been reviewed, verified and summarised, an iterative optimisation process will generally be required to define a suitable concept design.

During the pre-feasibility study, optimisation tools such as HOMER and ASIM can be used (refer to section 8.3 below). Some companies have also developed their own proprietary optimisation tools (such as ABB remote optimisation model or AECOM's *CleanOpt* tool).

During the detailed feasibility study, network modelling software such as DIgSILENT, PowerFactory or PSS SINCAL are often used to analyse load flow and system stability. These software packages are not optimisation tools - they are used to confirm the ability of pre-defined concept(s) to meet certain standards or requirements. Having a complete and thorough understanding of the impacts that a project is going to have on the electricity network is a key activity in the design of off-grid renewable energy systems. The electrical engineering and analysis is usually time-consuming and can be a major hurdle to projects if not completed appropriately.

The feasibility study will typically lead to the definition of a detailed concept design and technical specifications that will include:

- Sizing of wind and/or solar systems
- Wind and solar equipment specification and configuration
- Sizing and specification of the storage system (if applicable)
- Site location options and preliminary plant layout
- Civil and structural concept design (earthworks, roads, access, foundation, mounting frames etc.)

- Electrical concept design including Single Line Diagram, cable reticulation, protection
- Network connection concept design
- Communication functional specification and concept schematic
- Renewable resource assessment and generation potential assessment
- Control and integration strategy, including diesel generation operation philosophy
- Construction schedule and other construction and commissioning considerations

Technologies used in off-grid systems are rapidly evolving. It is important to remain in contact with suppliers and use up-to-date technical and commercial information. Sub-assembly vendor categories to be considered include energy storage devices, wind turbines, control systems, solar panels, inverters and transformers.

As part of the optimisation process, a number of “enablers” can be considered such as energy storage devices, controllers, roll-out of smart meters or other demand management solutions designed to improve the concept design (refer to section 8.4).

In addition, ARENA aims to provide tools for industry to streamline their business case development and provide access to research and development groups to enable companies to stay up-to-date with the latest technology development.

8.3 Hybrid assessment tools

Table 36 Commonly used hybrid assessment tools

| Tool | Description |
|-------|--|
| HOMER | <p>HOMER is a software package initially developed by the US National Renewable Energy Laboratory (NREL). HOMER is normally used during pre-feasibility studies to model both the technical and financial factors in an off-grid renewable energy project.</p> <p>The software is used to model different micro-grid concepts, which can include system components chosen from HOMER’s database or defined by the user, these include:</p> <ul style="list-style-type: none"> - <u>Renewable energy components</u>: Solar photovoltaic (PV), wind turbine, run-of-river hydro power, biomass power fuel cell. - <u>Thermal generation components</u>: diesel generator, gasoline generator, biogas generator, alternative and custom fuels generator, co-fired generator, electric utility grid, microturbine - <u>Storage</u>: flywheels, battery bank, flow batteries, hydrogen <p>The load must be defined as a daily profile (hourly) with potential seasonal variations. Deferrable load (such as water pumping or refrigeration), thermal loads and energy efficiency measures can also be modelled.</p> <p>During the simulation, HOMER performs energy balance calculations for each configuration that has been pre-defined by the user. It compares the load (electric and thermal) to the supply from each of the generation component (renewable and thermal) and decides how the storage should be used (charge, discharge or neutral). The cost of each option is assessed and options are ranked according to the financial merit.</p> |
| ASIM | <p>ASIM is an excel-based modelling tool developed by Power and Water Corporation with funding support from ARENA. It simulates mini-grid renewable/diesel power system operations on a one second basis to help analyse the technical and financial performance of a hybrid system. The one second analysis helps detect system stability issues (e.g. station blackouts) and other transient behaviour.</p> <p>ASIM is composed of two components (excel spreadsheets and a C# power system model). This enables the user to analyse and interpret the modelling results within the spreadsheet. Since ASIM is open source, users will be able to modify the control algorithms to simulate their particular system, which will improve the accuracy of the results.</p> |

| Tool | Description |
|------------------------|---|
| | ASIM's functionality enables optimisation of system sizing (including PV size and spinning reserve requirements) and whole of life financial analysis PV/diesel hybrid systems. |
| PVSyst | <p>PVSyst is a solar simulation software developed at the University of Geneva (Switzerland), and widely used by the solar PV industry.</p> <p>The software is able to support the design and yield assessment of a grid connected or an off-grid solar plant. Most parameters can be tailored to the project, which means that the software can be used for preliminary or detailed analysis. The assessment involves the choice of meteorological data, the definition of the system design, shading studies and losses assessment.</p> <p>The analysis is based on a detailed hourly simulation of an average year, although an estimate of different probabilities of exceedance is possible (from P50 to P99).</p> <p>The project financials can also be modelled within PVSyst. However, detailed financial analysis is generally conducted in a separate model that uses PVSyst output yield estimates as one of the key inputs.</p> |
| Other assessment tools | Other software packages exist that can be used for the assessment and design of off-grid generation systems. These include solar modelling software packages such as PV-Design Pro, PV*Sol; general system simulators such as MATLAB or Simulink; network simulation software such as PowerFactory and PSS/E; and wind software such as WAsP or Windfarmer and others. |

8.4 Enabling Technologies

As the penetration of renewable energy increases, additional enabling technologies must be used to ensure the stability of the electricity system. These include communication and controls, energy storage, load management, among others. These technologies on average will significantly increase the cost of the project; however they can also enable a larger reduction in fuel use than would otherwise be possible. Additionally, due to their innovative nature, use of these technologies will usually require some government support or other incentives such as ARENA's RAR program.

8.4.1 Energy storage

There are three broad energy storage configurations that could be considered prior to developing the concept design. These configurations are generally described in Table 37 below:

Table 37 Overview of energy storage configurations with indicative performance factors

| Energy Storage Configuration | Description | Indicative max. instantaneous renewable penetration | Approximate reduction in fuel consumption |
|------------------------------|---|---|---|
| Long-term storage | Energy storage for load shifting | Greater than 50% | 10% to 100% |
| Short-term storage | Short-term power delivery for power quality | 30% to 50% | 5% to 15% |
| No storage | | Less than 30% | 0% to 10% |

Source: AECOM

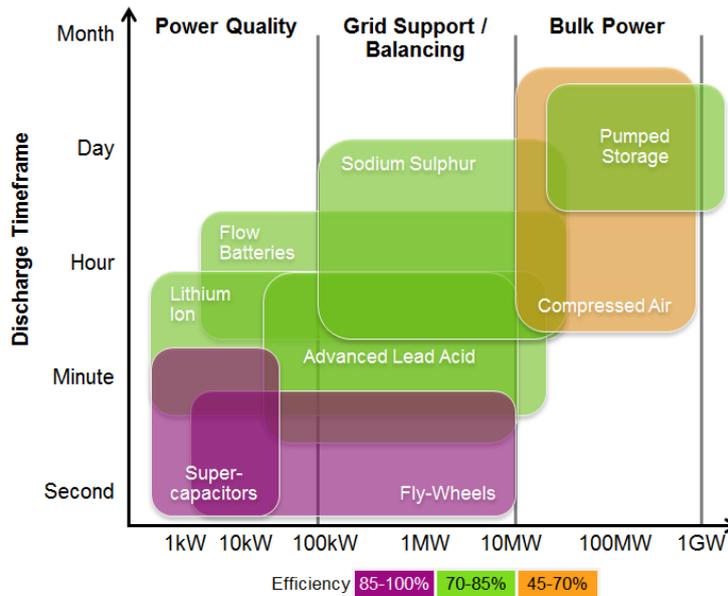
Note that the maximum instantaneous renewable penetration shown in Table 37 are subject to a number of variables such as system size, reliability standards, spinning reserve, generation technology and more. Similarly, the fuel reduction percentage is approximate and will depend on factors such as the load shape, renewable resource and generation profile.

The choice of storage configuration significantly impacts the amount of variable renewable generation that can be installed in the power system as well as the concept design and economics of the overall project. Energy storage

is very expensive, so the benefits of economies of scale reduce as additional enabling technologies are required to achieve higher penetrations.

The penetration level and operating philosophy of the energy storage also impacts the technology selection. There are a number of different energy storage technologies, from batteries and capacitors to mechanical storage such as fly wheels or pumped hydro. Figure 34 below provides a brief overview of the applicability of some energy storage technologies.

Figure 34 Suitability of different energy storage technologies for grid-scale applications



Source: AECOM

8.4.2 Diesel generator performance

The technical characteristics of the diesel engine-generator (“genset”) affect the permissible penetration levels of variable generation. Some of these characteristics are described in Table 38.

Table 38 Diesel genset characteristics

| Genset Characteristic | Description |
|-----------------------|--|
| Low-load restrictions | At low loads, diesel gensets’ operating costs increase significantly through both reduced fuel efficiency and increased maintenance costs. In addition, diesel genset manufacturers typically provide limits on the minimum output of approximately 30 per cent of the rated capacity, as well as the length of time it can operate at low loads. Gensets with better low load performance are better suited to hybridisation projects as they allow higher penetrations of variable generation. |
| Step load | A genset’s maximum step load capability affects the system’s ability to respond to sudden large increases in load. This may be caused by a large reduction in the renewable power plant’s output. |
| Ramp rate | Similar to step load, a genset’s maximum permissible ramp rate affects the system’s ability to respond to large increases in load (over a longer period of time than step-loads). |

Most remote hybridisation projects will be seeking to integrate renewables into existing diesel fuelled generation, where the performance characteristics of the plants are already set. However, parties considering hybrid plants should investigate the performance of diesel gensets when purchasing new generation plant (i.e. for new loads and replacement of existing gensets) to facilitate higher penetrations of renewables.

8.4.3 Cloud tracking

Fully automated cloud monitoring systems under development, can be used in conjunction with the power system's controls to allow short term forecasting of solar PV generation. Once commercially proven these systems will allow higher penetration of solar generation without requiring additional energy storage backup or excessive "spinning reserve".

In theory the control system will suitably adjust the intermittency level of the solar array depending on the forecast cloud cover. Cloud Tracking Software commonly utilise cameras to observe the cloud patterns in the sky. Taking into account other factors such as the sun trajectory and the location of the solar array, the software then analyses the data to profile likely shading events caused by cloud cover.

While largely untested, Cloud Tracking Software is a promising method of providing relative cheap intelligence to the control system to help enable higher penetrations of renewables and reduce the energy storage required to cover the intermittency of solar generation.

8.4.4 Demand management

Demand Management is another cost effective way of reducing the energy storage reserves required to cover the variability of solar generation. However, it is highly dependent on the availability of curtailable loads on the off-grid network. Curtailable loads are power consuming processes which can be decreased (curtailed) at a moment's notice by the hybrid controls system.

When determining the potential to implement demand management, it can be useful to categorise some of the largest loads as critical or non-critical. Within the non-critical category, there will be significant variation. For example, some loads may be curtailable for short periods only (minutes or seconds), while others may be curtailable for longer periods (hours). It is also important to consider whether loads can be fully or only-partly curtailed.

Some examples of curtailable loads include: chillers, heaters, water pumps and non-critical production processes.

8.4.5 Control systems

The hybrid control system will integrate the diesel genset operation with the renewable generation and other enabling technologies (demand management, energy storage etc.) into a control philosophy that seeks to meet the constraints of the Grid Code (i.e. power quality and reliability), while minimising operation costs.

Defining the overall control philosophy is a complex task that should consider the following:

- Existing control system information
- Load stepping and ramp-rate procedures
- Existing operating reserves
- Energy storage state of charge and operation limitations
- Remote control functionality
- Load shedding arrangements (i.e. automatic or manual and speed of)
- Grid operation requirement
- 'Grid code' requirements
- Power station and load monitoring structure
- Other intelligence (e.g. operational patterns such as worker shifts, cloud tracking etc.)

8.5 Common hybrid risks

The following table highlights some of the key considerations and risks encountered in an off-grid hybrid system. A developing risk analysis should be conducted at the beginning of the project and updated on a regular basis.

Table 39 Common hybrid risks

| Key risk area | Suggested mitigation approach |
|--|---|
| <p>Renewable Integration As the penetration of renewable energy increases, the variability of generation can cause electrical stability issues, if not configured correctly.</p> <p>Also there remains a risk of operating the existing diesel plant at low loads which can affect its efficiency as well as the maintenance costs through commonly seen issues such as bore glazing.</p> | <ul style="list-style-type: none"> - A number of technologies and operation methodologies can be used including storage, demand management, curtailment of the renewable energy generation, maintaining spinning reserve etc. The difficulty lies in defining the optimal balance between all these solutions - A strong concept and detailed designs are required to ensure that these risks are engineered out. - In all cases, the reduced efficiency of the diesel generator, impact of curtailment, storage efficiency, impact of demand management etc. must be accounted for during the feasibility study and the final design. |
| <p>Battery Integration Battery technology can store the excess renewable energy and discharge it when needed to avoid dispatching fuel fired generators. It can also help maintain the stability of the electricity system. However, integrating batteries can be costly and complex. Many of the technologies on offer in the market lack proven longevity and it can be difficult to obtain detailed up-to-date technical or commercial information from suppliers.</p> | <ul style="list-style-type: none"> - Explore the use of alternative hybrid renewable integration options either in addition or separate to the battery energy storage system. This should include a closer investigation of the demand management options already considered and also complementary hybrid enabling technologies such as fly wheels, resistor banks or diesel UPS. |
| <p>Faulty equipment delivered to site Due to the remoteness of the off-grid sites, the delivery of faulty equipment can result in significant delays and cost overrun.</p> | <ul style="list-style-type: none"> - Early engagement with suppliers to review and agree quality assurance procedures (i.e. Factory Acceptance Tests) will help mitigate this risk. Products and suppliers must be carefully selected based on track record, technical capability and commercial credibility. - Review and verification of supplier test reports and certificates prior to leaving the factory. |
| <p>Site constraints The site may present a number of constraints including: topology, shading from vegetation, planning and approval restriction, distance to the connection point, dusts, noise restriction, visual impact etc.</p> | <ul style="list-style-type: none"> - A site investigation is critical to identify the constraints and take them into account during the definition and the optimisation of the plant design. |
| <p>Community acceptance Community acceptance should not be overlooked as strong opposition can cause major delay or even lead to the project being abandoned.</p> | <ul style="list-style-type: none"> - Early and ongoing consultation is essential to ensure that all stakeholders feel involved and informed about the project |
| <p>Resource dataset Many remote sites do not have a reliable weather dataset in close proximity to the proposed site that can be historically or statistically referenced as a reliable basis for future forecasting.</p> | <ul style="list-style-type: none"> - Understanding of financier's requirements regarding resource reliability will be essential to ensure finance can be obtained. - Onsite solar and/ or wind measurement can prove necessary, in which case the measurement campaign should start early to avoid delaying the project |

8.6 Project procurement – contracting strategy options

There are multiple options to consider when selecting the project procurement approach, each with their own advantages, risks and coordination challenges. Some of the factors that will need to be considered by the project host in selecting the project procurement strategy are:

- Risk appetite, capability and resources available for the project on-site and the level of involvement in the project management, construction, commissioning and transport logistics of each package
- Quality control and management of defects during construction and beyond the defects liability period
- Time schedule, particularly supporting studies such as environmental and renewable resource monitoring which may impact on the scope of works
- Interfaces between the various work packages and the risk of suppliers or contractors discharging responsibilities
- Desired level of involvement and control in the negotiation of supply contracts from the major components in each work package (the ability to ensure that warranty, performance conditions and spares to adequately cover the operation and maintenance of the facility in the future varies)
- Costs of each of the elements of the project including equipment, labour, logistics and spares etc.
- Existing IPP integration

The advantages and disadvantages of some of the most common procurement strategies are summarised in Table 40.

Table 40 Contracting strategy options

| Option | Contract Structure | Advantages | Disadvantages |
|--|---|--|--|
| Engineer, Procure, Construction Management (EPCM) | Single EPCM Contractor who tenders and manages separate supply contracts for different work packages (e.g. civil, electrical, equipment procurement etc.) | <ul style="list-style-type: none"> - EPCM Contractor acts on behalf of the project owner or host and takes responsibility for construction management and supervision. - Limits the development and construction costs as the EPCM would generally be engaged to do all upfront design studies and contract/construction management. - Less up front specification work, which can enable projects to be fast-tracked. Popular contracting structure in the mining industry during the mining boom due to benefits of early completion outweighing additional costs/risks. - Greater control over specific equipment selected. - Greater flexibility than EPC i.e. contract packages can be more easily modified to suit outcomes of environmental studies. | <ul style="list-style-type: none"> - All performance, cost and schedule risks are transferred to the project owner. The EPCM Contractor helps to manage risk but generally doesn't take system performance risk. Generally seen as higher risk than EPC and Multi-Contract. - Project owners will need to allow contingency for the unknown procurement and construction risks. - Additional integration complexity due to multiple contracts. |
| Engineer, Procure, Construct (EPC) | Single fixed price EPC contract for the full project | <ul style="list-style-type: none"> - Fixed price lump sum contract and hence costs are easier to manage / forecast. - Single contractor responsible for system integration, interfaces and the performance of all of its components. - Risk of performance, interface, delivery and costs are borne by one single EPC Contractor therefore a lower risk for the project owner. - The predominant delivery structure applied to power projects globally for the last 20 years. | <ul style="list-style-type: none"> - There may be limited scope for the project owner's staff to learn about the system during the construction phase. - May lack flexibility/control in respect to project staging, sub-contractor selection, equipment selection and technical design. - More up-front design and specification work required by the Project Owner. - Both contractor and project owner will need to allow contingency for the unknown procurement and construction risks. - Novation of warranties and supply agreements can be problematic – the owner may not negotiate directly with suppliers. |

| Option | Contract Structure | Advantages | Disadvantages |
|---|--|---|---|
| Multi-Contract (EPC + Supply) | This is a typical hybrid contract approach whereby there is a main EPC package and one or more supply only contracts. E.g. the owner might select an inverter and PV technology and have supply contracts with the manufacturers. The EPC would then construct using these products. | <ul style="list-style-type: none"> - Less risk than EPCM option for the project owner. - Multiple fixed price lump contracts and likely cost saving over EPC and EPCM strategy. - Ability to generate greater competition for subcontracts. - Provides greater opportunity for the project owner to be actively involved in equipment selection and integration of the project into the existing infrastructure. - Greater flexibility than EPC i.e. contract packages can be more easily modified to suit outcomes of environmental studies (i.e. wind and bird monitoring). - Ability to efficiently utilise the project owner's capability and costs by integrating supply only contracts or work packages that have limited interfaces - Increased flexibility over single EPC while still having an EPC contractor 'on the hook' for the key project performance risks. | <ul style="list-style-type: none"> - More than in EPC option. - Undefined interfaces and project definition can create delays and possible variations. - Greater contracting, cost and construction coordination and management required by project owner. Greater number of supply contracts to be negotiated and managed. - Extent of supply only contracts will be limited by the project owner's resources and capability to integrate the equipment. |
| Build Own Operate (BOO) + Power Purchase Agreement (PPA) | An Independent Power Producer (IPP) will build, own and operate the power plant based on a guaranteed purchaser of the plant's output (through the terms and conditions of a PPA). | <ul style="list-style-type: none"> - Very little CAPEX for the project owner (paid for by the IPP) - Single contract (i.e. PPA) - Single party responsible for system integration, interfaces and the long term performance of all of its components. - Risk of performance, interface, delivery and costs are borne by IPP. - This option is common delivery model used by remote mine sites for their power supply and management. | <ul style="list-style-type: none"> - Reduced control of operation of plant - Difficult to integrate new power generation projects with existing PPAs due to take-or-pay arrangements (or similar) - Can be difficult to include load curtailment and energy storage operating procedures in the PPA - Project owner has reduced control on operating practices of power plant, which can restrict future improvements to operating procedures |

9.0 Bibliography

- ABARE & Geoscience Australia. (2010). *Australian Energy Resource Assessment*.
- ABB. (2012). *Case Study - Coral Bay wind/diesel/PowerStore - Western Australia*.
- ABS. (2011). *ABS Regional Population growth Australia 2011*. Retrieved from ABS: <http://www.abs.gov.au/ausstats/abs@.nsf/Previousproducts/3218.0Main%20Features22011?opendocument&tabname=Summary&prodno=3218.0&issue=2011&num=&view=>
- ABS. (2011). *Regional Population Growth, Australia, 2011*.
- ABS. (2013). *ABS Census of Population and Housing*. Retrieved 10 8, 2014, from <http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4102.0Main+Features10April+2013>
- ABS. (2013). *ABS2011*. Retrieved from Regional Population Growth, Australia, 2012-13: <http://www.abs.gov.au/ausstats/abs@.nsf/Products/3218.0~2012-13~Main+Features~Main+Features?OpenDocument#PARALINK3>
- AEMC. (2012). *Possible Future Retail Electricity Price Movements: 1 July 2011 to 30 June 2014*. Retrieved from <http://www.aemc.gov.au/market-reviews/completed/possible-future-retail-electricity-price-movements-1-july-2011-to-30-june-2014.html>
- AEMC. (2013). *2013 Residential Electricity Price Trends*.
- AEMO. (2010, July). *AEMO Corporate*. Retrieved March 30, 2013, from Introduction to Australia's National Electricity Market: www.aemo.com.au/corporate/0000-0262.pdf
- AEMO. (2012). *Energy Statement of Opportunities*.
- AEMO. (2013). *Distribution loss factors the financial year 2013 2014*.
- AEMO. (2013). *Regional Boundaries and Marginal Loss Factors the 2013-14 Financial Year*.
- AEMO. (2014). *Electricity Statement of Opportunities*.
- AER. (2013). *State of the energy market 2013*.
- AGEA, A. G. (2011). *Australian Projects Overview*. Retrieved April 4, 2013, from <http://www.agea.org.au/geothermal-energy/australian-projects-overview/>
- AquaGen, T. (n.d.). *Lorne Pier Demonstration Unit*. Retrieved April 1, 2013, from <http://www.aquagen.com.au/projects/lorne-pier-demonstration>
- ARENA, A. R. (2013). *About ARENA*. Retrieved April 2, 2013, from ARENA.gov.au: <http://www.arena.gov.au/about/index.html>
- Army Technology. (2010, 2 26). *Casualty Costs of Fuel and Water Resupply Convoys in Afghanistan and Iraq*. Retrieved 10 2, 2014, from Army Technology: <http://www.army-technology.com/features/feature77200>
- Austrade. (2013). *Mining and Resources*. Retrieved April 29, 2013, from <http://www.austrade.gov.au/Invest/Opportunities-by-Sector/Resources>
- Austrade. (2014). *Investment opportunities in Australian resources and energy*. Retrieved 09 2014, from Austrade.
- Australian Energy Resource Assessment. (2010). *Australian Energy Resource Assessment*.
- Australian Government (c). (2009). *Geothermal energy gets a \$35M boost*. Retrieved April 4, 2013, from [http://minister.ret.gov.au/MediaCentre/MediaReleases/Pages/GeothermalEnergyGetsa\\$35MBoost.aspx](http://minister.ret.gov.au/MediaCentre/MediaReleases/Pages/GeothermalEnergyGetsa$35MBoost.aspx)
- Australian Government. (2014). *Part 2: Expense Measures (continued)*. Retrieved 11 6, 2014, from Budget 2014-15: http://www.budget.gov.au/2014-15/content/bp2/html/bp2_expense-11.htm
- Australian Institute of Energy. (n.d.). *Fact Sheet 10: Tidal Energy*.
- Baker. (1991). *Tidal Power*.

- Behre Dolbear Group. (2012). *2012 Ranking of countries for mining investment where 'not to invest'*. Chicago: Behre Dolbear Group.
- Bloomberg. (2012, December 4). Diamonds dug in gusty Arctic too remote for diesel fuel.
- BOM, B. o. (2012). *Average Daily Solar Exposure*. Retrieved March 27, 2013, from http://www.bom.gov.au/jsp/ncc/climate_averages/solar-exposure/index.jsp
- BREE (a). (2013). *Beyond the NEM and the SWIS: 2011-12 regional and remote electricity in Australia*. Canberra: Commonwealth of Australia.
- BREE. (2011). *Australian Energy Projections to 2034-35*. Bureau of Resources and Energy Economics (BREE).
- BREE. (2012). *Economic Analysis of End-use Energy Intensity in Australia*. Canberra: BREE, Bureau of Resources and Energy Economics.
- BREE. (2013). *Australian Energy Technology Assessment*. Retrieved from <http://www.bree.gov.au/documents/presentations/AETA-31July.ppt> and http://www.bree.gov.au/documents/publications/aeta/Australian_Energy_Technology_Assessment.pdf
- BREE. (2013). *Australian Energy Technology Assessment*. Retrieved from <http://www.bree.gov.au/documents/presentations/AETA-31July.ppt> and http://www.bree.gov.au/documents/publications/aeta/Australian_Energy_Technology_Assessment.pdf
- BREE. (2013). *Energy in Australia* .
- BREE. (2013). *Resources and Energy Major Projects*.
- BREE. (2013). *Ressource and Energy Major Projects - April 2013 listing*. Canberra: Australian Bureau of Agricultural and Resource Economics and Sciences.
- BREE. (2014). *Resources and Energy Major Projects*.
- Cairns and Far North Environment Centre. (2011). *Renewable Energy for Far North Queensland: A Discussion Paper*.
- CBD, C. B. (2013). *CBD Home*. Retrieved April 2, 2013, from [cbd.gov.au](http://www.cbd.gov.au): <http://www.cbd.gov.au>
- CEC (a), C. E. (2011, October). *Review of the Australian bioenergy industry 2011*. Retrieved April 20, 2013, from <http://www.cleanenergycouncil.org.au/technologies/bioenergy.html>
- CEC (d), C. E. (2008, September). *Australian Bioenergy Roadmap*. Retrieved March 27, 2013, from <http://www.google.com.au/url?sa=t&rct=j&q=potential%20for%20stationary%20bioenergy%20generation%20in%20australia&source=web&cd=1&cad=rja&ved=0CD8QFjAA&url=http%3A%2F%2Fwww.cleanenergycouncil.org.au%2Fdms%2Fcec%2Findustrydevelopment%2Fbioenergy%2F01-Austra>
- CEC, C. E. (2011). *Clean Energy Australia report 2011*. Retrieved March 27, 2013, from <http://www.google.com.au/url?sa=t&rct=j&q=clean%20energy%20report%202011&source=web&cd=1&cad=rja&ved=0CDIQFjAA&url=http%3A%2F%2Fwww.cleanenergycouncil.org.au%2Fdms%2Fcec%2Freports%2F2011%2FClean-Energy-Australia-Report-2011%2FClean%2520Energy%2520Australi>
- Clean Energy Council. (n.d.).
- Clean Energy Council. (2013). *Clean Energy Australia*.
- CME, T. C. (2013). *State Growth Outlook 2013*. Retrieved September 30, 2014, from <http://www.cmewa.com/UserDir/CMEPublications/2013%20State%20Growth%20Outlook446.pdf>
- CRCORE, C. R. (n.d.). *Challenges for industry*. Retrieved May 9, 2013, from <http://www.crcore.org.au/ind-challenge.html>
- CSIRO. (2012). *Ocean renewable energy: 2015-2050*. Retrieved from http://www.google.com.au/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&cad=rja&ved=0CDAQFjAA&url=http%3A%2F%2Fwww.csiro.au%2F~%2FMedia%2F4CD2D0753A9D424DAF1970E6652C2767.ashx&ei=Kx-bUdydBISZiAeo5oCQDQ&usq=AFQjCNFEo2OSx1NITDhhZN_JHdiFm0MhZQ&sig2=b80E-4mUX

- Department of Climate Change and Energy Efficiency. (2013). *DCCEE A-Z of Government Programs and Initiatives*. Retrieved March 30, 2013, from ClimateChange.gov.au: www.climatechange.gov.au/government.initiatives/renewable-target/need-ret.aspx
- Department of Energy. (2014). *National greenhouse account factors 2014*.
- Department of Families, Housing, Community Services and Indigenous Affairs. (2013). *A clean Future for remote indigenous communities*. Retrieved from <http://jennymacklin.fahcsia.gov.au/node/1194>
- Department of Families, Housing, Community Services and Indigenous Affairs. (2013). *Remote Indigenous Energy Program*. Retrieved April 2, 2013, from Fahcsia.gov.au: <http://www.fahcsia.gov.au/our-responsibilities/indigenous-australians/publications-articles/housing/remote-indigenous-energy-program>
- Department of Industry. (2013, December 17). *Energy White Paper Overview*. Retrieved September 22, 2014, from <http://ewp.industry.gov.au/pages/overview>
- Ecogeneration. (2008). *Coral Bay Wind-Diesel Power System*.
- Ecogeneration. (2011). *Hydroelectricity Generation in Australia*.
- Ecogeneration. (2011). *Hydroelectricity Generation in Australia*.
- EDL. (2012). *Energy Developments Ltd annual report*.
- Energy Matters*. (n.d.). Retrieved from Solar bore and surface water pumping: <http://www.energymatters.com.au/renewable-energy/solar-power/pumping/>
- EnergyAction. (2012). *Energy Action*. Retrieved March 30, 2013, from NEM vs. SWIS - A system comparison: www.energyaction.com.au/new-swis-comparison.html
- Entura, Hydro Tasmania. (2010). *Clean Energy Council Industry Report - Improving Off-Grid Renewable Energy Opportunities*. Cambridge, Tasmania: Entura.
- EPRI. (2010). *Electrical Energy Storage Technology Options*. Palo Alto.
- Ergon Energy. (2012). *Ergon Energy website*. Retrieved from Ergon Energy: www.ergon.com.au
- Ergon Energy. (2013). *Ergon Energy 2012-13 annual report*.
- Ergon Energy. (2013). *Ergon Energy Annual Stakeholder Report 2012-13*.
- Ergon Energy. (2014). *Demand Management Plan 2013-14*.
- Ernst and Young. (2014). *Renewable Energy Country Attractiveness Index*.
- Evans & Peck. (2011). *Assessment of the potential for renewable energy projects and systems in the Pilbara*.
- FrankfurtSchool. (2012). *Global Trends in Renewable Energy Investment 2012*. Retrieved March 27, 2013, from <http://fs-unep-centre.org/publications/global-trends-renewable-energy-investment-2012>
- Galaxy Resources. (2013). *Mt Cattlin*. Retrieved May 9, 2013, from http://www.galaxyresources.com.au/pro_raven_mt_cattlin.shtml
- Geoscience . (2012). *Geoscience Australia Major Powerstation's Database*.
- Geoscience Australia. (2012, June 18). *Minerals Basics*. Retrieved April 29, 2013, from <http://www.ga.gov.au/minerals/basics.html>
- GeoscienceAustralia. (2010). *Australian Energy Resource Assessment*. Retrieved March 27, 2013, from http://adl.brs.gov.au/data/warehouse/pe_aera_d9aae_002/aera.pdf
- Government of Western Australia Department of Aboriginal Affairs. (2013). *Western Australia Aboriginal Communities Map*. Retrieved from www.daa.wa.gov.au/Documents/Maps/Maps%20May%202013/State_Mappack.pdf
- GovtSA, G. o. (2014). *Renewables SA Diesel Generators Directory*. Retrieved September 30, 2014, from http://diesel.renewablesa.sa.gov.au/diesel_generators/search_action?grid=2&size=8&usage=1
- Green Energy Task Force. (2011). *Roadmap to Renewable and low emission energy in remote communities*. Northern Territory Government.

- (2010). *Green Telecom Networks*. Pike Research.
- Hemer, M. A., & Griffin, D. (2010). The wave energy resource along Australia's Southern margin. *Journal of Renewable and Sustainable Energy* 2, 15.
- Horizon Power. (2009). *Joint Western Power and Horizon Power White Paper Submission*.
- Horizon Power. (2012). *Horizon Power annual report*.
- Horizon Power. (2012). *Horizon Power Asset Investment Program*.
- Horizon Power. (2012). *New state-of-the-art solar hybrid power stations for Marble Bar and Nullagine*.
- Horizon Power. (2012-13). *Horizon Power operational report*.
- Horizon Power. (2013). *Annual Report 2012/13*.
- Horizon Power. (2014). *Annual Report 2013/14*.
- Horizon Power. (2014, 01). *On the Horizon (news letter)*. Retrieved 09 2014, from www.horizonpower.com.au/documents/1921725_28n_d02_.PDF
- Hydro Tasmania. (2014). *Project Information*. Retrieved 10 2, 2014, from King Island Renewable Energy Integration Project: <http://www.kingislandrenewableenergy.com.au/project-information/overview>
- IEA. (2010). *Marine Energy - Energy Technology analysis programme*.
- IEA. (2012). *World Energy Outlook*.
- IMO. (2014). *SWIS Electricity Demand Outlook*.
- IMO WA. (2014). *SWIS Electricity Demand Outlook*.
- Indigenous Essential Services. (2011). *Annual Report 2011*.
- Intelligent Grid Research Cluster. (2011). *Think small - The decentralised energy roadmap*.
- International Energy Agency. (2010). *Energy Technology Network – Hydropower*.
- MCE. (2008). *Community Service Obligations, National Framework*. Ministerial Council on Energy.
- NFEE. (2004). *Energy Efficiency Improvement Potential Case Studies – Industrial Sector, March 2004*. Report prepared by Energetics for SEAV.
- Northern Territory Cattlemen's Association. (2009). *About the NT Cattlemen's Association*. Retrieved 10 2, 2014, from http://ntca.org.au/our_association/index.html
- Northern Territory Government. (2011). *An evaluation of the relative merits, feasibility, and likely costs of the potentially available renewable energy technologies to be used in the NT, including geo-thermal, solar, biomass and tidal*.
- Pacific Energy. (2014). *Service Capabilities and Representation*. Retrieved 10 8, 2014, from <http://www.pacificenergy.com.au/our-business/service-capabilities-and-representation.html>
- Parkinson, G. (2013). *Origin quits geothermal as Geodynamics prepares 1MW pilot plant*. Retrieved April 4, 2013, from <http://reneweconomy.com.au/2013/origin-quits-geothermal-as-geodynamics-prepares-1mw-pilot-plant-47777>
- Power and Water Corporation. (2013). *Annual Report*.
- Power and Water Corporation. (2013). *Statement of Corporate Intent 201-13*.
- Power Water Corporation. (2013). *PWC Northern Territory Electricity Network*. Retrieved from www.powerwater.com.au
- Queensland Treasury. (2013). *Budget 2012-13 Appendix B - Concessions Statement*.
- REN21, R. G. (2014).
- RenewablesSA. (2011, September). *Existing Installations*. Retrieved March 27, 2013, from <http://www.renewablesa.sa.gov.au/about-south-australia/existing-investments>

- RenewablesSA. (2013). *Diesel Generators Directory*. Retrieved from RenewablesSA:
<http://www.renewablesa.sa.gov.au/investor-information/diesel-generators-directory>
- Rottneest Island Authority. (2014). *Wind Turbine*. Retrieved 10 2, 2014, from
<http://www.rottneestisland.com/conservation/wind-turbine>
- Shire of Ngaanyatjarraku. (2012). *Shire Information*. Retrieved 10 2, 2014, from
<http://www.ngaanyatjarraku.wa.gov.au/index.php/our-shire/shire-information>
- Snowy Hydro . (2010). *Snowy Hydro website*.
- SustainabilityVIC. (2013, February 13). *Wave Energy*. Retrieved April 1, 2013, from
<http://www.sustainability.vic.gov.au/www/html/3047-wave.asp>
- Tidal Energy Australia. (n.d.). *Tidal Energy Australia*.
- TRL Solar. (2013). *Solar pole mounting system for solar bore and surface water*. Retrieved 10 2, 2014, from
<http://en.trlsolar.com/news/qyxw/2013/0923/227.html>
- VIC Government (a), V. G. (2011, March). *Notice of approval of amendment VC78*. Retrieved April 1, 2013, from
<http://www.gazette.vic.gov.au/gazette/Gazettes2011/GG2011S082.pdf>
- VIC Government (c), V. G. (2013). *Geothermal Energy FAQs*. Retrieved April 4, 2013, from
<http://www.dpi.vic.gov.au/energy/sustainable-energy/geothermal/geothermal-energy-faqs>
- VIC Government (b), V. G. (2013). *Feed-in tariff for new applicants*. Retrieved April 1, 2013, from
<http://www.dpi.vic.gov.au/energy/environment-and-community/victorian-feed-in-tariff-schemes/new-feed-in-tariff>
- Wang, E., Fengnian, S., & Manlapig, E. (2011). Pre-weakening of mineral ores by high voltage pulses. *Minerals Engineering*, 455-462.
- Western Power. (2014). *Annual Report 2014*.
- Winning, D. (2012). *Australia adjusts to new energy role*. The Australian.
- World Bank, *Energy*. (n.d.). Retrieved from
<http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTENERGY2/0,,contentMDK:22855502~pagePK:210058~piPK:210062~theSitePK:4114200,00.html>
- WorleyParsons. (2012). *Pilbara Algae Industry Study*.

Appendix A

Renewable Resources and Technology Status

Appendix A Renewable Resources and Technology Status

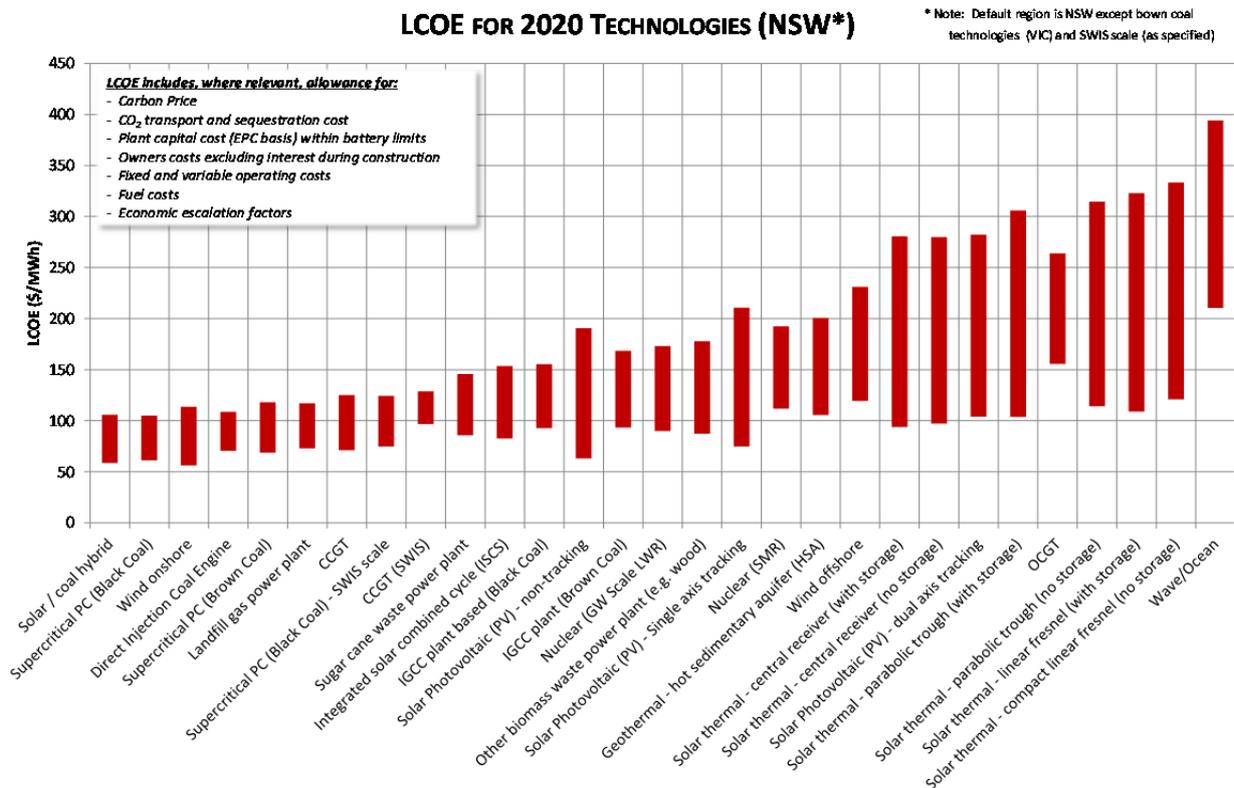
Australia current draws upon a variety of energy generation resources as part of its energy mix and has sort to adopt a variety of renewable energy technology to take advantage of its various renewable resources.

The relative costs and maturity of different technologies are constantly evolving in response to the policy environment, learning effects as technologies mature, economies of scale, commodity prices driven by local and global demand and changes to the price of input costs. For example, supportive government policy, in combination with rapid expansion in the global production of PV modules and substantial decreases in the price of polysilicon, has contributed to dramatic reductions in the price of PV units and hence the LCOE over the past two or three years. This has contributed to the 150 per cent increase in installed solar PV capacity in Australia between 2010 and 2011.

These factors are expected to continue to make renewable energy technologies more cost competitive with fossil fuel-fired technologies over the next four decades. As a result, the Australian generation mix will evolve to reflect these developments. BREE projects that by 2049–50 the share of renewable energy sources in the electricity generation mix will increase dramatically to 51 per cent, from 10 per cent in 2010–11 under Treasury’s carbon price projections.

The Australian Bureau of Resources and Energy Economics developed an *Australian Energy Technology Assessment* in 2012 which the most up-to-date cost estimates for 40 electricity generation technologies under Australian conditions. The costs were normalised into a levelised cost of electricity (LCOE) benchmark that allows for cross-technology comparisons over time. The figure below assumes technology learning and development maturity by 2020 and focuses primarily on grid connected generation means however it does provide a plausible indication of renewable technology options and their relative competitiveness if adapted to a remote application.

Figure 35 Projected LCOE for Power Generation Technologies in Australia by 2020 (NSW), with carbon price set to zero.



Source: (BREE, Australian Energy Technology Assessment, 2013)

The below table provides a summary of the research conducted with focus made on technologies suitable to a greater than 10kW remote renewable application. Renewables in the off-grid renewable energy market will in the short term be dominated largely by retrofitting wind and solar at low levels of penetration with existing off-grid

power stations. As the confidence in this emerging market develops and new technologies become available it is expected that other technologies will become the primary energy source in remote locations.

Table 41 Off-grid Renewables Technology & Resource Potential Overview

| Off-grid Clean Energy Options | Typical Plant Size | Technology Availability | Australian Deployment Potential | Forecasted annual av. growth 2008-35 & Share of Energy Production ⁶ | Current Off-grid Market Potential ⁵ | |
|---------------------------------|--------------------|-------------------------|---------------------------------|--|--|------------------------------|
| | | | | | Off-grid Communities | Off-grid Mining & Industrial |
| On-shore Wind | <3MW | Commercial | High | 10.1 per cent Growth 14 per cent Share | ✓ | ✓✓✓ |
| Off-shore Wind | <7MW | Commercial | Limited | | - | - |
| Micro Wind | <100kW | Commercial | Moderate | | ✓✓ | ✓ |
| Energy Storage | <10MW | Commercial | High | N/A | ✓✓✓ | ✓✓✓ |
| Hybrid Integration Technologies | Various | Various | High | N/A | ✓✓✓ | ✓✓✓ |
| Rooftop Solar PV | <20kW | Commercial | High | 4.1 per cent Growth 1 per cent Share | ✓✓✓ | ✓ |
| Utility Solar PV | <300MW | Commercial | High | | ✓ | ✓✓✓ |
| Concentrated Solar Thermal | | Commercial | Moderate | | - | ✓ |
| Large Hydro | <20GW | Commercial | Limited | 0.2 per cent Growth 4 per cent Share | - | ✓ |
| Small Hydro | <2MW | Commercial | Limited | | ✓ | ✓ |
| Geothermal | <300MW | (Pre) Commercial | Moderate | N/A Growth 4 per cent Share | ✓ | ✓ |
| Bioenergy | <150MW | Commercial | Limited | 2.1 per cent Growth 1 per cent Share | ✓ | ✓ |
| Wave | <200MW | Pre-Commercial | Moderate | N/A | ✓ | ✓ |
| Tidal / Current | <250MW | Pre-Commercial | Moderate | N/A | ✓ | ✓ |
| Renewables | | | High | Forecasted as 25 per cent of Energy Production by 2035 | | |

⁵ There is very large renewable resource in Australia however, the size of the market (for the coming years to 2020) is largely driven by the Renewable Energy Target.

⁶ Forecasts obtained from BREE's Australian Energy Projections to 2034-35, Dec 2011. Note these projections do not focus on the off-grid renewable market more the macro Australian energy mix.

Hybrid Power Systems and Enabling Technologies

Hybrid Power Systems and Enabling Integration Technologies

Technical Description

While Australia has an abundance of renewable resources, many of the technologies adopted provide an intermittent supply output and must be integrated with a continuous supply of continuous generation.

Hybrid power systems combine different technologies to form an integrated power delivery system to a load or network. They can include the combination of a form of renewable energy with another renewable, a fossil fuel technology or a form of energy storage or a combination of all of these.

Energy Storage can be integrated in a variety of ways to help manage the intermittency experienced by many renewable resources. It can include flywheels (kinetic energy), pumped hydro storage, and thermal or battery technologies. Depending on the particular hybrid or stand-alone renewable application will determine the duration of storage required. Short term storage is conventionally used to manage power quality while long term storage often requiring greater amounts of energy to be stored.

In remote applications **Smart Grids** technologies can be adapted in a range of ways. With the growing availability of IT infrastructure in remote locations remote micro-grids can obtain greater visibility and control of the load, monitor and manage network performance and generation input. It can be adapted into metering technology to better understand remote load characteristics, reduced operating costs by deploying pre-paid meters through to embracing advanced telemetry and control technologies to manage system flexibility.

Integrated Control and Energy Management Systems can enable greater functionality particularly in remote applications by being able to balance supply and demand as a result of system balance requirements and renewable energy input. Many inverter technology suppliers are adapting sophisticated control and protection functionality with their products to enable hybridised installation to operate effectively without additional hardware.

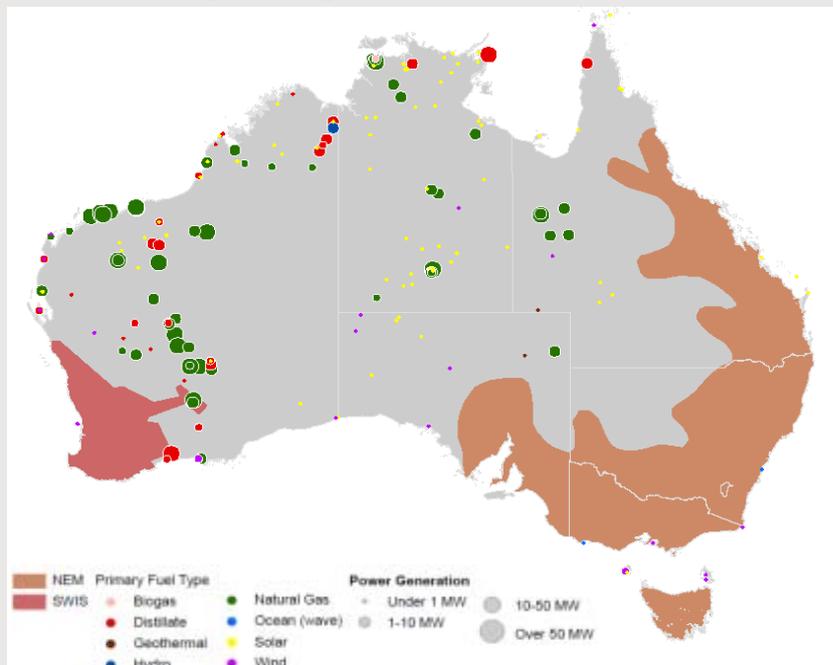
Australian existing off-grid power stations and enabling technology market

Enabling technologies are an essential technology in remote application to assist the smooth integration of a variety of renewable energy sources.

Hybrid or stand-alone remote renewable systems will benefit from further application to remove perceptions of being a complicated and unreliable technology option.

Together they have the potential to improve efficiency in consumption of fossil fuel and increase the input from renewable energy fuel sources.

Figure 36 Off-grid Gas and Diesel Power Generation



Source: AECOM

Hybrid Power Systems and Enabling Integration Technologies

Economics

Australia has a few case studies of renewable/fossil hybrids however they remain relatively uncommon though with the uptake of off-grid renewables in Australia driven by increasing operating fuel costs of existing off-grid plant in addition to Government subsidies such as ARENA's RAR Program will together provide incentive to the market to integrate renewables.

Main feasibility drivers

There are some clear feasibility drivers of adopting enabling technologies into hybrid systems or stand-alone off-grid renewable plant, include:

- A dispatchable generation means is critical for many off-grid power grids to maintain supply as an independent system and enabling technologies are essential in many cases to integrate renewables.
- The benefits of the renewable input can be maximised through optimised integration of enabling technologies.
- By optimising the overall system efficiency can help the business case for renewables.

Is there a business case for off-grid hybrid systems or enabling?

Enabling technologies are an essential supporting element in any off-grid renewable system, particularly hybrid systems.

On-Shore Wind Generation

Wind Generation

Technical Description

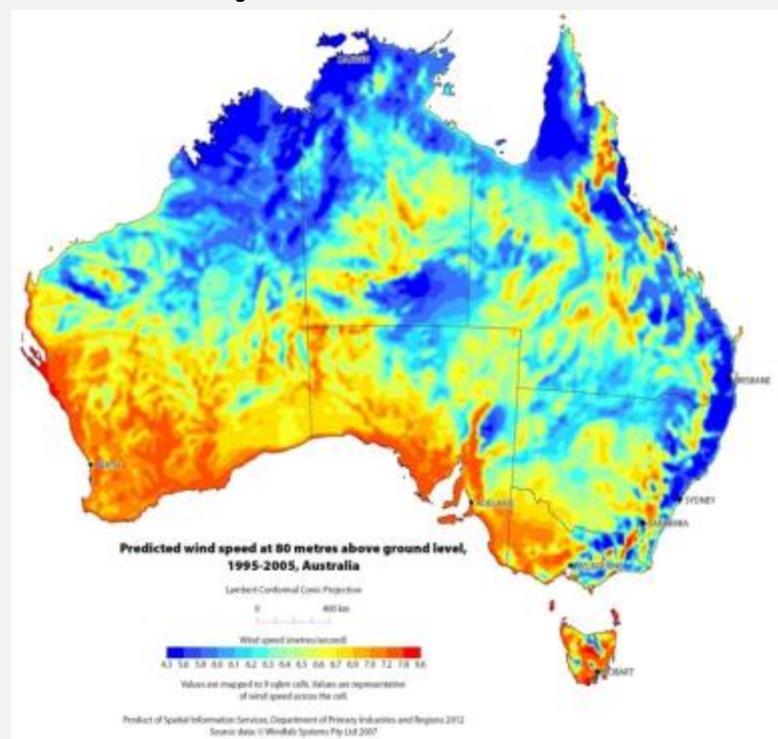
Utility scale on-shore wind generation represents the most mature form of renewable energy generation (excluding hydro). On-shore utility scale wind farms typically contain units in the 1 MW to 3 MW range with hub heights of 70 to 100 metres and rotor diameters of 70 to 120 metres. Utility-scale wind farm usually have a lower cost per kW compared to small and medium scale wind turbines.

Small to medium scale wind turbines (from a few watts to a few hundred kilowatts) can be ground mounted or roof mounted. There are a number of existing technologies on the market with horizontal or vertical axis. These technologies are still relatively expensive and far less mature than utility scale wind turbines.

Australian wind resource

The best regions for wind energy in Australia are generally along the south-western, southern and south-eastern coast and extending inland as shown in the Renewable Energy Atlas below.

Figure 37 Wind Resource of Australia



Source: Windlab Systems, SA Government

State of the Australian wind market

The installed capacity of wind farms in Australia has increased rapidly since the introduction of the original 2001 Mandatory Renewable Energy Target. South Australia has the largest installed capacity of wind generation plants in Australia, with 15 operating wind farms and total installed capacity of 1,203 MW, accounting for 48 per cent of Australia's total installed wind capacity (RenewablesSA, 2011). Despite the significant deployment of off-shore wind farms globally in recent years, there is no known plan for off-shore wind energy generation in Australia.

Currently, utility-scale on-shore wind energy is currently the least expensive form of renewable energy generation in Australia and is therefore expected to provide the largest contribution to the Renewable Energy Target. Although a number of developers have already secured the sites with the greatest wind potential, there remains significant untapped wind resource and hence high market potential for wind energy in Australia.

The capacity of wind required for the electricity retailers to meet their Large-Scale Renewable Energy Target (LRET) obligations through to 2020 will depend on the capacity factor of the individual wind farms. Based on an average 32 per cent capacity factor and assuming that wind contributes 75 per cent of each retailer's LRET obligation, it is assumed that the overall market size for wind generation in Australia is 11GW.

Wind Generation

Small and medium wind farms have been used to supply power to small communities such as the 600kW Rottnest Island, WA wind turbine to supplement existing diesel-generated power.

Economics

The deployment of wind power in Australia is largely driven by the LRET. With increasing competitiveness and a strong Australian dollar, the installed cost of utility scale wind farms is currently in the order of AU\$1.5 - 2.5 million/MW. The Levelised Cost of Energy (LCoE) of wind energy has also reduced considerably in recent years due to improvements in turbine efficiency and reliability. Typical recent LCoE figures for wind farms in Australia are believed to be in the order of AU\$80-100/MWh. The Clean Energy Council state the price of wind-generated electricity is approximately AU\$90-120/MWh (CEC, 2011).

The capital cost of off-shore wind energy is approximately double that of on-shore wind energy in the current market.

Main feasibility drivers

In addition to the typical project development considerations of the wind farm, the following should be considered:

Site specific wind resource

The feasibility of a wind farm development depends heavily on the local wind resource, which is very site specific. The wind resource in the remote areas needs to be assessed on a project by project basis. It is clear that several large commercial wind farm projects have been constructed and are under development throughout the country at facilities that are generally close to the coast and aligned with the extent of the SWIS or NEM or within areas where the wind resource is well known such as Broken Hill, NSW.

Elsewhere knowledge about Australia's wind resource is reasonably poor. Mapped results need to be treated with great caution, given the accuracy of the modelling employed and the lack of correlation with any detailed wind resource monitoring. Detailed information is often held closely by those who have invested in obtaining it. Financiers typically require at least one year of onsite wind resource monitoring with a wind mast at a height that corresponds with hub heights of potential wind turbines prior to investing into a project.

Development and Regulatory Approval

Obtaining a Development Approval for a wind farm is typically seen as more challenging than for a solar plant. Wind projects are subject to a number of regulations and standards which can vary between jurisdictions. The Development Approval process will include a number of studies, and will define strict regulations around noise assessment, ecological impact and visual amenity. It is not rare for a wind project to encounter strong community opposition, particularly if the community has not been adequately consulted in the project development process. Community consultation is an important activity for successfully developing a wind farm.

The Victorian Government recently approved Amendment VC78 to the Victoria Planning Provisions (VIC Government (a), 2011) which recently imposed more stringent planning considerations for wind farm developments in Victoria, including the requirement to provide a plan showing all dwellings are within two kilometres of proposed turbine locations.

Transport

Logistics of transporting large turbines and specialised equipment such as large cranes for installations to remote locations needs to be considered carefully during the feasibility study, including road access.

Site Constructability

Wind farms are often in remote locations and access to construction materials needs careful consideration in addition to an understanding of the geotechnical characteristics.

Grid Connection

Typically wind projects connecting into remote networks need careful consideration due to their intermittency and impact on a weak network's stability.

Time of production

One of the obstacles for wind energy development is the variability of the resource. In the National Electricity Market (NEM), there is currently sufficient spinning reserve for wind variability to not be a significant challenge. However, the time of production has a significant impact on the revenues. The production from the South Australian and Western Australian wind farms are generally greater at night, during off-peak demand times.

Wind Generation

Is there a business case for off-grid wind systems?

There is a business case based on a Levelised Cost of Electricity (LCoE) basis for utility scale wind farms to compete with electricity generated using diesel. In theory, off-grid applications could therefore offset their diesel by deploying wind energy.

However, the wind resource being very site specific, it is difficult to draw a general conclusion. Wind energy is certainly an option to consider for off-grid communities but it needs to be assessed on a project by project basis. In particular, small scale wind will likely have a higher LCoE than utility scale in addition to the costs involved in control and integration any system. Also, many of the remote opportunities for renewable integration in northern Australia are susceptible to monsoonal or cyclonic conditions which will affect construction and design rating of wind projects in these regions.

Solar Photovoltaic (PV)

Solar PV Generation

Technical Description

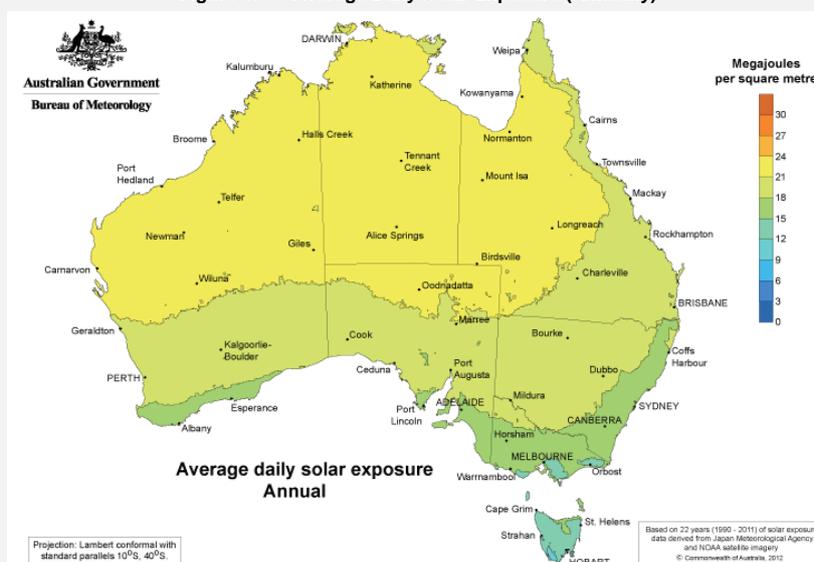
Solar PV technologies convert sunlight into electricity using semiconductor materials that produce electric currents when exposed to light. Solar PV can be installed on roofs or ground mounted in large fields. Solar PV panels can be fixed or in a tracking arrangement (single axis or dual axis).

Australian Solar PV resource

Australia has the highest solar radiation per square metre of any continent (IEA 2003) globally. Australia receives an average of 58 million PJ of solar radiation per year (BoM 2009), almost 10,000 times larger than the Australian total energy consumption.

Theoretically, if only 0.1 per cent of the incoming radiation could be converted into usable energy at an efficiency of 10 per cent, all of Australia's energy needs could be supplied by solar energy. Although the regions with the highest solar radiation are deserts in the northwest and centre of the continent, as shown in Figure 38, there are significant solar energy resources in areas with access to the electricity grid. The solar energy resource (annual solar radiation) in areas of flat topography within 25 km of existing transmission lines (excluding National Parks), is nearly 500 times greater than the annual energy consumption of Australia.

Figure 38 Average Daily Solar Exposure (Annually)



Source: (BOM, 2012)

State of the Australian Solar PV market

Small scale solar PV systems have been widely installed in Australia leading to the development of a strong local solar PV industry. The number of Clean Energy Council accredited installers and designers in Australia has grown from around 237 in early 2006 to nearly 4,273 by late 2011, nearly an eighteen fold increase (CEC, 2011). The original deployment was largely driven by former generous state government feed-in-tariffs and other subsidies such as the solar multipliers. Although the number of new installations has declined in the last year, small scale solar PV (under 100kW) continues to be driven by the Small-Scale Renewable Energy Scheme (SRES).

Large-scale solar PV is establishing itself with Australia's largest solar PV installation developed by Frist Solar at Greenough River Solar Farm in Western Australia (10 MW plant) and a number of larger systems are currently in development. Development in large-scale solar was initially driven by the Federal Government's investment into the Solar Flagships program and the Large-Scale Renewable Energy Target (LRET). ARENA and the CEFC are expected to provide further support in the future deployment of large scale solar.

Concentrated solar PV systems that focus sunlight onto PV modules is in its infancy in the Australian market. Aside from demonstration projects, there is a 235 kW concentrated solar PV installation at Alice Springs Airport.

Solar PV Generation

Economics

In recent years, solar PV module cost reductions supplemented by a strong Australian dollar resulted in significant solar capital cost reductions. Commercial scale PV systems are currently expected to have an installed capital cost between AU\$2 million/MW and AU\$3 million/MW. Bloomberg New Energy Finance released a report with a median Q1 2012 solar PV LCOE of approximately \$170/MWh (FrankfurtSchool, 2012). Lower prices have been seen internationally however relatively high prices in the Australian market are expected to remain in the near future, driven by wage levels as well as limited large-scale experience.

Many mines and communities in remote locations source electricity from diesel generation, and often pay over \$300/MWh in fuel and carbon only (i.e. excluding CAPEX). These costs are expected to rise over time and are vulnerable to price shock events or supply chain interruptions in international markets.

Solar PV and other renewables can be integrated with existing diesel units to provide a highly reliable power supply. Such renewables now provide a cheaper source of electricity while maintaining the mining industry's stringent reliability requirements; some renewables are now cheaper than diesel power — supplying electricity at competitive rates.

Main feasibility drivers

In addition to the typical project development considerations of the Solar PV plant, the following should be considered:

Existing electricity supply

Positive business cases are largely dependent on the existing electricity supply available. Remote off-grid communities that rely on existing diesel generation have a stronger business case for implementation of solar PV as it can offset the high operating cost of diesel generation.

To date, solar PV is unlikely to be competitive with off-grid gas generation without government funding or subsidies.

Location Consideration

Sites that require minimal work to optimise the capacity factor of a system will minimise construction costs. In order to minimise earthwork costs, a ground mounted solar PV system will require a large amount of relatively flat land with a typically preferred land gradient below 5 per cent and north facing. Fixed tilt systems typically exceed 2 hectares per MW of solar plant. Consideration of trees, buildings or surrounding hills that may cause shading and hence reduce electricity production is also essential. Most off-grid systems are located in areas with available flat land and typically of low value. Consequently, the large footprint of solar PV systems is unlikely to present a significant challenge.

Locating of solar PV plants in remote locations can mean they are susceptible to theft or vandalism. Also access to construction resources, serviceability in isolated locations and project size for the development cost investment return should also be considered.

Is there a business case for off-grid Solar PV systems?

For a current delivered diesel price estimated at around AU\$1/L for typical mining projects or approximately AU\$1.30/L for remote communities including the Fuel Tax Credit, integrating solar PV into off-grid systems operating on diesel is now a cost effective option. Low levels of solar PV integrated into most systems require only minimal integration costs, provided some or all the existing generation assets would remain installed to support reliability. If a higher integration cost can be justified, the infrastructure to support a higher solar PV penetration level can be included (such as batteries and short term flywheel storage).

In addition to the financial benefits, sourcing energy from solar PV insulates against rising diesel fuel costs and the potential fuel price volatility in international markets. It also reduces exposure to the carbon price and minimises the issues related to uncertainty in the forward price of carbon.

Solar Thermal

Solar Thermal

Technical Description

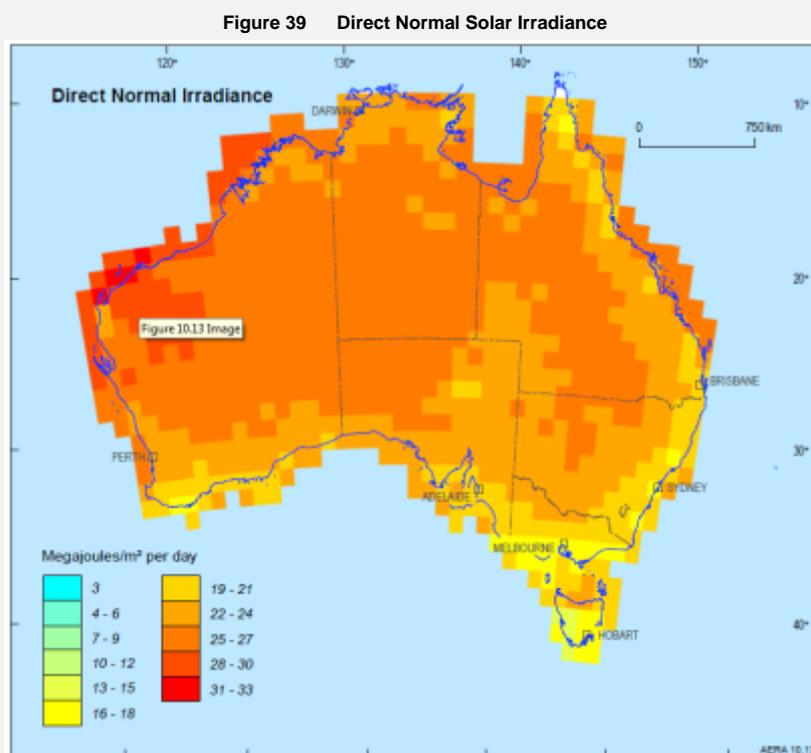
Concentrated solar thermal power (CSP) involves using lenses or mirrors to focus a large area of sunlight onto a single point which creates intense light and heat that is used to generate electricity.

Various techniques and configurations are used for CSP plants globally. These include parabolic troughs or Linear Fresnel with a linear absorber tube running through a focal point, or mirrors that concentrate solar energy to the top of a tower.

Australian Solar Thermal Resource

Solar thermal resource is determined by the amount of direct normal solar irradiance (DNI) as CSP relies upon DNI to focus onto a collector to generate heat and electricity. Provided below is a map of the annual average DNI at a resolution of 10,000km² grid cells. It shows there is a high solar thermal resource in the central regions of all states except Victoria and Tasmania. In particular, there is a very high solar thermal resource on the coastal regions of Western Australia.

A 2008 study by Wyld Group and MMA found locations with high potential for solar thermal systems based on high DNI, proximity to local loads and high electricity costs from alternative sources. These locations included the Port Augusta region in SA, north-west VIC, central and north-west NSW, Kalbarri near Geraldton in WA, and Alice Springs to Tennant Creek in NT (GeoscienceAustralia, 2010).



Source: (GeoscienceAustralia, 2010)

State of the Australian solar thermal market

Currently there are only a few working solar thermal power plants in Australia. The largest standalone CSP power station in Australia is the Liddell Power station, which is a demonstration plant of approximately 1.5 MW. A 44 MW solar thermal boost project is being constructed at Kogan Creek, Queensland to support an existing coal power station. The Kogan Creek project received considerable upfront subsidies from the State and Federal Government.

The industry experience and technology is still quite new in Australia. Unlike solar PV, which is very modular and has been able to establish itself in the domestic market, CSP is much more feasible in the form of large-scale projects or as integrated directly into the organic Rankine cycle of existing thermal plants.

The Australian Government through the Australian Renewable Energy Agency's (ARENA) Emerging Renewables Program is funding a feasibility study into hybridising solar thermal with gas at Collinsville Power Station. The \$5.6 million study will assess the viability of converting a decommissioned 180MW coal power plant into a 30MW hybrid solar thermal/gas power station by maximising use of existing infrastructure. If feasible, it aims to encourage further coal power plant conversions.

Solar Thermal

Economics

Solar thermal technologies currently have a higher overall cost of energy compared to solar PV. Solar Thermal energy costs are currently estimated to be in the order of AU\$200-300/MWh with a typical capital expenditure of AU\$5 million/MW (Entura, Hydro Tasmania, 2010).

Main feasibility drivers

In addition to the typical project development considerations of the Solar Thermal plant, the following should be considered;

Scale

The business case for solar thermal strengthens for large scale applications (typically 50MW and above) and therefore requires large areas and significant load to be supplied.

Large flat area

For some solar thermal technologies including parabolic troughs and linear Fresnel lenses, a flat site with a gradient below 5 per cent is preferred. In contrast, a flat area is not necessary for solar power towers or parabolic dishes. A large area is also required with an estimated 2 hectares of land required per MW of electricity generated (GeoscienceAustralia, 2010).

Most off-grid systems are located in areas with available flat land and typically of low value. Consequently, the large footprint of solar thermal systems is unlikely to present a significant challenge.

Wind loading

Aside from high DNI, it is important to consider the wind loads at a site as a CSP plant comprises of large structures. Low wind areas are preferred as this will reduce the additional amount of reinforcement required and thus construction costs.

Access to water

CSP plants require access to small/medium volumes of water for cleaning mirrors and maintaining the designed reflectivity. Larger volumes of water will also be required for the mechanical water based cooling systems typically associated with a CSP plant. However, this can be avoided with an alternative dry based cooling system.

Solar Glare/ Reflectivity

There are various organisations such as airports and nearby communities that are concerned about solar glare from CSP plants. Generally the project must prove there is no detrimental impact to overhead flight paths or nearby communities.

Opportunity for integrated storage

Whilst thermal energy storage is expensive, a CSP plant with energy storage can decrease the cost per kWh produced as it can dispatch electricity during demanded periods when it is of most value.

Tidal

Tidal

Technical Description

Harnessing the energy potential of the oceans tides falls into two main technology categories:

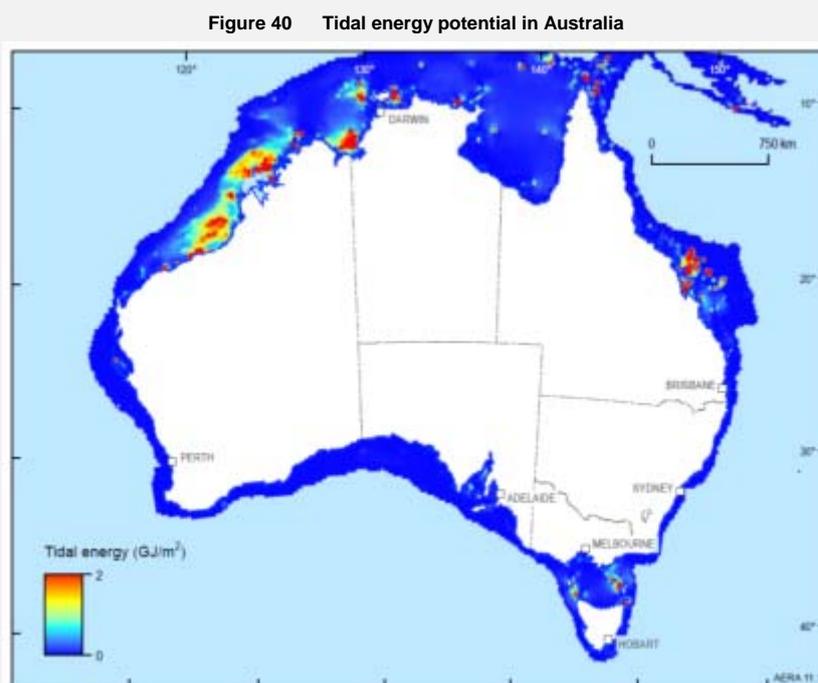
- **Tidal barrages** which are essentially a dam or dyke type structure which encloses a bay, tidal lagoon, inlet or estuary. A power station containing low head turbines, similar to those used in conventional hydropower facilities are installed in the barrage and generate electricity by exploiting the potential energy of the rising and falling tides.
- **Tidal stream or current generators** are free standing turbines which are founded on the sea bed in tidal or ocean current channels. These turbines are similar to wind turbines in that they harness the kinetic energy of the fluid flow (in this case the tidal currents). Tidal stream generators employ very similar technology to wind turbines however they benefit from the much higher energy density of tidal currents; meaning that a much smaller rotor can be used to produce the same energy output.

Both these technologies are still comparatively underdeveloped and remain a high cost to integrate meaning there is only limited project examples around the world.

Australian Tidal & Ocean Current Resource

The north west of Australia experiences a tidal range of up to 10 m, one of the largest in the world. It is this region from Port headland north to Darwin that has the greatest potential for tidal electricity generation with both barrage and tidal stream generators possible. The region is also dotted with inlets and other large tidal water bodies which may be ideal for tidal generation.

There are also four main ocean and non-tidal coastal currents surrounding Australia which have a potential to generate in the order of 44TWh/year (CSIRO, 2012).



Source: (ABARE & Geoscience Australia, 2010)

State of the Australian tidal & ocean current market

The world's most productive wave energy is more available in countries with unsheltered coastlines, facing oceans where wind is converted to wave energy over fetch distances of hundreds to thousands of kilometres. This includes the Americas, Australia, Ireland, Portugal, parts of Scandinavia, South Africa and the United Kingdom.

The potential for power generation from the oceans tides and currents is undoubtedly large, however tidal energy potential is comparatively low compared with wave energy. Currently commercial scale tidal generation facilities operational globally, are primarily tidal barrages. There are currently no tidal generation facilities in operation in Australia although tidal generation in Australia has been investigated since the 1960's and 1970's.

The Doctors Creek site near Derby in Western Australia was investigated in the 1990's for a 48MW tidal barrage development. The project proposed to construct two barrages across the two arms of Doctors Creek, one retaining the high tides and the other the low tides. With the water elevation difference created between the two arms it was possible to generate 48MW of continuous tidal power. The project was abandoned due environmental concerns and

Tidal

cost blowouts and in 2004 a diesel power plant was built to meet the local electricity needs. The Doctors Creek site has since been resurrected is once again under consideration with a revised layout capable of generating 100 MW. Other sites in Western Australia such as the Ord River (Tidal Energy Australia), Walcott Inlet, Secure Bay, St George Basin and Rothsay Water (Baker, 1991) have also been considered but not investigated in sufficient detail to determine the feasibility of these sites.

Economics

The cost of developing a tidal power project in Australia is still largely unknown as no such facilities have been developed yet. It is likely to be highly variable and dependent on site conditions, particularly the tidal range, topography and bathymetry, geology and proximity to existing transmission infrastructure.

The production costs of tidal energy technologies are estimated by the IEA to be from US\$60 /kWh to US\$300/kWh (2005). Tidal barrage schemes are at the lower end of this scale and tidal stream generators at the upper end of this scale (ABARE & Geoscience Australia, 2010).

Main feasibility drivers

In addition to the typical project development considerations of the tidal plant, the following should be considered:

Predictability

The main benefit of tidal energy is that unlike other forms of renewable energy, tidal energy is very easily predictable. When paired with storage (i.e. pumped storage hydro) the predictable nature and immunity to climatic conditions of tidal generation means that it can provide reliable base load electricity supply.

Barrage type schemes may also serve a secondary purpose in some locations such as enabling rail or road transportation across a bay or inlet.

Resource far from the electricity users

The dislocation of the tidal energy resources from potential energy users presents a significant challenge for future tidal generation in Australia due to the high cost of transmission.

Environmental impact

High potential environmental impacts are also a key barrier to development in Australia particularly for tidal barrage schemes. (Australian Institute of Energy)

Is there a business case for off-grid tidal systems?

The tidal and ocean current potential is limited to relatively small areas along the Australian shore, which significantly limits the potential for off-grid tidal systems. In addition, there are significant economies of scale in developing larger tidal systems, which means that the technology wouldn't be suitable to supply small off-grid loads.

The high predictability of tidal electricity generation could however be attractive in some remote application, including to the mining industry along the North West coast of Australia. However, the cost of the technology is still high compared to other renewable energy sources such as wind and solar PV.

Bioenergy

Bioenergy

Technical Description

Bioenergy uses biomass (organic material) to produce electricity, heat or liquid fuels for transport.

In Australia, biomass is primarily utilised in two forms:

- Direct combustion of biomass to heat water into steam for a steam turbine to generate electricity
- Use of landfill gas in the gas turbine to generate electricity

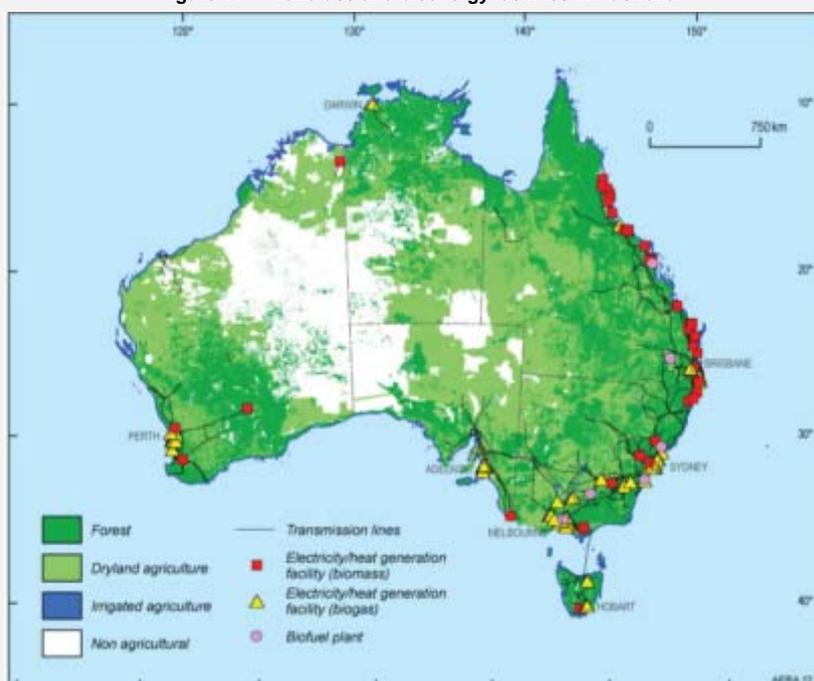
Globally, biomass has been converted into electricity using methods including anaerobic digestion, pyrolysis and gasification.

Australian Bioenergy Resource

The potential bioenergy resources in Australia are large and diverse with unused biomass residues and waste streams a significant under-exploited resource.

The Clean Energy Council has estimated the long term electricity generation potential to 2050 of these biomass resources below. It suggests bioenergy can contribute around 73TWh of electricity to Australia by 2050. By comparison, the 20 per cent Renewable Energy Target by 2020 is 41TWh.

Figure 41 Land use and bioenergy facilities in Australia



Source: (GeoscienceAustralia, 2010)

State of the Australian bioenergy market

Currently, Australia is generating bioenergy from waste by-products to ensure there is a sustainable supply that does not compete with native forests, edible crops and fertile lands. Biomass sources used in Australia for generating heat and electricity include bagasse, wood waste, landfill gas, sewage gas, black liquor, food and agricultural wet waste.

In 2011, electricity generation from bioenergy (including biomass and biogas) amounted to 773MW, which is around 1 per cent of total electricity generation in Australia. Over 60 per cent of this was from bagasse combustion with landfill gas the second largest contributor (CEC, 2011).

Accounting for the Renewable Energy Target (RET) and other government policies, ABARE predicts bioenergy will have an average annual growth rate of 2.2 per cent, largely from bioenergy generation projects in Queensland.

It is possible that biogas could supplement natural gas within a few decades; however energy crops are likely to be a competing with food crops for suitable agricultural land. Both terrestrial freshwater algae and marine algal seaweeds are a promising alternative feedstock for biogas generation and these would not be competing for land resources. Biogas could be carbon neutral and may fit well with an energy mix of biofuels and renewable energy sources.

Bioenergy

Programs and policies supporting biomass electricity

Through the RET, Large-Scale Generation Certificates (LGCs) are applicable to the following biomass types; wood waste, agricultural waste, energy crops, bagasse, black liquor or landfill gas, waste from processing of agricultural products, food waste, food processing waste, biomass-based components of municipal solid waste, sewage gas and biomass-based components of sewage. LGCs are created by renewable energy power stations directly in the online REC Registry.

The Victorian Government provides a feed-in-tariff of a minimum 8 c/kWh for excess electricity exported to the grid for biomass systems less than 100kW (VICGovernment (b), 2013).

The Australian Capital Territory (ACT) Government has introduced the ACT Waste Management Strategy 2011-2025, which sets out goals to achieve full resource recovery and a carbon neutral waste sector. From this strategy, the ACT Environment and Sustainable Development Directorate are currently seeking expressions of interest for waste processing systems that recover resources from urban forest materials and residual waste streams into higher value applications till May 2013.

Table 42 Long term generation potential of animal waste

| Resource | Long term potential (GWh) |
|---|---------------------------|
| Agricultural-related wastes | 50,566 GWh |
| Sugarcane | 7,800 GWh |
| Wood-related wastes | 5,060 GWh |
| Urban biomass (including urban timber wastes) | 4,320 GWh |
| Landfill gas | 3,420 GWh |
| Sewage gas | 929 GWh |
| Energy crops | 534 GWh |
| Total | 72,629 GWh |

Source: (CEC (d), 2008)

These figures are in line with the estimate from Clean Energy Council (presented in Table 42), which provided a detailed electricity generation potential by segment and for a wide variety of biomass sources by 2020 and by 2050. The three most promising segments for future bioenergy projects are agricultural and sugar cane waste, forest residues and urban waste.

Agricultural and residual waste

Over the past few years, new opportunities for anaerobic digestion have been identified in the food processing and farming industries and studies have been undertaken on meat processing sludge and animal manure. Berrybank piggery has been producing 3.5MWh per day since 1991 from its 0.225 MW power plant fuelled by pig manure. The Clean Energy Council (2008) estimated the long term potential from this industry of about 200GWh per year. Feedlot cattle and poultry farms are estimated to have a long-term potential of 440GWh per year and 840GWh per year respectively. Abattoirs or slaughterhouse represent a potential for development from the utilisation of solid wastes. If by 2020, 30 abattoirs implement anaerobic cogeneration plants, 340GWh per year can be generated, with a long-term estimate of about 1770GWh per year.

Urban waste

Utilisation of urban solid organic wastes, such as timber, paper, food and garden waste is steadily growing and has significant potential for energy generation. In 2002-03, approximately 9.5 Mt of organic urban waste was sent to landfill annually. The potential electricity generation for 9 Mt of urban waste is 103GWh, with a long term estimate of around 4300GWh (Clean Energy Council 2008).

Bioenergy

Forest residues

Australia has extensive areas of forest and dry agricultural land that could potentially be accessible for biomass crop production as illustrated in Figure 41. There is a potential to utilise wood waste and forest residues for electricity generation. Some industry stakeholders have recently proposed to use wood wastes and other bio-energy resources for co-firing conventional thermal power stations and suggested that the Carbon Tax could be sufficient to incentivise the growth of this market.

The use of residual forest waste is controlled by some regulatory mechanisms, including Regional Forest Agreements to prevent potential of environmental damages on the Australian forests' ecosystem. The regulations limit the utilisation of waste residues from forests as a source for renewable energy.

Economics

The cost of a biomass facility varies depending on the size, site, transportation, labour involved, energy capturing and conversion technology and waste material. It is likely that bioenergy power stations greater than 1MW are cheaper with estimated capital costs for a 40MW plant at around AU\$2.5 million per MW of installed capacity, in contrast to more than AU\$8 million per MW for a plant size less than 1MW (CEC (a), 2011).

The positive business case increases for bioenergy production models that generate electricity from cheap or 'negative-cost' residues or waste at the biomass source site such as at landfill and sewage sites, paper, saw or sugar mills.

Main feasibility drivers

In addition to the typical project development considerations of the biomass plant, the following should be considered:

Availability of biomass

A biomass system requires a significant amount of organic material. The feasibility of the system is dependent upon the availability of this organic material at the volumes required for the desired plant capacity. It also depends on the composition and quality of the organic material as the more contaminants within a waste stream the more complex the processing system.

Some types of biomass can be used to produce other commodities such as food given valuable fertile lands. There are also competing alternative uses for forestry and agricultural wastes such as composting and feed for animals. It is important the choice of biomass is carefully considered to avoid any potential negative environmental and social impacts.

There is a large source of biomass however its availability also depends on many parties within the supply chain and how potential biomass is currently handled. Current forestry, agricultural and waste processes are generally seasonal may likely need to change in order to effectively divert potential biomass.

Transportation

The location of the bioenergy power plants requires a balance between biomass supply transportation costs and the electricity load. For biomass with low calorific value, it is preferable for the plant to be as close to the biomass source in order to minimise transport costs of large volumes of biomass.

Approvals

Planning approvals can be difficult to obtain for certain forms of biomass systems due to stringent health and safety requirements.

Is there a business case for off-grid bioenergy systems?

The rainfall generally is relatively low in Australia but areas where rainfall exceeds 300mm per annum may show potential for mallee cropping and straw.

In the Pilbara and other mining regions, the management of waste generated from remote mining communities and mining sites is becoming a focus as they develop comprehensive waste recycling and disposal plans. The business case for off-grid landfill gas and waste to energy plants for electricity generation may be possible in some regions.

Hydro

Hydro

Technical Description

Hydropower produces approximately 16 per cent of the world's electricity and over four-fifths of the world's renewable electricity (IRENA 2012).

Hydropower systems use the energy in flowing water to produce electricity or mechanical energy. There are two basic configurations to harness the moving water to produce energy: firstly dams with reservoirs and secondly "run-of-river systems" that do not require large storage reservoirs and are often used for small-scale hydro projects.

Hydro systems can be very large and able to produce thousands of megawatts such as the Hoover Dam of 2,074 MW (USA), the 22,500MW Three Gorges Dam (China) and the 10,000MW Guri dam (Venezuela).

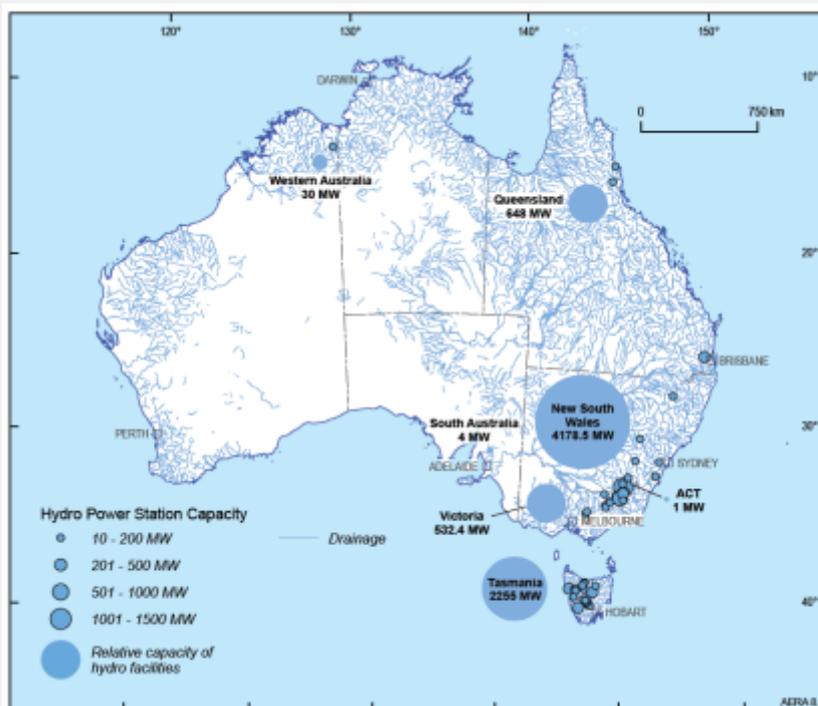
However, small run of river hydro, which can be a few megawatts down to less than 100kW, has been around a very long time, and is now experiencing an increase in popularity globally. It has an important role to play in the future sustainable development of our planet.

Australian Hydro Resource

Hydropower is a mature energy generation technology that has been employed in Australia for more than 100 years. Currently hydropower contributes on average around 14,000 GWh of electricity annually in Australia, which represents more than two thirds of the total renewable electricity generation. Australia has 108 operating hydroelectric schemes with a combined generating capacity of 8,186 MW (Ecogeneration, 2011). Sixteen of these schemes have a capacity of over 100 MW and just 3 with a capacity greater than 500 MW or more, all of which are located in the Snowy Mountains Scheme, the largest being Tumut 3 which has a capacity of 1,500 MW (Geoscience, 2012).

Despite the large size of the Australian land mass, the hydropower potential is comparatively small compared to other countries. This is due to Australia's low and variable rainfall, high rates of evaporation, and limited areas of suitable topography.

Figure 42 Australian operating hydroelectric facilities (> 10 MW)



Source: (GeoscienceAustralia, 2010)

State of the Australian hydro market

It is not anticipated that we will see new large scale hydropower development in Australia in the next decade due to the scarcity of suitable sites. Future growth in Australia's hydropower generation capacity is expected come from:

- rehabilitation and upgrade of existing hydropower plants
- retrofitting of hydropower plants to existing water storage dams, irrigation canals and water pipelines.
- development of new small scale run-of-river hydropower plants

Hydro

With the exception of the AGL's 140 MW Bogong Power Station in Victoria, commissioned in 2009, new hydropower developments in recent years have been small and mini hydropower developments. These schemes offer a number of advantages over large scale hydro including lower environmental impact, lesser demand on valuable water resources, ability to utilise existing water resources infrastructure, and much shorter development timeframes.

Opportunities for small scale hydropower development are known to exist on many streams in Victoria, New South Wales and Queensland and also in the retrofitting of water dams.

Over 80 per cent of the hydropower capacity in Australia is located in Tasmania and New South Wales. The Snowy Mountains Hydroelectric Scheme in NSW, which has a capacity of 3,800 MW, accounts for around half of Australia's total hydroelectricity generation capacity. There are also hydroelectricity schemes in north-east Victoria, Queensland, Western Australia, and a single mini-hydroelectricity project in South Australia (Geoscience, 2012)

Economics

The cost of developing a hydropower project is highly variable and dependant on the site conditions, particularly topography, geology, hydrology and proximity to existing transmission infrastructure. The capital cost of developing a hydropower project is typically between AU\$1.5million/MW and AU\$6million/MW (International Energy Agency, 2010) and operating costs are estimated at AU\$0.03-0.04/kWh. In some instances the development cost can be lower where it is possible to utilise existing infrastructure, such as retrofitting a hydro plant to an existing water storage dam. The following Australian examples demonstrate the inherent variability in hydropower development cost:

- Jounama hydropower plant (14.4 MW) – Snowy Hydro (2010) AU\$16.5million, AU\$1.15million/MW (Snowy Hydro, 2010)
- 6 Mini-Hydropower Plants (7 MW) – Melbourne Water (2010), AU\$25million, AU\$3.6million/MW (Ecogeneration, 2011)
- Bogong Power Station (140 MW) – AGL (2009) AU\$234million, AU\$1.7million/MW (Australian Energy Resource Assessment, 2010)
- Wivenhoe Dam Mini Hydro (4.5 MW) – Stanwell (2003) AU\$7.6million, AU\$1.7million/MW
- "The Drop" Mini Hydro (2 MW) – Pacific Hydro (2002) AU\$6.5million, AU\$3.3million/MW
- Pindari Dam Mini Hydro (6 MW) – Stanwell (2001) AU\$9.2million, AU\$1.5million/MW
- Ord River Hydro Scheme (30 MW) – Pacific Hydro (1997) AU\$76million, AU\$2.5million/MW (Clean Energy Council)

The Levelised Cost of Electricity is similarly variable.

Main feasibility drivers

Australia has a limited number of large rivers and hence there are limited sites available for large-scale deployment of hydropower. It is commonly agreed that Australia has already developed most of its hydro potential.

Is there a business case for off-grid hydro systems?

Scarcity of Australia's water resources and potential environmental impacts are the key constraints to development of new hydropower assets in Australia.

While retrofit mini hydropower projects have previously been approved in Australia, there is very little precedent for new small scale green-field hydropower development. It is generally viewed that obtaining a Development Approval for these projects is considerably more challenging than for other renewable technologies due to the unavoidable impact on a watercourse.

Recent droughts and increasing variability in Australia's rainfall further contribute towards an uncertain future for hydropower in Australia.

Wave

Wave

Technical Description

Globally, wave power generation is in its infancy with most technologies still in the research and development phase or early phases of the demonstration and commercialisation learning curve.

There are a very large number of wave technologies, all based on the principle on the exploitation of the wind-driven wave energy. There are three general categories: Oscillating Water Column systems (with a pneumatic chamber and air turbine), Oscillating Body systems (with various rotation bodies) and Overtopping Devices (based on the use of reservoirs).

Australian Wave Resource

The wave resource is typically a combination of waves generated by wind blowing across the ocean surface, and ocean swell created by the interaction of weather pressure systems moving across the ocean surface in conjunction with wind. The wave and swell components have differing wavelengths and amplitudes and wave energy converter technologies are typically optimised to capture one or other of these components.

There have been a number of studies to quantify the Australian wave resource; however there is a lack of primary measured data and hence significant uncertainties in the estimations of the magnitude and characteristics of the wave resource.

Figure 43 Spatial distribution of time-averaged wave power on the Australian continental shelf (kW/m)



Source: (GeoscienceAustralia, 2010)

State of the Australian wave market

In Australia there are companies actively developing wave power technologies, and Table 43 lists the wave power pilot and demonstration projects installed and operating in Australian waters.

Table 43 Wave power pilot and demonstration projects in Australia

| Project | Company | State | Start up | Capacity |
|---|-------------------------|-------|----------|----------|
| Fremantle Wave Energy Research Facility | Carnegie Wave Power Ltd | WA | 2005 | 0.10 MW |
| Port Kembla (wave energy) | Oceanlinx | NSW | 2006 | 0.50 MW |
| Lorne Pier Demonstration unit | AquaGen Technologies | VIC | 2010 | 0.0015MW |

Source: (GeoscienceAustralia, 2010), (AquaGen, n.d.)

Australia has an exceptional wave energy resource with one study estimating that approximately half of Australia's electricity demands could be met if 10 per cent of the wave energy resource along the south-western margin of Australia were used to generate electricity study (Hemer & Griffin, 2010). Interestingly, the study also noted that

Wave

there are temporal-spatial variations in the incidence of the wave energy: specifically that when the southern coast incident wave power peaks, the western coast tends to be calm and vice versa. This finding implies that if the Western Australian grid electricity networks were interconnected with the NEM, a distributed deployment of wave energy generation across the south-western margin would collectively be able to provide a reasonably consistent supply of electricity (in aggregate the generation profile would have similar characteristics to a base load generator). In the short to medium term, the growth of the wave energy sector is anticipated to be relatively slow in Australia whilst wave technologies undergo research and development and progress through the demonstration and commercialisation learning curve. Current proposed demonstration projects for Australia are shown in Table 44.

Table 44 Proposed demonstration wave projects

| Project Description | Company | State | Start up | Capacity |
|---|--------------------------|-------|----------|----------|
| Perth Wave Energy | Carnegie Wave Energy Ltd | WA | 2014 | 5 MW |
| Port Fairy project – grid-connected bioWAVE | BioPower Systems | VIC | 2013 | 0.25MW |
| Commercial scale greenWAVE device | Oceanlinx | SA | 2013 | - |
| Portland | Ocean Power Technologies | VIC | - | 19MW |

Source: (SustainabilityVIC, 2013)

The wave resource along the south-western margin of Australia is among the best in the world. The total wave energy on the entire Australian continental shelf at any one time, on average, is estimated to be about 3.47 PJ. In general, wave energy appears to be closer to major population centres and the electricity grid than tidal or ocean thermal energy.

Most of the current generation of wave energy converters are designed to operate in water depths up to approximately 50m. The spatial distribution of time-averaged wave power on the Australian continental shelf (kW/m) in water depths of 50m or less is illustrated in Figure 43 where the colour scaled wave power at each location represents a time-average of an 11 year time series from March 1997 to February 2008, and the state figures are the mean of the available power.

There are significant differences in the wave regime between the south-western margin and eastern coast of Australia as illustrated in Figure 43. The optimal deployment of most wave energy converter technologies requires sites with consistent unimodal sea states. The wave regime along the South-Western Australian margin is particularly attractive for wave generation projects.

Economics

Wave power technologies are in their early stage of commercialisation. The Levelised Cost of Electricity is likely to be similar to global predictions for the first quarter of 2012 at around \$450/MWh (FrankfurtSchool, 2012).

The Australian Energy Resource Assessment refers to the International Energy Agency production costs between US\$60 – 300 per kW (in 2005 dollars), with wave systems at the higher end of the cost spectrum.

Until the technology develops, the cost of wave power will likely be higher than other more mature renewable energy technologies.

Main feasibility drivers

In addition to the typical project development considerations of the wave plant, the following should be considered;

Resource

The wave resource and the proximity of a load are key aspect of the feasibility of a wave project.

Geotechnical environment

For the wave technology involving anchoring to the ground, the geotechnical of the marine ground is absolutely critical. The wave technology system will purposely been implemented in areas with strong wave power, and there have been cases of system that have been pulled off the ground and landed on the cliff.

Wave

The submarine topography is also a key factor in the selection of the transmission cable route and the choice of construction techniques.

Environmental Impact

The wave power system as well as the grid connection will have an impact on the submarine environment and studies including ecological impact assessment, submarine noise assessment and environmental impact assessment will likely be required.

Is there a business case for off-grid wave systems?

More primary measured data is required to quantify Australia's wave resources. The Victorian government has aimed to address this challenge having deployed two buoys to monitor the waves at Port Campbell and Cape Bridgewater.

There is no commercially mature wave technology at this point in time, resulting in most government funds being directed at research and demonstration projects. For example, the Perth Wave Energy project received ARENA funding for the world's first demonstration of a complete grid-connected, commercial scale Cylindrical Energy Transformation Oscillator (CETO) system.

Due to the immaturity of the technology, the capital cost of the system including grid connection is still relatively high compared to other renewable energy sources. In 2010, the IEA suggested that wave power costs were between \$6.8million/MW and \$9million/MW (IEA, 2010).

Geothermal

Geothermal

Technical Description

Geothermal energy uses the natural heat from deep ground wells to produce electricity via a turbine and heat. Geothermal energy is a major resource and potential source of low emissions renewable energy suitable for base-load electricity generation and direct-use applications.

This heat is either held within dry rocks or transferred into water which is held underground in aquifers, or through direct heat associated with surface volcanic activity. As Australia is not an active volcanic country the primary geothermal resources are sedimentary aquifers and hot dry rocks.

Based on the IEA, the global geothermal capacity is approximately 9GW, with an electricity generation potential less than 1 per cent of the global electricity demand.

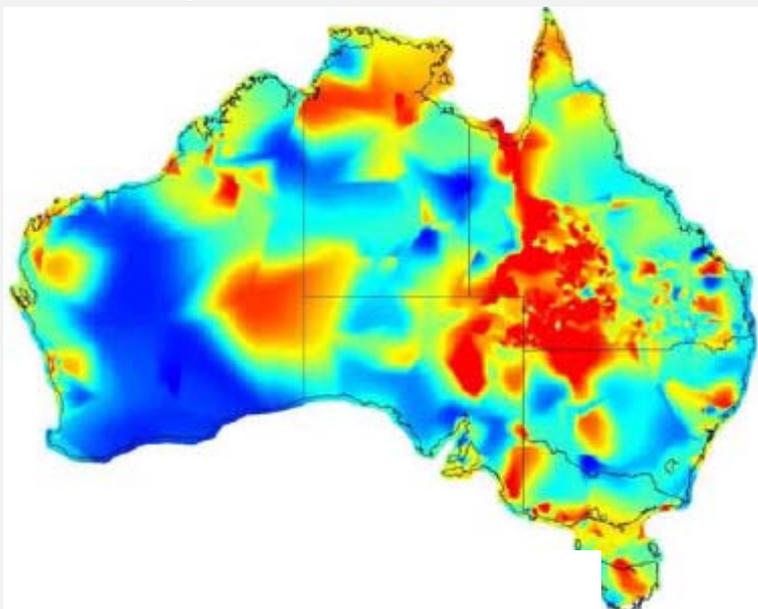
Australian Geothermal resource

Australia has substantial potential for Hot Rock/ Engineered Geothermal Systems and Hot Sedimentary Aquifer resources. These are respectively associated with buried high heat-producing granites and lower temperature geothermal resources associated with naturally-circulating waters in aquifers deep in sedimentary basins.

Australia's geothermal potential has recently been estimated to be circa 2,572,280PJ (Sub-economic Identified Resources) and a recent reports estimates that geothermal electricity generation could account for up to 40 per cent of the Renewable. However, there is a knowledge gap around geothermal potential as only sporadic drilling tests at a limited number of locations in Australia have been executed.

There are known large geothermal resources in remote locations providing opportunities to connect to nearby large loads such as mines or processing facilities.

Figure 44 Potential for Geothermal in Australia



Source: Hot Rock Energy Program, Australian National University

State of the Australian Geothermal market

For geothermal electricity generation, Australia is at proof-of-concept or early commercial demonstration stage. The only commercial operating geothermal plant in Australia is the 80kW Birdsville Organic Rankine Cycle Geothermal Power Station. As such, significant Australian Federal Government funding has been directed to these early stages of development.

In 2009 government funding were awarded to four commercial-scale renewable energy projects as part of Renewable Energy Demonstration Program (REDP). The successful geothermal projects included a 30MW project developed by MNGI, which received a \$63 million grant and the 25MW Cooper demonstration project developed by Geodynamics, which received a \$90 million grant).

In addition, \$50 million funding was devoted to the Geothermal Drilling Program (GDP) to provide assistance to companies seeking to develop geothermal energy with the cost of proof-of-concept projects including drilling geothermal wells. Seven projects have received funding, capped at \$7million per project: (Australian Government (c), 2009)

Geothermal

- MNGI Pty Ltd - at Paralana, South Australia
- Panax Geothermal Ltd – at the Limestone Coast, South Australia
- Hot Rock Ltd – Koroit in the Otway Basin, Victoria
- Geodynamics – near Bulga in the Hunter Valley, New South Wales
- GRE Geothermal WA1 Pty Ltd – Perth metro area, Western Australia
- Greenerth Energy Ltd – near Geelong, Victoria
- Torrens Energy Ltd – Parachilna, South Australia

Since this allocation of funding, the geothermal companies have not raised enough capital to complete their projects, which had a negative impact on investor confidence for the geothermal market.

State governments have also contributed funding to various projects. The Victorian Government's Sustainable Energy Large Scale Demonstration Program awarded \$25 million to the Geelong Geothermal Power Project for proof of concept and a 12MWe demonstration plant (VIC Government (c), 2013). The Western Australia Government's Drilling Incentives Scheme provided a total of \$295,000 to Green Rock Energy Limited for drilling (AGEA, 2011).

In the private sector, Origin Energy joint venture with Geodynamics Limited invested significant fund in geothermal energy, including in the development of a concept for the Enhanced Geothermal System (EGS) project in the Cooper Basin, South Australia in March 2009. However, Origin Energy, has recently withdrawn further funding to the project closing the joint venture (Parkinson, 2013)

Currently, the only available funding for geothermal projects is the Australian Government's Australian Renewable Energy Agency (ARENA) \$126 million Emerging Renewables Program.

As geothermal project development relies upon large upfront capital investment, the geothermal market is likely to remain slow and small until additional private and government funding becomes available.

Economics

Until geothermal electricity generation projects are commercially viable the cost of geothermal electricity will remain uncertain. A major barrier is the upfront cost of establishing a geothermal plant. Around 70-80 per cent of the overall cost of geothermal electricity can be attributed to exploration, well-drilling and plant construction. In particular, drilling can comprise a third to half of the total cost of a geothermal project with cost estimated around \$10-15 million to drill to a well depth of 5km (GeoscienceAustralia, 2010).

Main feasibility drivers

In addition to the typical project development considerations of the geothermal plant, the following should be considered;

Exploration and proof of concept

Exploration and proof of concept is costly and there is a large risk in proving a geothermal resource is suitable and reliable for a certain electricity production yield. Some initiatives have aimed to improve transparency across the industry such as the creation of the Australian Code for Reporting Exploration Results, Geothermal Resources and Geothermal Reserves. In addition, the NSW and VIC government encourage information sharing, providing public access to interactive state maps and state resource assessments.

Location of the resource

For remote locations where there are known large geothermal resources, the challenge is finding a load to match the potential geothermal electricity generation or fund the additional transmission infrastructure to connect to the electricity grid.

Environment and Planning

Environment and planning issues are involved both at the exploration stage and development stage. The Victorian Government has been supportive of geothermal explorations, issuing over 20 exploration permits across the state. Recent explorations indicate hot sedimentary aquifers between Geelong and beyond the border of South Australia (VIC Government (c), 2013).

Geothermal

Is there a business case for off-grid geothermal systems?

Depending on the geothermal resource however some remote areas of Queensland, Western Australia, Northern Territory and South Australia may be good prospects for future geothermal power generation. Due to the maturity of many of the projects and limited understanding of the geothermal resource in Australia, geothermal developments will likely begin in locations that are situated close to either the SWIS or NEM due to the additional costs associated with remote applications of the technology.

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