CSIRO Future Grid Flagship Cluster

Project 3: Economic and investment models for future grids

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Deliverable 1b:

Literature Review and Updated Project Plan

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Introduction

Distributed Generation (DG), which is electricity generation located close to the load/demand. While the definition of DG is far from "settled" [1], for the purpose of this project, DG will refer to electricity generation that is produced and consumed within the catchment area of the local Distribution Network Service Provider (DSNP). Many in the energy economics and policy literature also use the term "embedded generation", which tends to reflect DG that has been incorporated into a larger electricity grid (but often still retains the ability to operate in isolation from the grid). Distributed power generation has been used for decades [2], and has been met with mixed success. There is a plethora of literature that examines the use of DG in developing countries [3-5], in relation to World Bank development projects [6], with respect to high penetration of DG in Australia [7-10], and for a more general discussion [5]. Furthermore, the DG literature has been growing and is now being examined in context of rural communities across different scales from household systems [11] to community mini-grids [12] and grid connected systems [13].

The two types of DG most commonly used are individual household electrification (the most common method being solar home systems (SHS)) and mini/micro-grids [13]. The future grid, while an amorphous conceptualization will evolve to such an extent that we may realise a potential energetic epistemological rupture where users and the electricity supply sector, may evolve to rely heavily on DG by 2050. However, the current hegemony of the centralised energy distribution system [14] will require significant assistance in overcoming the perceived infrastructural bias in the existing system [15-17].

Household electrification and mini-grids are discussed in sections below, where Mini-grids operate as a grid-type system within a community or area and function much the same as a large centralised grid, except electricity is generated locally and provided to the community (including businesses and other consumers). In contrast, individual household electrification is focused on providing electricity to individual households, and not to the community at large. Approximately 9% of Australian generation capacity is from distributed generation, of which approximately 32% is from renewable sources (mainly wind, bagasse and hydro) [8].

Following the analysis of the impacts and societal utility which DG could offer in an Australian context, the CSIRO [8] have concluded that DG appeared to be an effective greenhouse gas mitigation option due to the following:

- DG is more able to match growing demand by using smaller units, thereby reducing the impact of large stepwise additions to centralised generation capacity. The "lumpiness" of investment [18], in generation assets has long been seen as not only an optimal timing issue but also a soothsayer for dramatic shifts in price [19-21];
- DG allows for reduced electrical losses from transmission and distribution by locating generation close to the point of use. Although it has since been shown that the ability for DG to reduce distribution losses is highly dependent on the rate of deployment and its percentage of total load in that network [22, 23];
- DG is modular and can be tailored to end-user requirements [24-28].

The use of DG for grid-connected communities on rural feeders is likely to be particularly beneficial [29, 30]. These benefits are likely to result from improvements in losses and delays from network augmentation [30]. This would especially be the case where peak loads could be correlated with peak generation times [8], although DG may impose an additional burden on the network operator in terms of the equipment needed for voltage stability support under the new operating conditions of grid connected DG.

DG could also have a substantial impact on distribution network losses which are generally in the order of 11% in Australia, though losses may be higher on longer rural feeders, by reducing the load through the network. These losses are likely to reduce because cost-effective wires such as galvanised steel over long distances have high losses, and the more DG on the network, the lower the losses are likely to be. However, this is subject to DG penetration not exceeding the ‘saturation point’ in a distribution network which results in increased (not decreased) losses [8].

The potential benefits for generation located close to the point of demand are the primary benefit of grid-connected DG. While DG can potentially cause voltage stability issues and other network losses, it also has the potential to increase stability and defer network augmentation. Furthermore, DG is particularly suited to Australian regional and remote communities due to the length of distribution networks and sparse population.

Individual Household Electrification

Household electrification is considered to be at the very small scale and has been used primarily in developing countries that have previously had no access to electricity. These systems are generally scalable and can therefore cater to different electricity requirements. However, due to the high cost per kWh they tend to only be used to satisfy basic electricity requirements including lighting, radios, TVs, and to recharge batteries. Household electrification presents some advantages over a mini-grid especially when provided to households that have not previously had access to electricity. This is because it is not necessary to construct infrastructure to distribute electricity throughout a community, and newly electrified households tend to have relatively low electricity requirements (at least initially). When used for lighting and charging batteries (small units) household systems tend to be relatively inexpensive and not offer 24 hour a day power. This method of electrification has been favoured by many international donor agencies as a method for providing basic electricity needs - primarily via solar home systems (SHS) [31].

Household electrification when combined with appropriate training and a suitable institutional framework is an effective method of providing basic electricity needs. However, Australian communities already have electricity access and consequently very small systems generally will not be sufficient or affordable. Powering whole communities via individual distributed generators (whether via solar or other methods) is expensive, as economies of scale generally cannot be exploited. Further, even for communities that are not grid-connected, electricity distribution infrastructure is already in existence and can be exploited by larger systems. Consequently, household scale electrification will not be considered further in this review. Mini-grid systems are more closely aligned with existing institutional frameworks and can exploit existing infrastructure. Success of an electrification program tends to be reflective of the institutional framework underpinning it [8, 31].

Mini-grids

Mini-grids represent a compromise between scale, and adaptability to exploit local resources. They allow community scale electrification, centralisation of maintenance and repair responsibilities, and have been used with varying degrees of success around the world. In Australia, remote off-grid communities are powered by mini-grids with electricity typically provided via diesel generators [7, 32, 33].

Mini-grid systems also allow institutions and agencies that are familiar with large centralised distribution networks to apply their expertise and experience to the low voltage network. This can help overcome the challenges of adapting existing institutional frameworks and resolving economic, technical and organisational hurdles that can cause the failure of DG projects.

The key benefits of mini-grids include economies of scale, the ability to exploit local energy resources for electricity generation, scalability of production, matching generation capacity to community requirements, having electricity available for public buildings such as hospitals and closer alignment with existing institutional frameworks. Mini-grids are generally suited to communities where the population is less dispersed as this minimises the distribution network costs. They can provide 24 hour electricity and the capacity for that power to be used for a range of applications comparable to consumers connected to conventional electricity grids. 24 hour electricity availability is important because it allows for refrigeration of foods and medicine, and has also been linked to poverty alleviation which "can only be achieved if a wide range of productive and non-productive (welfare-enhancing) uses of electricity are established" (Yadoo & Cruickshank, 2012).

Mini-grids also have the potential to be incorporated into large centralised grids if those grids ever expand sufficiently to include the relevant community [32]. In this way, they can be a valuable transitionary electrification alternative to ensure reliable electricity access while centralised grids expand. Some technical issues have been identified regarding the integration of DG systems into larger grids. These generally relate to network stability and reinforcement and connection costs. Nevertheless, the prospect of grid-connected communities powered with DG that can also be isolated from centralised grids is advantageous, especially to communities that are in a grey area (or just beyond) where the viability of grid extension is too low at the time of electrification. The CSIRO [8], concluded that DG, especially when accompanied by Smart Grids (electronic demand and supply matching software that increases grid efficiency) have significant potential in Australia. This is especially the case, for communities that are connected to an electricity grid but are located away from the generation source, as local electricity generation can reduce the need for expensive infrastructure maintenance and upgrades due to aging infrastructure and increasing loads.

Mini-grids provide a practical alternative to grid extension, while still having the capacity to provide electricity in a manner similar to centralised electricity grids. The potential to exploit local resources (when utilising renewable technologies), and cater for community characteristics, while avoiding excessive costs associated with grid extension is also significant. It allows for more practical implementation of renewable energy into established distribution networks (both on and off-grid).

There is substantial literature regarding both urban and rural electrification. However, providing electricity to rural communities has become increasingly important likely resulting from persistent challenges associated with providing electricity in these areas and UN recognition that electricity access is an important component of improving rural livelihoods. Analysis of different approaches to rural electrification including the comparative advantages of grid extension versus distributed generation is increasingly common due to the high infrastructure costs of grid extension and the increasing significance of environmental considerations.

Regional and remote areas pose challenges not normally associated with the urban environment, such as geographical isolation, comparatively low electricity consumption and sparse populations. Consequently, the cost of providing electricity is more expensive [4]. Generally the additional costs associated with rural electrification are either directly subsidised by governments or socialised across the electricity network so that all consumers pay a common tariff (the latter is the method generally adopted in Australia). Much of the literature has focussed on providing electricity to rural communities in developing countries that have not previously had access (Table 1), sets out relevant literature regarding rural electrification, and the use of renewable energy.

The Australian electricity sector

Australia is a developed country with substantial natural energy resources and established electricity infrastructure. Like most developed nations it is almost 100% electrified. Some 99.9% of households have access to electricity [34], geographical size and relatively sparse population. Australia is highly urbanised. The majority of the population receives electricity via large centralised electricity grids that service major cities and towns. There is no national electricity grid. Instead, the majority of the population is serviced by three separate electricity markets, the National Electricity Market (NEM) which services Queensland, New South Wales, Victoria, Tasmania and South Australia – see Figure 4, the Darwin Katherine Interconnected System (DKIS) which operates in the Northern Territory – see Figure 5, and the Wholesale Electricity Market (WEM) which operates in Western Australia and incorporates the South West Interconnected System and the North West Interconnected System in the Pilbara – see Figure 6. As can be seen from Figures 4-6 a substantial geographical area throughout regional and remote Australia lies outside these networks. Communities that are not connected to an electricity grid receive their electricity via small distributed mini-grids as can be seen in Figures 5-6 and are generally powered by diesel generator. Households and businesses (generally farmers, or mining) that are located outside rural communities generate their own power on-site.

Australia faces unique challenges not generally associated with other developed countries. It has very low population density (2.9 persons per square kilometre in 2010) [35] and 89% of the population lived in urban areas in 2010 [36], primarily along the eastern seaboard. Consequently, a vast geographical area of Australia is sparsely populated, with communities located far from urban centres. These communities are generally located inland, and have different characteristics, different levels of economic development, and different energy needs. The need to engage with local communities is therefore of critical importance to facilitate community support and participation and also to ensure the energy system is appropriate for each community. Rural communities that are not connected to an electricity grid are generally powered by diesel generators. For example, in Queensland, Ergon Energy

(Ergon), the regional electricity utility has 33 power stations, not connected to an electricity grid that produce approximately 101,000 megawatt hours (MWh) of energy per annum, all except 3, relying entirely on diesel generators. Ergon operates a substantial network across regional Queensland, including a substantial Single Wire Earth Return (SWER) network that covers much of inland/Western Queensland. Figure 7 shows the extent of the SWER network operated by Ergon, and Figure 8 shows the extent of the Ergon distribution network.

The standard and reliability of electricity in Australian rural/remote communities is generally quite high as power is provided and administered by government utilities and/or agencies. In its network review, Ergon identified that the main reliability challenge for regional communities is the higher level of exposure due to significant radial line distance from a bulk supply or zone substation to the customer. Approximately 30% of Ergon Energy's customers are fed from radial sub-transmission networks, where a loss of one line will result in significant loss of supply. The use of SWER lines has caused some issues with voltage stability and harmonic balance (Energy, 2011). Further, 14% of SWER systems may be overloaded while a further 6% are at or near full cyclic capacity. System studies have also identified 18% suffering voltage quality constraints with a further 5% nearing voltage limits. Major challenges for isolated generation include difficulties in obtaining materials, equipment and contractor services in the isolated generation areas and the need to pay a premium for contractor resources when obtained. Ergon has specifically recognised the potential for off-grid systems to be developed to improve reliability and asset life, as well as reduce service and maintenance requirements (Energy, 2011).

Much of the Australian electricity literature considers the NEM, DKIS and WEM networks with an urban focus. There is surprisingly little literature addressing electrification in regional and remote Australia, particularly at a community scale. The literature presented in Table 2 provides a summary of the types of papers that have been published regarding rural electrification in Australia.

In addition to the articles set out in Tables 1 and 2, government departments, electricity utilities and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) have published relevant articles and reports. One of CSIRO's key research priorities is to "help Australia move to a clean, secure energy future and maximise the wealth from its resources" . Consequently, CSIRO has examined a broad range of factors regarding the Australian electricity industry, including issues associated with the integration of renewables in rural areas, and different renewable technologies. (Jim Hinkley et al., 2011) examined concentrated solar thermal, solar intermittency and the potential consequences of a high penetration of solar into electricity grids (Saad Sayeef et al., 2012) considered wind farms, community attitudes and social acceptance, (CSIRO, 2012; Dr Nina Hall, 2011; Maru, McAllister, & Smith, 2007) considered bioenergy/biofuels (Deborah O'Connell, David Batten, et al., 2007; Deborah O'Connell, Victoria Haritos, et al., 2007) considered large scale renewables in remote areas of Australia (Pittock, 2011) and distributed generation/smart grids (Cornforth, 2011; CSIRO, 2009). This literature examines both urban and regional on/off-grid connected areas. Nevertheless, there is little substantive economic analysis of the viability of renewables to supplement or replace existing generation particularly in remote areas. Many of the reports such as the comprehensive analysis of Intelligent grid and distributed generation (CSIRO, 2009) address rural and remote areas but do so at a macro-scale, focussing on what is required for broad-scale integration of renewables and distributed generation into the Australian electricity system. Consequently, understanding of what affects the implementation of renewable energy in regional and remote areas at the community level, together with a systematic methodological approach is lacking. Any analysis of the viability of distributed generation with renewable energy that is confined to purely financial considerations, will be of little utility given that consumer behaviour, and how consumers make decisions about their energy supply influences the adoption and support for deployment [8].

CSIRO [8], identified 6 barriers that exist for all forms of distributed energy (both renewable and non-renewable) consisting of:

1. Policy/regulatory barriers including short-term policy horizons [8, 37]
    a. the extent of separation between energy policy and social/environmental objectives
    b. lack of political will to effect change
2. Financial costs including the extent that the current cost of energy does not incorporate externalities and access to markets [8, 37]
3. Decision making barriers including lack of certainty with respect to efficacy of decisions, fear of disruption and delay, long project timeframes and absence of effective systematic decision making approaches;
4. Energy market structure and capacity barriers including lack of institutional experience with different technologies, distributed generation and, network ability to integrate intermittent technologies and two-directional flow,
5. Information barriers including access to data regarding weather conditions, network connection, network capacity, local electricity demand and usage
6. Technological barriers including technology immaturity

This project will contribute to overcoming most of these barriers in the regional and remote area context with the possible exception of technological barriers, as they are largely from an engineering perspective.

Further to the literature discussed above, there are a range of government programs and institutes that address the utility of renewable energy in the Australian electricity generation context. Desert Knowledge Australia, based in Alice Springs, operates a Solar Centre where different types of solar technologies are demonstrated in arid conditions of Central Australia. The Solar Centre makes historical data of the different technology types publicly available. The University of Queensland has the Global Change Institute, which has one of its priorities areas as renewable energy technology and implementation. A range of other government sponsored programs such as the now completed Bushlight program, and the 2012 Rural Indigenous Energy Program (RIEP) were both aimed at providing renewable energy to very remote indigenous communities across Australia. The Bushlight program aimed to provide electricity to remote indigenous communities using photovoltaic solar cells with battery backup. The RIEP is not confined to particular technologies, but is instead focused on replacing existing generation (generally diesel) with renewable energy in small communities (maximum 50 people) throughout Australia. A number of publications arose through the course of the Bushlight program. These range from analysis of the program itself, to 'how to' guides when dealing with indigenous communities and training. See for example, (Technology, 2006) which sets out an energy planning process for renewable communities; (Ltd, 2005) which was an independent evaluation report of the Bushlight Program with preliminary a conclusion that the use of solar PV was more cost effective than intermittent diesel generator use previously used and community appreciation for the benefits of solar PV installed. (Coull, 2007) articulates the Bushlight approach to powering small remote indigenous communities.

The literature reveals a range of challenges for electrification in Australia. These challenges differ between regions and communities, and when coupled with the implementation of renewables are not insignificant. Ultimately, the fundamental challenges to the viability of renewable energy used for community electrification relate to the harsh and varied Australian environment, the vast geographical area, low population density outside urban areas, and the relative inexperience with renewable energy use in Australia. Notwithstanding the existing Australian literature, and range of government projects, there remains a lack of understanding about what affects the viability of distributed generation with renewables, and the implementation of renewable energy in Australia.

Conclusion:

Table 1 and Table 2 show a diverse range of studies exist in the literature. However, it is possible to identify the seven core themes below:

1. Rural electrification is characterised by geographical remoteness, dispersed consumers, higher costs of supply and maintenance, low consumption and limited ability to pay [38, 39].
2. Successful community rural electrification projects generally require community participation and supportive institutional frameworks [38, 40-46].
3. Projects must be technically appropriate (exploiting available resources where possible), financially affordable, and reflect the energy requirements of the rural consumers [4, 5, 47-49].
4. Where rural consumers live relatively close together (such as in a village or town) then mini-grids are a more appropriate electrification option than individual household and/or business electrification [5, 49].
5. To ensure electricity is provided to regional areas, it is often necessary to directly subsidise or socialise the cost of providing electricity to regional and remote consumers (at least in part). This imposes external costs on governments and/or other electricity consumers and requires different approaches to electrification through grid extension to urban, or semi-urban consumers so as to minimise these costs [5, 49]
6. The provision of electricity is a valuable and necessary input for the improvement of rural livelihoods especially when combined with complimentary infrastructure, but of

itself can have limited impact in improving livelihoods, especially in an economic sense [41].

7. Research tends to be case based and focused on community types with common characteristics. These types of case-based studies sometimes attempt to generalise the results in a statistical sense. That is, it is suggested that analyses of similar community types, albeit in different contexts (and countries at times) are argued to provide generalizable results. The value of case studies is in the understanding gained following a detailed, in-depth analysis. This approach allows isolation of factors and drivers that are not readily apparent, or detectable in large statistical analyses [50, 51].

Figure 1: The National Electricity Market [52].

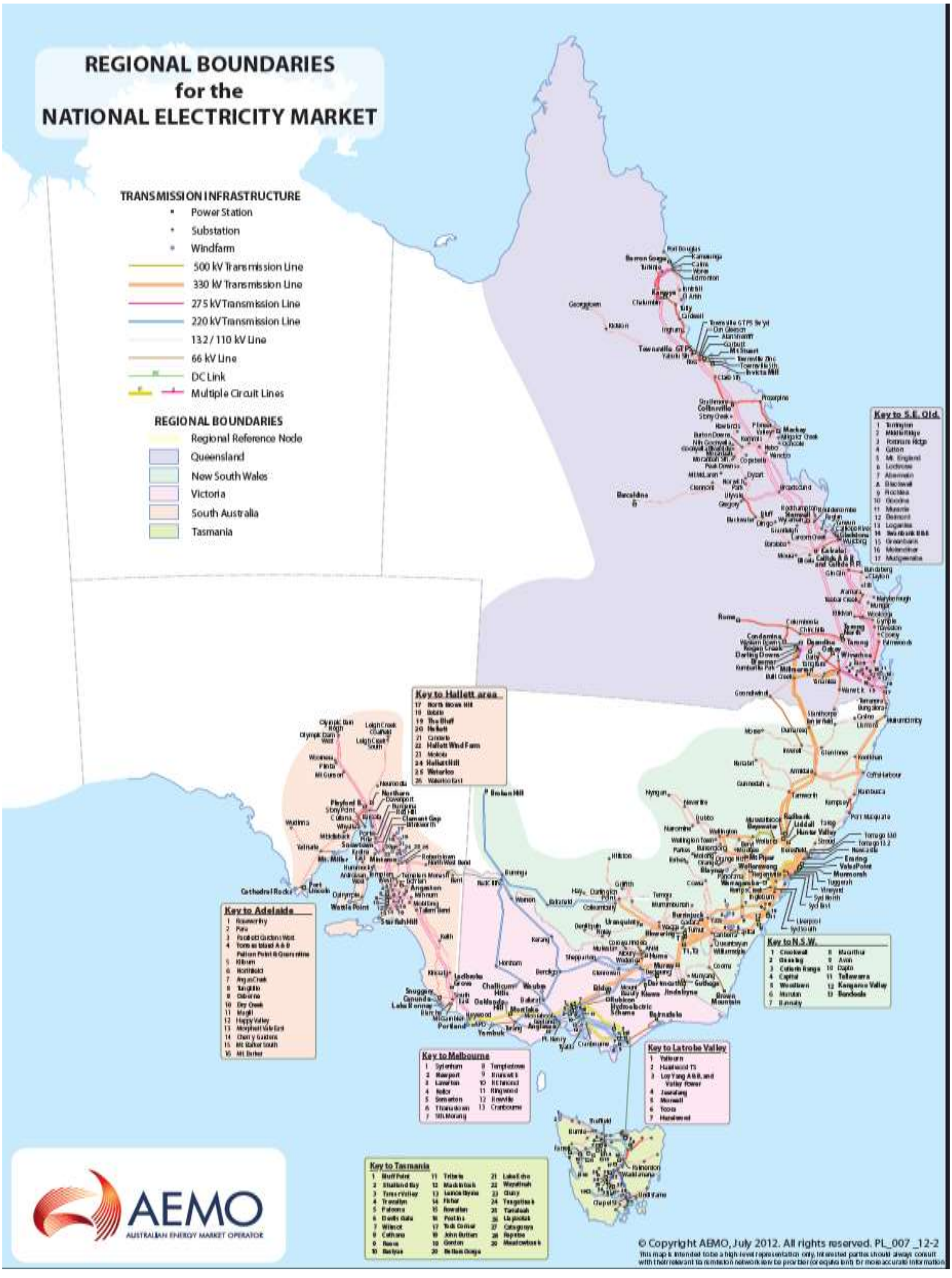

Figure 2: DKIS and NT Electricity Network [53].

Figure 3: WEM and WA electricity generation [54].

Figure 4 Ergon Electricity Distribution and Generation [55].

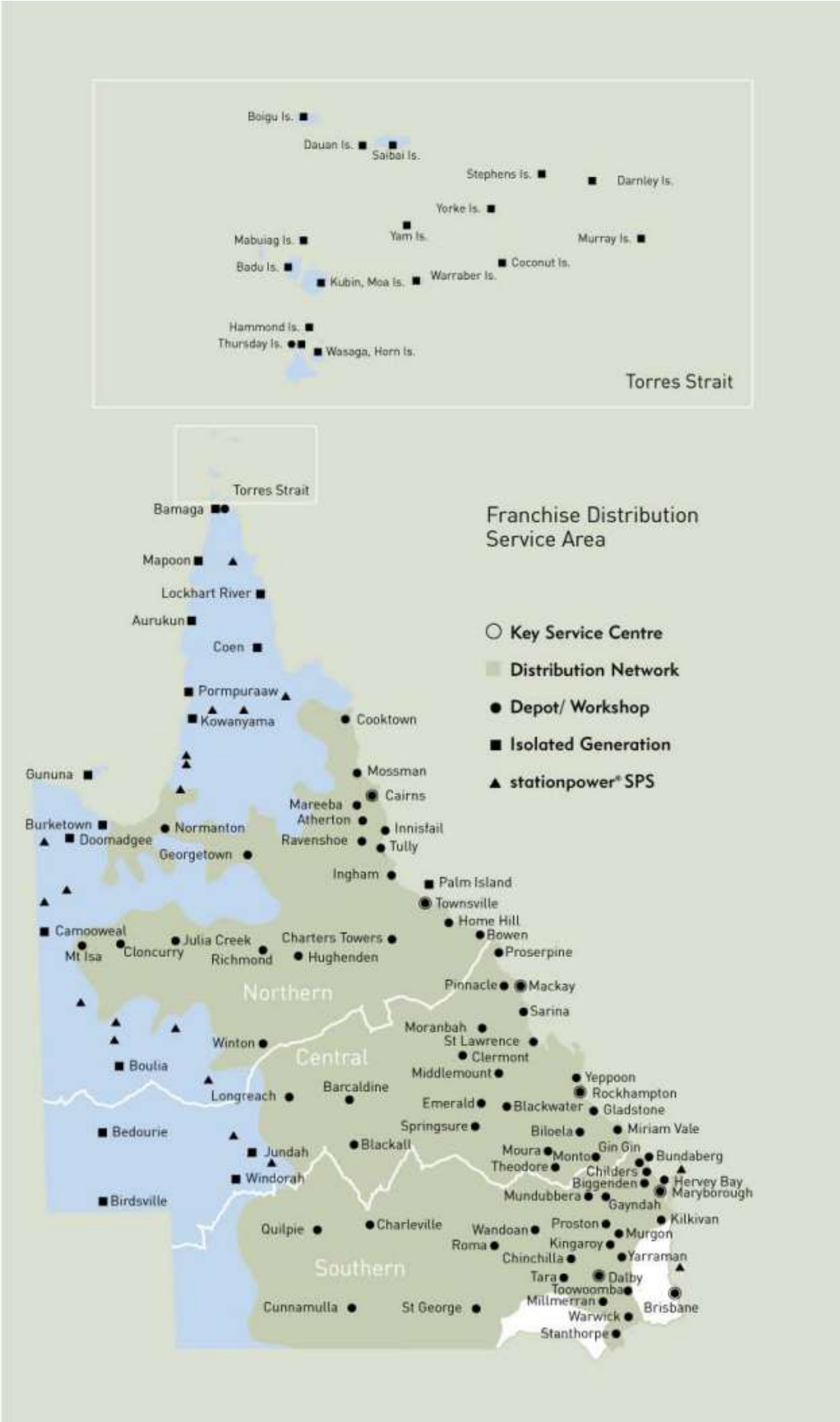

Figure 5: Ergon SWER Network [56]

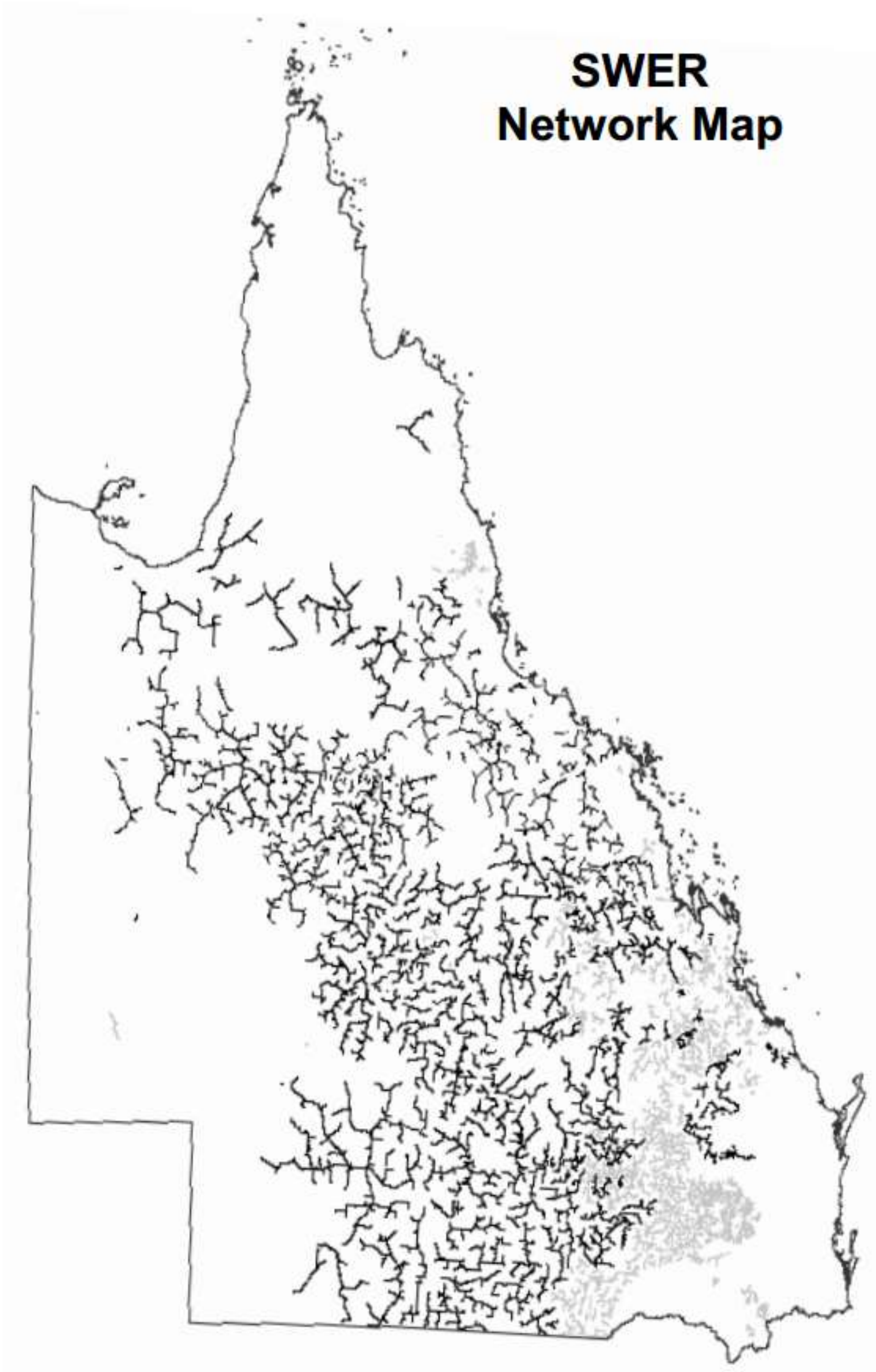

Table 1: International Literature Survey

Reference	Technology application	Location	Summary
Yadoo & Cruickshank, 2012 **[49]**	Renewables generally, with a focus on biomass gasifiers and micro-hydro plants	Nepal, Peru and Kenya	Evaluation of advantages and disadvantages of using renewable energy technologies for rural electrification, and policy considerations
Taele, Mokhutšoane, Hapazari, Tlali, & Senatla, 2012 **[57]**	Solar PV (SHS)	Lesotho	Evaluation of the Lesotho Renewable Energy-Based Rural Electrification Project which provides SHS to rural households in Lesotho.
Hong & Abe, 2012 **[43]**	Solar PV	Philippines	Evaluation of the centralised solar PV program on Pangan-an island in the Philippines
Singh, 2012 **[58]**	Various	Pacific Island nations	Evaluation of Pacific Island Nations and discussion regarding why the take up of renewables has been slow. Includes comparison between Pacific island nations and African/Caribbean counterparts.
Bhattacharyya, 2012 **[47]**	Various		Literature review of different projects and their methodological approach to evaluating viability in off-grid contexts.
Barnes, 2011 **[40]**	Various	Developing countries	Evaluation of institutional frameworks that have resulted in successful rural electrification programs
Yadoo, Gormally, & Cruickshank, 2011 **[46]**	Primarily micro-hydro, stand-alone solar, and onshore wind	United Kingdom, Nepal	Evaluation of case studies in Nepal and the UK to provide insight into off-grid electrification in developed countries (leveraging off knowledge gained in developing countries)
Palit & Chaurey, 2011 **[44]**	Various	South Asia (focussing on India, Bangladesh, Nepal, Sri Lanka)	Literature review of off-grid (primarily rural) electrification position of South Asian countries, and discussion of issues that need to be better addressed to facilitate off-grid electrification, and possibility of cross-country learning
Winkler et al., 2011 **[45]**	Various	Developing countries	Evaluation of institutional frameworks that have resulted in successful rural electrification programs
D'Agostino, Sovacool, & Bambawale, 2011 **[59]**	Solar PV home systems	China	Review of the effectiveness of the China rural electrification project (REDP)
Borgford-Parnell, 2011 **[60]**	Various	Mongolia, China	Analysis of Mongolian and Chinese energy systems and demand and potential synergies that could exist.
Ozturk, 2010 **[61]**	N/A	N/A	Literature review on the energy/growth nexus
Yadoo & Cruickshank, 2010 **[38]**	N/A	USA, Bangladesh and Nepal	Evaluation of institutional models (especially rural co-operatives) in the provision of electricity to rural consumers

Table 1 (Continued): International Literature Survey

Reference	Technology application	Location	Summary
Brent & Rogers, 2010 **[31]**	Onshore wind, solar and lead-acid battery energy storage technologies	South Africa	Evaluation of the sustainability of renewable energy technologies for off-grid applications focusing on a renewable energy system that had been implemented for village electrification in the Eastern Cape Province of South Africa
Abdullah et al., 2010 **[62]**	Hybrid diesel/ solar/hydro/fuel cell	Malaysia	Evaluation of the cost-effectiveness of existing solar PV system and solar/hydro schemes of the rural ICT are evaluated employing the HOMER simulation software.
Kaundinya, Balachandra, & Ravindranath, 2009 **[48]**	Various		Literature Review of rural electrification literature
Oikonomou et al., 2009 **[63]**	Onshore wind	Dodecanese islands, Greece	Evaluation of locations for application of onshore wind projects – applying the EU project EMERGENCE methodology
Lemaire, 2009 **[64]**	Solar PV	Zambia	Evaluation of fee for service companies to manage solar home systems in rural Zambia
Urmee, Harries, & Schlapfer, 2009 **[65]**	Solar PV (SHS)	Bangladesh, Fiji	Evaluation of issues that have arisen using renewable energy for rural electrification purposes, including discussion regarding why there has been slow increase in rural electrification
Byrne, Zhou, Shen, & Hughes, 2007 **[66]**	Small-scale wind/Solar PV/ solar/wind hybrids	Western China	Evaluation of utility of renewable energy generators to provide local electricity needs using lifecycle costing and geographic information system (GIS) methods, to provide resource, economic, technological and livelihoods assessment.
van der Vleuten, Stam, & van der Plas, 2007 **[67]**	Solar Home Systems	Rural Africa	Evaluation of the use of SHS in rural Africa and what lessons or information are relevant – in response to (Karekezi & Kithyoma, 2002 **[68]**)
Bastakoti, 2006 **[69]**	Hydroelectricity	Nepal	Evaluation of the livelihood impacts following installation of 5 MW hydro plant in rural Nepal
Madubansi & Shackleton, 2006 **[70]**	N/A	South Africa	Evaluation of how provision of electricity to 5 rural communities has changed energy profiles, and consumption patters
Karekezi & Kithyoma, 2002 **[68]**	Solar Home Systems	Rural Africa	Evaluation of the role of SHS in rural Africa
Martinot, 2001 **[6]**	Various	Developing countries	Evaluation of World Bank projects incorporating renewable energy in rural areas, and discussion of the factors that impacted project success

Table 2: Australian Survey of DG Literature

Reference	Topic
Buys, Miller, & Van Megen, 2012 **[71]**	Case study analysis of rural community perceptions of climate change using semi-structure interviews of residents (not just farmers) in the Eden/Gippsland region on the border of New South Wales and Victoria and the north-east of Tasmania.
O'Connell, Batten, et al., 2007 **[72]; O'**Connell, Haritos, et al., 2007 **[72];** Rodriguez, May, Herr, & O'Connell, 2011 **[73]**	Analysis of biofuels, and biomass gasification/electricity generation in rural Australia. Deborah O'Connell, David Batten, et al., 2007 **[72]**; Deborah O'Connell, Victoria Haritos, et al., 2007 **[72]**) examine biomass/biofuel research priorities for the Australian Rural Industries Research and Development Corporation. Rodriguez et al., 2011 **[73]** conclude that biomass is viable for use biomass fired electricity is viable in Mt Gambier using feedstock with a plant gate cost of 46 Australian Dollars (AUD) per tonne under the current REC price of 34 AUD per MWh
Martin & Rice, 2012 **[74]**	Examines the development of the renewable energy sector in Queensland, concluding that a range of socio-technical barriers persist.
McHenry, 2009 **[75, 76]**; McHenry, 2012 **[77, 78];** M. P. McHenry, 2012 **[79]**	Case based study of small systems (generally pastoral stations) the utility of various renewable technology options, and what has impact the up-take of renewable energy in rural/remote pastoral areas
Effendi & Courvisanos, 2012 **[80]**	Discussion of slow up-take in the use of renewable technologies in Australia in light of political aspects and public innovation policy
Rodriguez et al., 2011 **[73]**	Analysis of the cost of electricity generation using direct firing of biomass, and estimate the required Renewable Energy Certificate (REC) prices to make it competitive with coal fired electricity generation and discussion of findings in the context of regional energy security and existing targets and incentives for renewable energies
Saad Sayeef et al., 2012 **[81]**	CSIRO report examining the effect is of high penetration of solar intermittency on Australian the NEM. The report noted that when solar generation, mainly PV, is attached to a rural feeder where the grid has high impedance, an increase in penetration is likely to cause large voltage swings to be observed. These increased voltage swings may have the potential to impact the stable operation of the network. It is also likely that PV inverters would trip off with these voltage swings, resulting in larger power fluctuations and therefore worsening the voltage swings.

Table 2 (Continued): Australian Survey of DG Literature

Reference	Topic
Falk & Settle, 2011 **[82]**; Kuwahata & Monroy, 2011 **[83]**; Marinova & Balaguer, 2009 **[84]**; Moloney, Horne, & Fien, 2010 **[85]**; Palutikof, 2010 **[86]**; Schläpfer, 2009 **[87]**; Yusuf, Goh, & Borserio, 2011 **[88]**; Wilkinson, 2011 **[89]**; Zahedi, 2011 **[90, 91]**	Analysis of the Australian energy system, the potential of renewable energy, challenges to incorporating renewables into the existing electricity supply (particularly from a government policy perspective)
Pittock, 2011 **[92]**	Analysis of desert/remote Australia and the potential contribution of renewable energy as the ramifications of climate change, and oil resource depletion take effect, including potential impacts on development.
Buys et al., 2012 **[71]**; CSIRO, 2012 **[93]**; Gross, 2007 **[94]**; Hindmarsh, 2010 **[95]**; Kinrade, 2007 **[96]**; Moloney et al., 2010 **[85]**	Analysis of the importance and role of community acceptance for renewable energy projects across Australia, particular wind energy
Hall, 2011 **[97]**; Hicks & Ison, 2011 **[42]**	Case studies that examine community owned renewable energy projects in Australia, and their potential to increase renewable energy use across rural Australia (even in grid connected areas)
Kuwahata & Monroy, 2011 **[83]**	Examines the types of renewable energy technologies in Australia that have the capacity to contribute to the growth of the renewable energy sector and suggestions re. the type of economic incentive instruments that could be applied to stimulate investment
Talal Yusuf et al., 2011 **[88]**	Discussion of existing energy sources and potential for renewables given Australia's available resources
Clifton & Boruff, 2010 **[98]**	Examination of the potential for concentrated solar power (CSP) in the Western Australian Wheat belt, concluding that CSP can be sited over large areas of the Wheat belt and tailored to local supply/demand patterns
Schläpfer, 2009 **[87]**	Discussion of Australia's energy policy and how it is biased against renewable technologies
Mitchell, Nagrial, & Rizk, 2009 **[99]**	Simulation of embedded solar generation in a suburban feeder network in Western Sydney where it was assumed that a solar panel was connected to the grid at each substation/load point on a radial distribution feeder. Concluded that there could be useful network benefit, and that storage has significant benefit, with a diminishing returns effect.
Schandl et al., 2008 **[100]**	Examination of Australia's resource use and expectations of future resource use patterns, concluding that there is there is significant potential for improvements in socio-technological systems and room for more sustainable household consumption
May & Brennan, 2006 **[101]**	Performs a sustainability assessment of power generation from Australian fossil fuels, notably black coal, brown coal and natural gas.
Harrison, Ho, & Mathew, 1996 **[102]**	Examination of small rural/remote communities and the appropriateness of renewable technologies versus existing (diesel generator) supply

Project 3 Updated work plan for 2013-2015.			
Project title:			
Research activity	**Expected completion date**	**Outcome**	**Corresponding Deliverable Number**
1. Literature Review	(Completed)	Broad scale deployment of renewables • Barriers to entry • Infancy of co-ordinated CO_2 abatement via renewables deployment • Techno-economic barriers (focused more on technology costs) • Regulatory barriers • Market structure • Incumbency	1a
2. Literature Review	(Completed)	Transmission expansion • Incentive structures for TNSP's • Planning and expansion • Scale efficient expansion • "Build it and they will come"	1a
3. Literature Review	(Completed)	Distributed generation (DG) • Global deployment, with particular focus on EU • DNSP incentives to adapt and encourage the deployment of DG • Examine international adoption and encouragement for DG as a method to improve reliability (FCAS and NCAS) • Market and economic barriers • "A Decentralised World" and the value of storage	1b

Project 3 work plan for 2013-2015.			
Project title:			
Research activity	**Expected completion date**	**Outcome**	**Corresponding Deliverable Number**

4. Data Validation	Dec 2013 /Jan 2014	Technology cost data agreement
		• Inputs into AETA and UQ LCOE models
		  ○ AETA modelling framework based on Worley's LCOE methodology released with 2012 AETA
		• Discussion with UNSW, USYD and UN with respect to:
		  ○ CAPEX and LRMC price formulation
		• Redistribution of technology costs to all members
		• Creation of technology costing framework for cluster modelling and accepted set of assumptions
			2

5. Data Validation	Dec 2013 /Jan 2014	Transmission topology agreement • USYD/UN IEEE 14 bus system • UQ representation • Discussion on transmission zone topology • CSIRO resource availability	2
6. Data Validation	Dec 2013 /Jan 2014	Gas price and availability forecasts to be shared with P2 for their gas network expansion model.	2
7. Protocols for model integration	Dec 2013 /Jan 2014	CSIRO Energy Sector Model (ESM) ↔ UQ PLEXOS/ANEM Market Models • Redevelop collaborative simulation database • Data integration exogenous to PLEXOS/ANEM with algorithms to integrate • Generation types/scenarios • Capacity available/retirement • Investment • Potential limitations of investment in ESM (Smoothness) and Plexos (Lumpy) • Issues with NLP vs. MIP optimisation • Resolve resolution issues with time step integration (Plexos ½ hourly and ESM yearly/seasonal duration curves) • Establish simulation time horizons	2

Project 3 work plan for 2013-2015.			
Project title:			
Research activity	**Expected completion date**	**Outcome**	**Corresponding Deliverable Number**
8. Protocols for model integration	Dec 2013 /Jan 2014	UN and USYD PLEXOS database integration • Network topology data sharing where applicable • Plexos UQ ↔ UN database integration will be fairly straight forward • Also USyd/UN IEEE 14-Bus system fairly well published and uses standard IEEE framework • UQ to discuss IEEE 30-bus work with UN	2
9. Benchmarking and Model Validation	Dec 2013 /Jan 2014	After establishing final generation and network topology we will examine historical • Generator behaviour • Price and Demand behavioural issues • Run base case 2010 and 2011	2
10. Benchmarking and Model Validation	Dec 2013 /Jan 2014	Provide a range of pre-emptive scenarios developed by UQ • Draft states of the world to be discussed with cluster • Re-modelling 2010/2011 using alternative policy frameworks These draft alternative policy frameworks will provide the cluster with an initial view of: • Likely future UQ modelling • Framework robustness • Points of comparison and inter project model and data revalidation • Suitability of draft states of the world Opportunity to integrate UN, UNSW and USYD scenarios for publication	2

Project 3 work plan for 2013-2015.			
Project title:			
Research activity	**Expected completion date**	**Outcome**	**Corresponding Deliverable Number**

11. Formal Scenario Development	Dec 2013 /Jan 2014	• Identify key policy options
		• Contextualisation of policy mixes
		• Examine likely paths for:
		    ○ Carbon abatement policy
		    ○ Fuel mix
		    ○ Renewables target
		    ○ “Nuclear”
		    ○ International factors
		• Develop states of the world
		• Re-evaluate modelling from base case/benchmarking process to incorporate alternate scenarios
		• Identification and evaluation of potential variable sensitivities
		    ○ Particularly fuel and carbon price forward curves
			2

12. Reporting	Dec 2013	End of Financial Year Report	2

13. Literature Review	1/6/2013	Battery Storage and Electric vehicles (EV),
		• Vehicle-to-Grid (V2G)
		• Deployment rates
		• Barriers to entry
		    ○ Liquid combustible fuel dominance/incumbency
		    ○ Battery life/Charge opportunities
		    ○ Capital cost requirements to meet growing charging station demand
		• Market dispatch and aggregation of battery storage
			3

14. Modelling	30/4/2014	Modelling multi-node transmission network models in Plexos and ANEM for integration into cluster agreed scenarios.	3
15. Modelling	30/4/2014	Analysis of global gas markets and potential price and supply availability impacts for the NEM.	3
16. Modelling	30/4/2014	Implementation of gas market forecasts into Plexos/ANEM and Project 2 (UN) gas network optimisation platform.	3
17. Modelling	30/9/2014	Co-Optimisation framework for deployment of generation technology and gas pipeline networks in collaboration with Project 2 (UN and CI Dong).	4

18. Modelling	30/9/2014	Design of electricity markets and transmission access arrangements in collaboration with Project 4 (CI MacGill and CSIRO).	4
19. Report	30/9/2014	**End of Financial Year Report**	4
20. Modelling	31/3/2015	Incorporation of modelling platforms for scenario deployment in electricity and fuel market platforms	5
21. Report	31/3/2015	Preparation and agreement of final model scenarios with all other projects and the CSIRO in light of the result of the Future Grid Forum	5
22. Report	Dec 2015	Final report and deployment of results and presentation of strategic priorities for key stakeholders	6

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