Centre for Energy and
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Cluster Project 4 – Robust energy policy frameworks for investment in the future grid: Draft Deliverable Report 2

by

Jenny Riesz, Peerapat Vithayasrichareon, Iain F. MacGill

Centre for Energy and Environmental Markets
University of NSW

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*Corresponding author: Iain MacGill
School of Electrical Engineering and Telecommunications, and Centre for Energy and Environmental Markets
The University of New South Wales, Sydney, NSW2052, Australia.
Tel.: +61 2 9385 4920, Fax: +61 29385 5993.
E-mail: i.macgill@unsw.edu.au

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1. Introduction

1.1. CSIRO Cluster Project Background

The broad objectives of this CSIRO Cluster project are:

- The development and application of an interdisciplinary policy assessment framework to better understand and assess existing and proposed policy options for driving appropriate investment in the electricity industry given its unique technical (e.g. system security), economic (e.g. network investment) and wider social (e.g. affordability imperatives) characteristics. A key focus is on the interactions between these policies.
- Development of a high level (ie. focused on broader policy relevant perspectives rather than just detailed technical and economic modelling) quantitative policy analysis tool for exploring the potential impact of different policies on the most economic future electricity generation portfolios.
- Application of this policy assessment framework and quantitative policy analysis tool to develop high level insights on coherent and comprehensive climate and energy policy frameworks to drive appropriate investment in the future grid. A particular focus is on maximising the synergies and minimising possible conflicts between multiple policy instruments such as might be seen with renewable energy targets and network investment drivers.

1.2. Scope of this report

This report is the second deliverable Milestone report for the CSIRO Future Grid project from the University of New South Wales. It includes discussion on the following topics:

- ***Interdisciplinary assessment framework*** – A summary of a proposed interdisciplinary assessment framework for policy relevant to the electricity sector
- ***Survey on Australian and international options and experience*** – A high level survey of Australian and international options and experience in policy relevant to the electricity sector, within the proposed interdisciplinary framework. This includes identification of the areas where further detailed research is likely to be useful and warranted to better understand the development of an efficient and successful future grid.
- ***Extensions to quantitative modelling tool*** – An overview of the extensions that have been developed for the quantitative modelling tool.
- ***Policy scenario development*** – Preliminary principles for the development of useful scenarios for quantitative analysis of policies affecting future grids.

2. Interdisciplinary assessment framework

Various attempts have been made to develop holistic and comprehensive assessment frameworks for policy, as summarised in the literature review in the first Milestone Report (Jones, Noone, & MacGill, 2013). This section summarises the intended approach to policy assessment, seeking a practical path forward that will allow the provision of meaningful policy analysis, founded upon the existing literature.

The electricity sector is highly complex, which makes it non trivial to develop an assessment framework for electricity-relevant policy. Electricity affects, and is affected by, almost every aspect of Australia's economy. It is managed and operated by a multitude of organisations each with differing and sometimes overlapping roles. Furthermore, electricity supply is bounded by unique constraints, including a multitude of technical limitations, social and equity implications, and economic challenges (such as the monopolistic nature of networks).

To develop a tool for policy assessment, it is necessary to first define what is meant by policy in the electricity sector. We define three "policy pillars", which are the broad categories of policy that affect the development of future grids. These are illustrated in Figure 2.1 with some examples listed. They are loosely defined as follows:

- ***Regulation*** – Any planning or investment processes that are managed mostly via regulation (rather than a market-based mechanism). At present, the Australian Energy Regulator (AER) is responsible for overseeing most regulation processes related to network investment planning in Australia. Various state-based organisations are also responsible for regulated determination of retail electricity tariff caps in some states, such as the Queensland Competition Authority (QCA) in Queensland, for example.
- ***Market Design*** – Aspects of the Australian electricity sector that are dictated by the design of the wholesale electricity market. On the east coast, this is the National Electricity Market (NEM). The market rules are mostly determined by the Australian Energy Market Commission (AEMC), with direction from the Standing Council on Energy and Resources (SCER) where Ministerial decision making is required. The market rules are applied by the Australian Energy Market Operator (AEMO).
- ***External Policy Drivers*** – These are policies put in place by local, State or Federal Governments which either deliberately or inadvertently affect the development and operation of the electricity sector.

In general, any policy can affect all of these areas simultaneously, often in complex and subtle ways. Therefore, any policy assessment must carefully consider the coherence of the policy in question within the context of the arrangements in place in all three policy pillars.

Figure 2.1 - The Three Policy Pillars (with examples)

1. Regulation	2. Market Design	3. External Policy Drivers
• Transmission network planning • Distribution network planning • Grid codes	• Fundamental market design • Spot market rules • Ancillary service market rules	• Carbon policies • Renewable & energy efficiency policies • Fuel policies

The complex and interrelated nature of the policy pillars makes cross-comparison between international markets challenging. An identical policy could be implemented in two different markets and produce very different outcomes, depending upon how that policy interacts with the surrounding market, regulatory and external policy factors. For example, subtle differences in grid codes or spot market rules can dramatically change the way that a renewable support policy functions. This makes it difficult to formulate simple conclusions about policy frameworks in a general sense. Instead, for meaningful conclusions to be drawn, each policy must be considered on a case by case basis within the complete framework in which it will operate.

The complexity and interrelated nature of the various aspects under each of the policy pillars also makes it extremely difficult to develop a useful policy assessment framework. It would need to be simultaneously sufficiently detailed to provide meaningful insights, but also sufficiently broad to be applicable to the wide range of policy types and the complex environments in which they operate.

Therefore, instead of attempting to develop a "one size fits all" assessment framework, we have focused on developing a practical assessment of the policy landscape in Australia, informed by international experiences. This assessment looks in detail at the various aspects under each policy pillar and seeks to identify where there are gaps, overlaps or unintended consequences, with a particular focus on those that are likely to become increasingly problematic as we transition to the future grid. Learnings from international experiences are a valuable component of this process, helping identify how the future grid might evolve, and how this will be affected by policy settings.

In general, good policy mechanisms will be:

- Successful at efficiently producing a clearly defined desired outcome,
- Coherent with the existing regulatory, market and external policy frameworks, ensuring minimal perverse or unintended consequences,
- Robust and resilient to change and uncertainty, and
- Provide accurate signals to relevant stakeholders about the consequences of their actions.

However, the merits and disadvantages of any policy in question will necessarily depend upon the intended purpose of that policy, and the broad context in which it operates.

The following section provides a high level survey of the policy landscape under the three policy pillars in Australia. Analysis is focused on areas that have been identified as exhibiting the potential for improvement, suggesting the opportunity for further analysis over the coming two years of the CSIRO Future Grid project.

3. Survey on Australian and international options and experience

This section provides a summary of a preliminary survey of the electricity-relevant policy landscape in Australia, under the three policy pillars identified in the previous section. Analysis thus far has focused only on the National Electricity Market (NEM).

Where detailed analysis has been conducted readers are referred to the relevant reports, with a brief summary of findings provided here. Publications completed are summarised for the reader in section 3.4, and the proposed areas of focus for future work are summarised in section 3.5.

3.1. Regulation

Transmission network planning processes

Transmission network planning processes were discussed in depth in the previous Milestone Report (Riesz, Noone, & MacGill, 2013). The processes around the development of transmission grids in Australia were outlined in detail, and compared with international literature and experiences. It was highlighted that the AEMC has recently completed an extensive multi-year review of transmission planning processes via the Transmission Frameworks Review (TFR). The TFR recommends implementing the "Optional Firm Access (OFA)" model, which aims to improve locational signals for generation investment, and to better co-optimise development of transmission networks with generation. The details of how this mechanism might be implemented are currently being developed by the AEMC and AEMO.

Analysis of the proposed OFA model yields several concerns. The most prominent of these is the proposed transition arrangements, which aim to provide certainty to incumbents about a minimum degree of financial network access for their "remaining economic life". This creates a competitive disadvantage to new entrants, since any new entrant would be required to purchase network access while incumbents are not. This creates the potential for significant windfall gains by incumbents, particularly since the process of determining their "remaining economic life" is likely to be open to negotiation and encourage rent seeking behaviour.

International markets have struggled with similar issues upon the introduction of nodal pricing models. The transition to nodal pricing necessarily creates winners and losers, and in many cases compensation has been deemed important to gain the support of all stakeholders for the introduction of the new pricing model (Neuhoff, 2013). However, it is highly non trivial to determine the optimal distribution of compensation payments, and in some cases the process applied has led to windfall gains by incumbents. There is potential to learn from these international examples, and suggest alternative transition mechanisms for the NEM upon the introduction of the OFA model. This is proposed as an important area for further work under the CSIRO Future Grid project, with interested readers referred to the previous Milestone report for more details (Riesz, Noone, & MacGill, 2013).

The processes for establishing new network assets for connecting remote renewables were also explored in depth in the previous Milestone report (Noone, Riesz, & MacGill, 2013). It was identified that the current arrangements are inadequate, and do not appropriately allow for major new transmission assets to be established. However, the proposed arrangements under the Transmission Frameworks Review could significantly ameliorate previous concerns under the earlier Scale Efficient Network Expansion proposal. This may allow a revisiting of this proposal. Learnings from international experiences in California, Texas and elsewhere also assist by providing examples of ways to limit risk exposure for consumers. Further work in this space is warranted to establish detailed mechanisms that could effectively allow transmission assets of this nature to be established.

CIGRE has recently launched a new working group on the topic "Coordination of grid investments with expansion of generation and new technologies". This provides an opportunity to examine alternative models for transmission investment with an international team of experienced professionals. The group intends to deliver a benchmark of measures implemented worldwide to allow a smoother coordination of investments, and a survey of best practices, analysing advantages and drawbacks of the main models and highlighting the conditions and prerequisites for their success. CEEM intends to engage with this group to contribute insights into Australia's experiences, and learn from international experiences.

Distribution network planning processes

Around half of retail customers' electricity payments are related to distribution networks (AEMC, 2013). This means that inefficiencies in the planning of distribution networks can have significant consequences for customer costs. Furthermore, with a shift to increasing proportions of energy being supplied by embedded generation, distribution grids are likely to need to evolve to manage bi-directional flows and wider ranges of voltage fluctuations, among other challenges. This has become an increasingly controversial issue, with adjustments to feed-in tariff levels to rooftop solar photovoltaics, and ongoing discussion about adjustments to network retail tariff structures.

These topics have formed the basis of a multi-year review by the AEMC (the Power of Choice Review) which recently completed (AEMC, 2012). A range of initiatives were recommended to better align incentives for distribution network service providers with the interests of consumers, and encourage greater implementation of demand side participation. Sequential implementation of many of these recommendations is currently underway.

Of growing interest is the potential for an increasing number of customers to primarily source energy from local renewables, moving towards using the grid for 'balancing' rather than as a primary source of energy. With further development of storage technologies, it may even become cost effective for some customers to disconnect from the grid entirely. In this scenario, network companies will need to carefully consider the way in which network tariffs are priced, to encourage customers to continue to use what could become stranded network assets, while discouraging continuing growth in peak demand (which would necessitate further costly investment in the grid). These concepts were explored in a book chapter by the authors, to be released in early 2014 (Riesz, Hindsberger, Gilmore, & Riedy, 2013).

Grid codes

Grid codes specify the minimum requirements for new generators connecting to the grid, across a wide range of technical parameters. The definition of appropriate grid codes is essential for secure operation of the grid, and interacts closely with other market design parameters.

For example, in the Hydro-Québec system a mandatory requirement for an emulated inertial response from new entrants has been implemented (Brisebois & Aubut, 2011). However, this may supply more response than is technically required, increasing costs. Furthermore, recent studies are showing that it may actually be detrimental to system security to have a rapid (but not sustained) simultaneous frequency response from all wind farms connected to the system, since this can lead to frequency oscillations (Ruttledge & Flynn, 2013). Although more complex to implement, appropriate incentives within market designs are likely to be a more efficient approach, especially in large markets where the additional complexity can be justified (Ela, Tuohy, Milligan, Kirby, & Brooks, 2012). Thus, grid codes interact closely with the design of the ancillary service market, and with other aspects of wholesale market design.

3.2. Market Design

Fundamental Market Design

There is a long-standing, ongoing debate about the fundamental design of electricity markets, focused around the manner in which "resource adequacy" should be managed, either via an "energy-only" market design, or more explicitly through a "capacity market" design.

Proponents of energy-only market models argue that they avoid the need for increasingly prescriptive regulations, and create better incentives for operations and investment (Hogan, 2005; Hogan, 2013). On the other side, proponents of capacity market models argue that an energy-only market cannot operate satisfactorily on its own; regulatory prescriptions for projected demand for energy, operating reserves and capacity are required (Cramton & Stoft, 2006; Cramton, Ockenfels, & Stoft, 2013). The debate is challenging to resolve due to a lack of sufficient evidence;

despite the presence of operating markets of both kinds for more than a decade, investment in energy infrastructure is most meaningfully analysed over longer timeframes (multiple decades). Furthermore, all markets have been subject to a range of external policy drivers that have undoubtedly affected investment, making it difficult to draw any firm conclusions about the success or failure of either market model.

The debate has re-entered the limelight over the past few years due to the transition towards renewable technologies. Renewable technologies have very low short run marginal costs, meaning that in a competitive market they will tend to drive typical spot market prices to very low levels. This has exacerbated the "missing money" problem in markets where there is political opposition to allowing a sufficiently high market price cap. Thus, several markets are now considering a move away from an energy-only market design towards a more explicit capacity market design of some kind. This includes the following electricity markets:

- ***Great Britain*** is in advanced planning stages of a move to a capacity market design (UK Government, 2013).
- ***Germany*** is in the midst of vigorous discussions on the optimal form of capacity market that could be adopted.
- ***Texas*** is in the early stages of a discussion around the possible need to move to a capacity market design (Baldick, 2013).

Given these significant shifts internationally, it is worth considering whether the energy-only market design presently implemented in the National Electricity Market (NEM) remains adequate in the context of very high renewable penetration.

This was the topic of a conference paper presented by the authors at the Solar Integration Workshop in London in October 2013 (Riesz & MacGill, 2013). Preliminary work indicates that the energy-only market design could remain adequate in theory, but the following parameters would need to be satisfied:

- ***Increase Market Price Cap*** – The Market Price Cap would need to be increased, probably to around $60,000 to $80,000/MWh, to ensure that market participants can remain profitable.
- ***Effective contracts market*** – This would need to be supported by an effective contracts market, to allow market participants to manage the increased risk of operating in a more volatile market.
- ***Increase Demand Side Participation*** – A significant increase in Demand Side Participation could make the energy-only market model much easier to manage by limiting price volatility.

Detailed analysis is presented in the conference paper (Riesz & MacGill, 2013).

Further work is required in a range of areas to extend and consolidate this work, including on the following topics:

- ***Distribution of aggregate revenues*** – The analysis described above determined the level of the Market Price Cap required for a 100% renewable power system to achieve cost recovery in aggregate. However, some renewable generators may not be operating at sufficient levels during periods of market scarcity, which may mean that they do not recover sufficient revenue to remain profitable. Further work is required to examine how the operation of variable renewables during periods of scarcity affects the distribution of revenues they earn in the energy-only market.

- ***Operation of the contracts market*** – The preliminary analysis has indicated that the continued success of the energy-only market is founded upon the successful operation of the contracts market. However, there is limited published information on the operation of this market, particularly on the details of over-the-counter contracts, which form a significant proportion of trades. Investment in new generating capacity is likely to require that retailers are willing to sign long term contracts of at least a decade in duration. Researchers in other nations (such as Germany) are skeptical that retailers would agree to such long term agreements, given a lack of certainty over future demand from their customer base. This forms the foundation of the argument that a capacity mechanism may be required in Germany. Thus, it is worthwhile to examine the manner in which new capacity investment has been supported in the NEM over the past decade, and determine whether such long term contracts have played a role.
- ***Examining renewable contracting*** – At present, renewable generation projects are supported by the Renewable Energy Target (RET) mechanism. In the past, retailer have signed long term Power Purchase Agreements (PPAs) with renewable projects in order to secure a supply of Renewable Energy Certificates (RECs) to meet their liabilities under the RET. These PPAs do not have a 'capacity component' in that they do not require the renewable generator to supply electricity at a particular point in time. Thus, they are fundamentally quite different to other kinds of contracts, which typically define an amount of electricity to be supplied at a particular point in time. Over the long term, an effective policy environment could see the RET becoming superfluous, with the externalities of fossil fuel generation (including greenhouse emissions) being priced appropriately. In this environment, it could be expected that developers of variable renewable generation (such as wind and solar photovoltaics) will need to develop new and innovative contract structures. These could involve combining peaking capacity (such as open cycle gas turbines, possibly operating on bio-fuels) with variable renewables to supply base contracts, where those are price more favourably than cap contracts alone. Thus, it could be instructive to examine the innovative contracting structures that could suit variable renewables, illustrating the way in which they might manage risk in a future market beyond the RET.
- ***Comparing Capacity Mechanisms*** – Further work is warranted to examine the various capacity mechanisms in operation and proposed for implementation in international markets, and consider which of these might be appropriate for

implementation in the NEM, if required. There is an opportunity to conduct this analysis with the CIGRE Working Group on the topic, which was established at the last CIGRE meeting in Cape Town in October 2013.

Spot market rules

Spot market rules are a key determining factor in the deployment of new technologies, since they can advantage or disadvantage new entrants with differing characteristics. They can also significantly influence the costs of integrating new technologies, such as variable renewables like wind and solar photovoltaics. This was the topic of a book chapter by the authors released in early 2013 (Riesz, Gilmore, & Hindsberger, 2013).

For example, variable renewable technologies such as wind and photovoltaics can be integrated most efficiently into markets with short (five minute) dispatch intervals, and a short delay between gate closure and dispatch. This ensures that the latest possible forecasts can be used in the dispatch calculation, minimising forecast errors and dispatch inefficiencies (Milligan & Kirby, Market Characteristics for Efficient Integration of Variable Generation in the Western Interconnection, 2010). Forecast errors are a significant determinant of frequency control reserves that must be maintained to ensure secure system operation, and therefore are a significant driver of system integration costs for variable renewables.

Furthermore, variable renewables are most cost effectively integrated into power systems that are fully co-optimised over the largest possible area and demand footprint (GE Energy, 2005). This ensures the maximum degree of diversity between renewable resources, and the maximum degree of flexibility in the balance of system to manage variability. It also allows forecast errors to be cancelled out between neighbouring regions where possible.

In general, the NEM has excellent characteristics for the low cost and efficient integration of variable renewable technologies. The NEM features a five minute dispatch interval, and a very short delay from gate closure to dispatch (less than five minutes). Furthermore, the entire NEM is co-optimised together by the NEMDE dispatch engine. Thus, analysis of the NEM market design has suggested that international markets would do well to learn from this Australian example.

Two other features of the NEM spot market design are relatively unique, and may also be advantageous for the integration of renewable generation. Firstly, the self-commitment model applied in the NEM may encourage greater flexibility. Secondly, the lack of a day-ahead market may encourage generators to trade more actively in the real time market, further increasing the flexibility available to the system operator. These two aspects may become increasingly important as the proportion of variable renewables increases. The advantages offered by these two features of market design may not be based in economically rational behaviour, but rather may stem from irrational market behaviour founded in social psychology and organisational rigidity. Further analysis of these aspects could yield important lessons for international markets.

Another topic of interest with regards to wholesale market rules is the issue of system integration costs. These are the system costs of adding new generation to a system, which may not be directly 'paid' by that market participant. These costs are typically raised with relation to variable renewables such as wind and photovoltaics, but they also apply equally to any new entrant, including traditional fossil fuel plant. System integration costs are often raised by proponents of nuclear power, in an attempt to provide a basis on which "baseload" nuclear power can be compared on an equal footing with variable renewable technologies. However, the attribution of system integration costs is a highly vexed issue (Milligan, et al., 2013). The NEM has some advantages over other systems in that many of the integration costs due to frequency control ancillary services are directly payable by market participants, and are therefore more appropriately signalled to investors. However, some costs remain borne by the system, and could not fairly be attributed to any new entrant any more than they could be attributed to incumbents (Milligan, et al., 2013). A study that outlines these issues in the Australian market context would be useful to highlight the complexities in making statements about system integration costs.

Ancillary service market rules

Ancillary services, particularly frequency control ancillary services, encapsulate many of the integration costs and challenges for variable renewable generation. Therefore, examination of the effectiveness of frequency control ancillary service (FCAS) markets is key for understanding how electricity markets are likely to manage the transition to high proportions of renewable generation.

The FCAS market in Australia was the topic of a conference presentation by the authors at the Wind Integration Workshop in London in October 2013 (Riesz & MacGill, 2013). This study illustrated three relatively unique aspects of the FCAS market in the NEM which are particularly beneficial for the integration of variable renewable generation:

- ***Dynamic reserve setting*** – fully dynamic determination of regulation reserves based upon real-time measurement of the time error,
- ***Causer pays payment recovery*** – a sophisticated 'causer pays' mechanism for recovery of regulation payments, and
- ***Primary Frequency Response market*** – a fast primary frequency response market that requires full response within six seconds.

Three aspects of the NEM FCAS market design were also identified to need adjustment as the market progresses towards higher proportions of renewable generation. These identify areas for further research, and are as follows:

Optimising contingency response times

With the entry of large amounts of novel generation technologies, it may prove valuable to revise the 6 second, 60 second and 5 minute contingency response times. These response times are based upon the capabilities of existing generators in the NEM. For example, the synthetic primary frequency response from a wind turbine may be able to respond more rapidly than 6 seconds, yet be unable to cost effectively sustain the response for a full 60 seconds (Ela, et al., 2013; Brisebois &

Aubut, 2011). Revised response times may allow these new technologies to participate more effectively, reducing system costs.

Inertia

At present, no electricity system in the world has implemented a market or incentive based reward for generators providing inertia. Some markets (such as Hydro Quebec) have introduced mandatory inertia requirements as a condition of connection (Ela, Kirby, Navid, & Smith, 2011). A possible market design for inertia is detailed in (Ela, et al., 2013).

Like many markets, the NEM may need to introduce incentives for the provision of inertia, as non-synchronous generation displaces inertia-providing units. However, it is likely that very high penetrations of variable renewables would need to be achieved before this is a concern (60-80% instantaneous generation) (Ela, et al., 2013; Bomer, 2010). Inertia has been identified as a possible issue in the NEM which could be addressed via the introduction of an inertia market, or a very fast FCAS service (Jackson, 2012; Ackermann & Kuwahata, 2011). However, this is not considered urgent.

It may also be worth considering other alternatives to an inertial response. For example, it may be possible for many units to provide a very fast FCAS service which could replace or reduce the need for inertia. Furthermore, as the quantity of non-synchronous generation increases it may no longer be necessary to maintain the system within such narrow frequency bands. These alternatives should be considered in more depth.

Following service (Flexibility mechanisms)

Increasing penetrations of variable renewables will demand faster ramp rates of the remaining generation fleet (or an appropriate response from dispatchable loads). In some circumstances, the ramp rates required may exceed the aggregate ramping capability of the generators online, necessitating the dispatch of a faster generator out of merit order. This can distort electricity prices, or may dis-incentivise flexibility (Ela, Kirby, Navid, & Smith, 2011).

To assist in addressing this issue, many markets include a "following" ancillary service, which provides ramping capability over timeframes longer than the dispatch interval. Other markets are considering the introduction of an explicit flexibility mechanism (Xu & Tretheway, 2012).

At present such a service does not appear to be required in the NEM, with sufficient flexibility being available via the real-time five minute market. Out of merit dispatch due to ramp constraints is rare. However, with increased penetration of variable renewables these occurrences are likely to become more frequent, perhaps necessitating the introduction of a following FCAS service, or an explicit flexibility mechanism to ensure generators receive an accurate price signal for the value of system flexibility.

3.3. External policy drivers

There are many examples of external policy drivers that affect the development of the future grid in Australia. A number are outlined below.

Carbon policy

Climate mitigation policy has a strong influence over the development of the future grid. The present carbon pricing scheme affects investment decisions, and the Emissions Reduction Fund currently under development by the present Government can similarly be expected to influence the electricity sector. Even in the absence of explicit carbon policy, investment decisions are likely to be made with an understanding that future policy interventions are likely, creating a reluctance to invest in emissions intensive options (Paton, 2013).

With the present flux in climate mitigation policy, there is an opportunity to engage with the Government on the design of incoming policy. There appears to be a relatively "clean slate" approach to policy development, meaning that there is opportunity to influence decisions towards better mechanisms and scheme design, targeting stronger outcomes for consumers and for the environment.

A particular area of focus for CEEM has been analysis of the Contracts for Closure mechanism proposed by the previous Government. With the present oversupply of capacity in the electricity market there have been calls from market participants to bring back a similar scheme, making payments available to generators to compensate for early withdrawal from the market. CEEM released a working paper in October 2013 examining whether a payments for closure mechanism would be a good policy choice under the incoming Direct Action scheme (Riesz, Noone, & MacGill, 2013). The paper highlighted issues with a payment for closure mechanism, including the fact that payments for closure can exacerbate barriers to exit by creating the expectation of compensation for closure. This can prevent market participants from responding in a timely manner to market signals, and may have contributed to creating the present market oversupply.

Renewable & Energy efficiency support policies

Policies that support the development of renewable energy are obviously key in influencing the development of the future generation mix. A wide range of support mechanisms have been applied internationally, with each having merits and disadvantages. A range of support mechanisms have also been applied in Australia, such as the RET, the ACT Solar Auction, and the Clean Energy Finance Corporation (CEFC).

Energy efficiency policies are also highly significant for the development of the future grid, since they strongly influence future demand levels, which are a key influencing factor for generation investment. The recommendations from the AEMC's Power of Choice Review could have significant implications through greater encouragement of demand side participation and energy efficiency measures. Energy efficiency may also be supported through the Coalition's Emissions Reduction Fund, depending upon how the scheme is designed.

Since the success or failure of each policy is highly dependent upon the environment in which it operates, it will be important to consider the coherence of the changing policy environment on an ongoing basis. CEEM hopes to engage with the Coalition on the design of the Emissions Reduction Fund, aiming to ensure a coherent and comprehensive policy environment for the development of a low carbon future grid.

For example, the RET scheme was originally designed to operate in partnership with the Clean Energy Future carbon pricing scheme. With the imminent repeal of that scheme appearing likely, the RET may no longer function optimally. In particular, analysis suggests that the RET shortfall charge may be too low to continue to support renewable investment in the absence of the carbon price. This could be exacerbated by the approach of the 2030 scheme end date, which is already within the lifetime of renewable projects installed today. Thus, with the repeal of the carbon price, adjustments to the RET mechanism may be required. This was explored in a recent CEEM working paper (Riesz, Noone, & MacGill, 2013).

The manner in which renewable projects are financed is a key determining factor in the costs of developing renewable generation. Renewable technologies ubiquitously have the majority of their cost upfront (as capital). This means that their total development cost is very exposed to the cost of capital. The cost of capital will be determined by financing structures, which are in turn influenced by the policy mechanisms that support renewable development. There is an opportunity to work with international partners in Germany to examine the financing structures that have been implemented for renewable development in various markets, and to examine how these have been affected by the policy mechanisms in place in those markets. The Australian market offers a range of examples, by comparing renewable financing during different phases of the RET scheme (2000 to 2009 when the RET was operating successfully, 2009 to 2011 when the market was oversupplied, and 2012 to 2013, when some market recovery could be expected, but has been inhibited by ongoing policy uncertainty). It would also be instructive to consider renewable financing for projects supported by different mechanisms, such as the RET alone, additional Government grants (such as for the Greenough River 10MW PV project), the ACT Solar Auction, and projects supported by the CEFC.

Fuel policies

Policies that apply to fuel markets influence the relative costs of generation technologies, thereby affecting generation investment decisions.

For example, the present Government policy of allowing expansion of the Liquefied Natural Gas (LNG) on the east coast of Australia without the application of reservation policies is likely to cause domestic gas prices to rise significantly. This is likely to discourage investment in high capacity factor gas-fired plant in Australia over the coming decades.

CEEM has explored the implications of these developments in gas markets utilising the "quantitative tool" discussed in section 4. Uncertainty over future gas and carbon prices was applied to a range of generating portfolio mixtures, and the resulting electricity price distributions calculated. This work was presented at the Wind Integration Workshop in London in October 2013, and is currently being developed into a journal article (Vithayasrichareon, Riesz, & MacGill, 2013).

Another area of growing interest in international literature is the potential use of supply-side policies in the coal sector as a climate mitigation strategy. For example, recent modelling suggests that demand side policies that reduce demand for coal in Europe have minimal impact upon global climate outcomes, because the resulting decrease in the global coal prices causes demand increases in developing nations. However, a supply side approach that reduces export of coal shows relatively minimal potential for market adjustment, and thus shows potential as an effective climate mitigation mechanism (Haftendorn, Kemfert, & Holz, 2012). An approach of this nature would represent a fundamental shift in climate mitigation. As one of the small number of major coal exporting nations in the world, this could significantly affect Australia, and the the development of the future grid. CEEM is currently partnering with modellers at the University of Technology Sydney to explore the implications of a supply-side climate mitigation strategy of this nature.

Optimal utilisation of coal-fired assets in the future grid

With the evolution towards the future grid, it is very likely that there will be a transition away from the existing fleet of emissions intensive generation. At present the prevailing assumption appears to be that these plant will retire and be removed from the market. However, this existing infrastructure could create new opportunities for retrofit to fulfil new market niches.

For example, there is likely to be a need for a minimum proportion of generation at any point in time to be synchronously connected. However, existing coal-fired generators may have the potential for retrofit as synchronous condensers, supporting a wide range of grid operations. This may prove more cost effective than operating synchronous renewable generators out of merit order during periods when high quantities of non-synchronous generation is available.

Coal-fired generators may also be able to operate in a highly flexible manner, supporting efficient grid operation around variable renewables. The National Renewable Energy Laboratory (NREL) in Colorado recently completed a case study of a coal-fired plant in the USA which was originally developed to operate as a high capacity factor "baseload" plant, but which was subsequently retrofitted and operated as a "super peaking" plant, often cycling multiple times during a day to meet peak demand. Despite the significant increases in maintenance costs, this was judged by the plant operators to be a more cost effective way to operate the asset. There may be potential for similar retrofit of coal-fired assets in Australia, extending the value they offer to the market during the transition to the future low emissions grid.

There is a need for analysis to determine where these opportunities may lie, and to determine whether they can be accessed under the present policy framework. Adjustments or additional policy mechanisms may be required to ensure that these opportunities can be accessed efficiently.

3.4. Summary of relevant publications completed

The following table provides a summary of some key publications completed in 2013 that have particular relevance to the UNSW Cluster project.

Table 1 – Relevant publications completed

Policy Pillar	**Description**	**Reference**
Regulation	Policy Assessment Frameworks – Literature review	Jones, M., Noone, B., & MacGill, I. (2013). ***Cluster Project 4 – Robust energy policy frameworks for investment in the future grid: 1st Deliverable Report.*** Sydney: Centre for Energy and Environmental Markets, University of New South Wales.
	Frameworks for transmission locational and sizing decisions – Literature review	Riesz, J., Noone, B., & MacGill, I. (2013). ***Cluster Project 4 – Robust energy policy frameworks for investment in the future grid: Deliverable Report 1b – Part A: Frameworks for transmission locational and sizing decisions.*** Sydney: Centre for Energy and Environmental Markets, University of New South Wales.
	Connecting remote renewables – Literature Review	Noone, B., Riesz, J., & MacGill, I. (2013). ***Cluster Project 4 – Robust energy policy frameworks for investment in the future grid: Deliverable Report 1b: Connecting Remote Renewables.*** Sydney: Centre for Energy and Environmental Markets, University of New South Wales.
	Scenario analysis on possibilities for decentralisation or customer disconnection from future grids	Riesz, J., Hindsberger, M., Gilmore, J., & Riedy, C. (2013). ***Perfect storm or perfect opportunity? Future scenarios of the electricity sector and their implications for utilities***. In F. P. Sioshansi, The Rise of Decentralized Energy - What is at stake for the electricity supply industry?

Policy Pillar	Description	Reference
Market Design	Preliminary analysis on the adequacy of the energy-only NEM design with high renewables	Riesz, J., & MacGill, I. (2013). ***100% Renewables in Australia - Will a Capacity Market be Required?*** 3rd Solar Integration Workshop - International Workshop on Integration of Solar Power into Power Systems. London. http://ceem.unsw.edu.au/sites/default/files/documents/SIW13_Riesz-CapacityMarkets-2013-09-02a.pdf
	Preliminary analysis on the adequacy of the NEM Frequency Control Ancillary Services market design with high renewables	Riesz, J., & MacGill, I. (2013). ***Frequency Control Ancillary Services - Is Australia a model market for renewable integration?*** 12th Wind Integration Workshop - International Workshop on Large-scale Integration of Wind into Power Systems as well as on Transmission Networks for Offshore wind power plants. London. http://ceem.unsw.edu.au/sites/default/files/documents/WIW13_Riesz-FCAS-2013-09-02a.pdf
	Literature review survey on market design characteristics for the integration of renewable technologies	Riesz, J., Gilmore, J., & Hindsberger, M. (2013). ***Market Design for the Integration of Variable Generation***. In F. P. Sioshansi, Evolution of Global Electricity Markets: new paradigms, new challenges, new approaches. Elsevier.
External Policy Drivers	Analysis of the potential pitfalls of a payment for closure policy mechanism	Riesz, J., Noone, B., & MacGill, I. (2013). ***Payments for Closure - Should Direct Action include payments for closure of high emission coal-fired power plants?*** Sydney: Centre for Energy and Environmental Markets, University of New South Wales. http://ceem.unsw.edu.au/sites/default/files/documents/Working%20paper%20-%20Payments%20for%20Closure%20-%202013-10-07a.pdf
	Quantitative modelling of the uncertainty in future gas and carbon prices, and the influence of varying proportions of renewable energy	Vithayasrichareon, P., Riesz, J., & MacGill, I. (2013). ***The role of wind and solar PV in mitigating the impact of uncertainty in the Australian electricity industry***. 12th Wind Integration Workshop - International Workshop on Large-scale Integration of Wind into Power Systems as well as on Transmission Networks for Offshore wind power plants. London. http://ceem.unsw.edu.au/sites/default/files/documents/Paper_WIW13-1207.pdf

Policy Pillar	Description	Reference
	Interactions between climate and energy (particularly restructuring) policy	MacGill I. and S. Healy. (2013). ***Is Electricity Industry Reform the Right Answer to the Wrong Question? Lessons from Australian Restructuring and Climate Policy***. In F. P. Sioshansi, Evolution of Global Electricity Markets: new paradigms, new challenges, new approaches. Elsevier

3.5. Summary of proposed priority research focus areas for 2014 - 2015

The above analysis suggests that the following areas could be inadequate under the existing policy frameworks, and are likely to be meaningful areas for further analysis. At this time, the P4 group aims to target research in these areas over the coming two years of the CSIRO Future Grid project.

Table 2 - Summary of proposed priority research focus areas for 2014 - 2015

Policy Pillar	Research topic	Description
Regulation	Transmission planning frameworks	Examining international experiences, developing improved frameworks for transmission planning in Australia
	Optional Firm Access Model	Examining the transition arrangements proposed in the Transmission Frameworks Review
	Connecting Remote Renewables	Further extension of analysis to examine the planning processes for network development to access remote renewable resources
Market Design	Energy-only market design under high renewables	Further extension of analysis to determine whether the existing energy-only market design in the National Electricity Market is likely to continue to function with significant renewable generation, or whether a more explicit capacity mechanism may be required (with alternative design options to be considered).
	NEM design for renewable integration	An analysis of the NEM design with regards to the integration of variable renewables.
	FCAS Optimisation	Optimisation of frequency control ancillary services (FCAS) markets for the entry of new technologies
	Flexibility mechanisms	Exploring whether the present market rules appropriately reward and incentivise flexibility (both on operational and investment timeframes), and if not, developing appropriate market mechanisms.
	System integration costs	Determining whether the integration costs of variable renewables are appropriately captured

Policy Pillar	Research topic	Description
		by the market, and quantifying and comparing these to other technologies.
External Policy Drivers	Emissions Reduction Fund Design	Examining possible designs for the climate mitigation policies of the incoming Government
	Optimal utilisation of coal-fired assets in the future grid	Examining the costs and benefits of potential for retrofit of coal-fired units as peaking capacity, flexible capacity, low minimum load operation or as synchronous condensers, and exploring whether the existing market framework appropriately incentivises and rewards these options.
	Renewable financing structures	Exploring the way in which renewable projects are financed, and how this is affected by external policy drivers (and other policy settings).
	Risk and investment portfolios	Examining the costs and benefits of using renewable generation as a part of a portfolio to ameliorate the risk of future gas and carbon price rises
	Supply-side climate mitigation policies	Exploring the potential for the use of supply side policies for climate mitigation, with a particular focus on targeting the coal sector (for example, ramping down fossil fuel exports).

4. Extensions to quantitative modelling tool

4.1. Initial Tool Extensions

Incorporating additional network investment costs

One of the key limitations of the quantitative modelling tool for assessing future generation portfolios was its limitation in incorporating transmission network costs associated with future generation portfolios. The modelling tool has, therefore, been extended to incorporate high level metrics of additional transmission network investment costs associated with particular generation portfolios. This aspect is particularly important given the increasing share of renewable generation resources which are often located in remote areas and further away from load centres.

In the tool extensions, transmission costs associated with newly built power plants are included as a part of annual fixed investment cost for particular generation portfolios which can be expressed as follows:

$$FC_n = ((Annualised\ CapCost_n + FOM_n) \times I_n) + Annualised\ \ TxCost$$

where *Annualised CapCost*$_n$ is the annualised capital cost ($/MW) and *FOM*$_n$ is the annual fixed O&M cost ($/MW) and I_n is the installed capacity (MW) of technology *n* in the portfolio and *Annualised TxCost* is the annualised transmission costs ($).

Additional transmission costs associated with new generation plants are calculated based upon their distances to the nearest load centres or major transmission hubs and indicative transmission cost estimates in $/MW/km provided by planning utilities or published in consultancy reports. Annualised transmission costs can then be calculated based on economic lifetime of a transmission line and weighted average cost of capital (WACC).

Considering wider range of low-carbon generation technologies

Another initial extension to the tool includes incorporating wider range of low-carbon technologies. Previous applications of the tool with low-carbon technologies included wind, hydro and nuclear generation technologies.

In this aspect, the tool has incorporated solar PV as part of future generation portfolio. PV generation is assumed to be given priority in the dispatch due to its low operating cost by comparison with conventional technologies. With this assumption, the simulated hourly PV generation is subtracted from hourly demand over a year. The resulting net demand after accounting for PV generation, is rearranged to obtain a residual load duration curve (RLDC). It is this curve that will be served by conventional technologies in the portfolio.

4.2. Application of the tool extensions

This aspect of the tool extension has been applied to a NEM case study with high PV penetration where new PV plants were modelled in different locations including major cities and some regional areas. High level additional transmission costs for centralised PV plants in regional locations were modelled. These regional locations consist of Cobar (NSW), Dalby (QLD), Long Reach (QLD), Mildura (VIC), White Cliffs (NSW), Whyalla (SA) and Woomera (SA). Figure 1 shows a map of the selected locations for large-scale PV plants for the modelling and the exiting NEM transmission network.

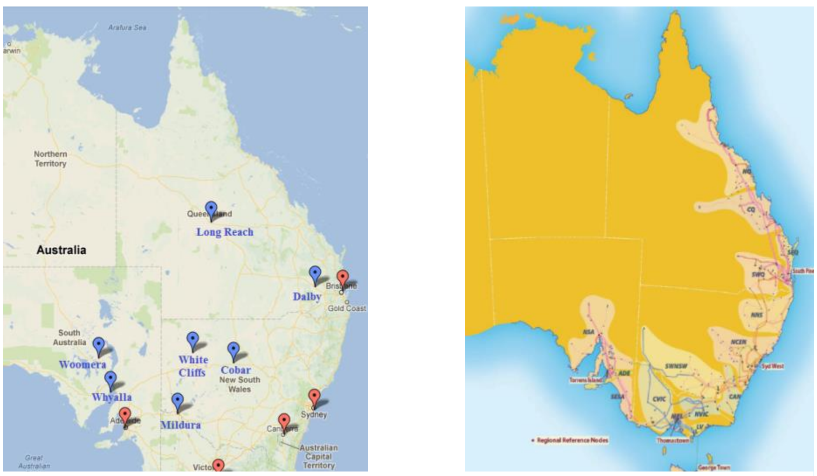

Figure 4.1. Locations of PV plants for the modelling

Transmission cost estimates for different line length were based on those provided in the 2011 National Transmission Network Development plan as shown in Table 1 (AEMO, 2011). The indicative transmission cost estimate for high voltage AC lines applied in the case study was $700/MW/km[1].

Table 3. Transmission cost estimates for different line length (AEMO, 2011)

Line length (km)	Transmission cost estimate	
	($ million)	($/MW/km)
100 km	160	714
250 km	415	740
500 km	760	680

Annualised transmission cost for each location was determined for different PV penetrations based on the transmission cost estimates ($/MW/km), installed PV capacity (MW), and distance (km) from the nearest load centre (or connections to the shared network). These details are shown in Table 2.

Table 4. Distance and annualised transmission costs for each regional location for different PV penetrations.

State	Location	Distance to the nearest load centre or major hub (km)	Tx cost ($m/MW)	Annualised transmission costs for different PV penetration ($ million)			
				5%	10%	15%	20%
NSW	Cobar	450	0.32	8.11	16.22	24.5	32.44
	White Cliffs	730	0.51	13.16	26.31	39.75	52.62
VIC	Mildura	450	0.32	8.11	16.22	24.5	32.44
QLD	Dalby	185	0.13	3.33	6.67	10.07	13.34
	Long Reach	485	0.34	8.74	17.48	26.41	34.96
SA	Whyalla	70	0.05	1.26	2.52	3.81	5.05
	Woomera	165	0.12	2.97	5.95	8.98	11.89

In this aspect, higher PV penetration would lead to an increase in overall generation costs due largely to increased fixed cost and additional transmission costs required to integrate remotely located PV generation in the grid. However, the extent to of such increase in costs depends on many factors including the level of carbon price and the share of generation technologies.

5. Policy scenario development

UNSW has engaged with the other project P1-P3 teams and CSIRO partners on the preliminary development of scenarios. The following key principles are identified as being of particular importance in the development and selection of scenarios:

[1] The case study assumed a 330kV double circuit overhead transmission line with a summer rating of 1,245 MVA for each circuit with a power factor of 0.9 and total line capacity is 1,120 MW for each circuit. Recent transmission cost estimates used for the AEMO 100% renewables study are relatively lower (AEMO, 2013).

– ***Stretch*** – Scenarios should map the range of conceivably plausible futures, including scenarios that are considered less likely but possible. This is particularly essential during periods of high uncertainty where the future may be dramatically different from the present in ways that are as yet unknown. Useful scenario sets will provide a broad view of possible futures to assist in identifying the impacts upon various stakeholders. Less likely futures that have dramatic consequences can be very significant in driving decision making (despite their low probability of occurrence) when a risk management approach is properly applied. This cannot occur effectively unless those less likely (but 'dramatic') scenarios are modelled.

– ***Internal coherence and consistency*** – Scenarios should consist of a set of assumptions that are internally consistent. This can be facilitated by beginning with a high level description of the key drivers, and then developing these into the various detailed assumptions that are required for the modelling. Care must be taken when conducting sensitivity analysis (changing one variable within the scenario to explore its impact upon various outcomes) to ensure that the scenario remains internally consistent.

– ***Designed with the purpose in mind*** – No model or scenario set can capture everything about reality – models are always inherently an approximation of reality. Therefore, scenarios are best developed with the specific purpose for which they are intended in mind. This ensures that the approximations made are appropriate, given the intended purpose. Defining a clear intended purpose allows the most relevant spectrum of scenarios to be developed, and ensures that they probe the relevant parameters. For research, in particular, it can be useful to articulate the key questions that the scenarios should seek to answer, guiding their development. Even during explorative exercises, it is useful to define what it is that the scenarios seek to explore, to ensure they are appropriately constructed for that purpose.

– ***Avoid implying a "central" scenario*** – It can be tempting to define a "most likely" future scenario, and then develop "stretch" scenarios around this. However, this tends to lead to an overstatement of the degree of certainty around the assumptions in the scenarios. Given the extreme degree of uncertainty over future scenarios for the electricity sector at present, it is dangerous to create a perception that a "likely" scenario exists. To avoid this perception, it is better to define a range of plausible scenarios, with no particular one being identified as "central" or "most likely".

The preliminary modelling scenarios employed by CSIRO during the Future Grid modelling process appear to have followed these principles, creating a useful scenario set and modelling results. We suggest that it would be helpful for the input assumption sets and results data sets for these scenarios to be released to the P1-P4 teams to allow further analysis and prevent duplication of effort. These scenarios appear to be a good first place to start for further analysis, and for the development of other modelling scenarios (if required).

UNSW looks forward to continuing to work with the other project teams and CSIRO partners on scenario development.

6. Conclusions

This report provides a summary of the contributions of the team at UNSW towards the CSIRO Future Grid project in 2013, and an indication of future work planned for 2014 and 2015. This has been developed based upon the development of a high level interdisciplinary policy assessment framework, which has been applied to the Australian policy landscape, taking into account international experiences. Extensions developed for the quantitative modelling tool are also described, as well as a discussion around the principles for scenario development to support policy analysis.

7. References

Ackermann, T., & Kuwahata, R. (2011). *Lessons learned from international wind integration studies.* Energynautics GmbH, report for Australian Energy Market Operator.

AEMC. (2012, November 30). *Power of Choice - Stage 3 DSP Review*. Retrieved from Australian Energy Market Commission: http://www.aemc.gov.au/market-reviews/completed/stage-3-demand-side-participation-review-facilitating-consumer-choices-and-energy-efficiency.html

AEMC. (2013). *Electricity Price Trends Final Report: Possible Future Retail Electricity Price Movements: 1 July 2012 to 30 June 2015.* Australian Energy Market Commission.

AEMO. (2011). *National Transmission Network Development Plan.* Melbourne: Australian Energy Market Operator.

AEMO. (2013). *100 per cent Renewables study - Modelling outcomes.* Australian Energy Market Operator.

Baldick, R. (2013). ERCOT - Overview of renewable integration issues. *DIW*. Berlin.

Bomer, J. (2010). *All Island Facilitation of Renewable Studies; Final Report for Work package 3.* Ecofys and DIgSILENT, report for EirGrid.

Brisebois, J., & Aubut, N. (2011). Wind farm inertia emulation to fulfill hydro-Quebec's specific need. *in Proc. IEEE PES General Meeting, Detroit, MI*.

Cramton, P., & Stoft, S. (2006). *The Convergence of Market Designs for Adequate Generating Capacity with special attention to the CAISO's Resource Adequacy Problem.* A White Paper for the Electricity Oversight Board.

Cramton, P., Ockenfels, A., & Stoft, S. (2013). Capacity Market Fundamentals. *Economics of Energy & Environmental Policy, 2*(2), 27-46.

Ela, E., Gevorgian, V., Tuohy, A., Kirby, B., Milligan, M., & O'Malley, M. (2013). Market Designs for the Primary Frequency Response Ancillary Service - Part I: Motivation and Design. *IEEE Transactions on Power Systems, PP*(99), 1-11.

Ela, E., Gevorgian, V., Tuohy, A., Kirby, B., Milligan, M., & O'Malley, M. (2013). Market Designs for the Primary Frequency Response Ancillary Service - Part II: Case Studies. *IEEE Transactions on Power Systems, PP*(99), 1-9.

Ela, E., Kirby, B., Navid, N., & Smith, J. C. (2011). *Effective Ancillary Services Market Designs on High Wind Power Penetration Systems.* National Renewable Energy Laboratory (NREL).

Ela, E., Tuohy, A., Milligan, M., Kirby, B., & Brooks, D. (2012). Alternative Approaches for Incentivising the Frequency Responsive Reserve Ancillary Service. *The Electricity Journal, 25*(4), 88-102.

GE Energy. (2005). *The effects of integrating wind power on transmission system planning, reliability and operations: Report on Phase 2.* prepared for The New York State Energy Research and Development Authority.

Haftendorn, C., Kemfert, C., & Holz, F. (2012). What about coal? Interactions between climate policies and the global steam coal market until 2013. *Energy Policy*, 274-283.

Hogan, W. W. (2005). *On an "Energy Only" Electricity Market Design for Resource Adequacy.* Cambridge, Massachusetts: Centre for Business and Government, John F. Kennedy School of Government, Harvard University.

Hogan, W. W. (2013). Electricity Scarcity Pricing Through Operating Reserves. *Economics of Energy & Environmental Policy, 2*(2), 65-86.

Jackson, R. (2012). *AEMO Wind in the NEM.* Clean Energy Week Conference Presentation.

Jones, M., Noone, B., & MacGill, I. (2013). *Cluster Project 4 – Robust energy policy frameworks for investment in the future grid: 1st Deliverable Report.* Sydney: Centre for Energy and Environmental Markets, University of New South Wales.

Milligan, M., & Kirby, B. (2010). *Market Characteristics for Efficient Integration of Variable Generation in the Western Interconnection.* National Renewable Energy Laboratory (NREL).

Milligan, M., Kirby, B., Holttinen, H., Kiviluoma, J., Estanqueiro, A., Margin-Martinez, S., . . . Smith, C. (2013). Wind Integration Cost and Cost-Causation. *12th Wind Integration Workshop - International Workshop on Large-scale Integration of Wind into Power Systems as well as on Transmission Networks for Offshore wind power plants.* London.

Neuhoff, K. (2013). *Financial Transmission Rights - Theory and Policy: Discussion by stakeholders and Academics. Presentation at Berlin Conference on Electricity Economics: Modeling and Policy in the Energy Transformation - Germany, Europe, and Beyond: Conference of the DIW.* DIW Berlin.

Noone, B., Riesz, J., & MacGill, I. (2013). *Cluster Project 4 – Robust energy policy frameworks for investment in the future grid: Deliverable Report 1b: Connecting Remote Renewables.* Sydney: Centre for Energy and Environmental Markets, University of New South Wales.

Paton, J. (2013, February 2013). *Australian Wind Energy Now Cheaper Than Coal, Gas, BNEF Says.* Retrieved from Bloomberg: http://www.bloomberg.com/news/2013-02-06/australia-wind-energy-cheaper-than-coal-natural-gas-bnef-says.html

Riesz, J., & MacGill, I. (2013). 100% Renewables in Australia - Will a Capacity Market be Required? *3rd Solar Integration Workshop - International Workshop on Integration of Solar Power into Power Systems.* London.

Riesz, J., & MacGill, I. (2013). Frequency Control Ancillary Services - Is Australia a model market for renewable integration? *12th Wind Integration Workshop -*

International Workshop on Large-scale Integration of Wind into Power Systems as well as on Transmission Networks for Offshore wind power plants. London.

Riesz, J., Gilmore, J., & Hindsberger, M. (2013). Market Design for the Integration of Variable Generation. In F. P. Sioshansi, *Evolution of Global Electricity Markets: new paradigms, new challenges, new approaches*. Elsevier.

Riesz, J., Hindsberger, M., Gilmore, J., & Riedy, C. (2013). Perfect storm or perfect opportunity? Future scenarios of the electricity sector and their implications for utilities. In F. P. Sioshansi, *The Rise of Decentralized Energy - What is at stake for the electricity supply industry?*

Riesz, J., Noone, B., & MacGill, I. (2013). *Cluster Project 4 – Robust energy policy frameworks for investment in the future grid: Deliverable Report 1b – Part A: Frameworks for transmission locational and sizing decisions*. Sydney: Centre for Energy and Environmental Markets, University of New South Wales.

Riesz, J., Noone, B., & MacGill, I. (2013). *Payments for Closure - Should Direct Action include payments for closure of high emission coal-fired power plants?* Sydney: Centre for Energy and Environmental Markets, University of New South Wales.

Ruttledge, L., & Flynn, D. (2013). Quantifying the aggregate frequency response from wind generation with synthetic inertial response capability. *12th Wind Integration Workshop - International Workshop on Large-scale Integration of Wind into Power Systems as well as on Transmission Networks for Offshore wind power plants*. London.

UK Government. (2013). *Policy - Maintaining UK Energy Security*. Retrieved from gov.uk: https://www.gov.uk/government/policies/maintaining-uk-energy-security--2/supporting-pages/electricity-market-reform

Vithayasrichareon, P., Riesz, J., & MacGill, I. (2013). The role of wind and solar PV in mitigating the impact of uncertainty in the Australian electricity industry. *12th Wind Integration Workshop - International Workshop on Large-scale Integration of Wind into Power Systems as well as on Transmission Networks for Offshore wind power plants*. London.

Xu, L., & Tretheway, D. (2012). *Flexible Ramping Products - Draft Final Proposal*. California ISO.

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