CSIRO Future Grid Flagship Cluster

Project 3: Economic and investment models for future grids

Prof John Foster and Dr Liam Wagner

Deliverable 1a:

Short Literature Review and Project Plan

April 2013

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

1. International experience with transformations in electricity markets

1.1. Introduction

This short review will provide an analysis of the key challenges faced by electricity markets and their participants in increasing the penetration of large scale renewables. This review will assess the key barriers purely from an economic perspective. The global of deployment of large scale renewable energy has yet to live up to its full potential and our experiences (Masini and Menichetti 2012). However its future development is expected to have greater influence over electricity markets (Wüstenhagen and Menichetti 2012).

1.2. Renewable Energy Generation

The supply of electricity from renewable sources only contributed 19.5% of total electricity demand (BP 2012). Nearly all of this renewable production still relies on hydroelectric systems (~16% of total electricity demand). Furthermore this reliance on already established sources such as hydro is a major factor in limiting our growth of knowledge in deploying newer sources (Neuhoff 2005). The primary barriers for entry for renewables to be outlined in this review are quite clearly issues associated with incumbency and a lack of research and development into the technological challenges associated with new technology.

Market design and the incentives structure currently in place clearly favour utilities (aka Genco's) as being capable of facilitating the large scale deployment renewables (Loock 2012; Richter 2012). However in only a few jurisdictions such as the EU, have enjoyed a rapid rise in the acceptance and deployment of renewables (IEA 2012; IEA 2013). Furthermore, the ability for central planners and utilities to invest under uncertainty has clearly been impaired in liberalised electricity markets which has evidently compounded the market incumbency barrier (de Vries and Heijnen 2008).

The use of renewables as a primary source of electricity generation could present many benefits from a range of perspectives such as environmental and the diversification of supply. The need to reduce carbon emissions from stationary energy, while difficult, will prove to be a policy imperative in the coming decades to minimize the risks associated with climate change. Furthermore, reducing the risks that conventional fossil fuel based electricity generation face given their exposure to international fuel price volatility will also improve rewarding from both an economic perspective but will also enhance our goal to minimize Australia's energy security risks (Ball, Ehmann et al. 2011; Foster, Froome et al. 2013).

Internationally the typical barriers to entry which have hampered the broader deployment of renewable energy revolve around two key factors which have impeded their further progress.

Firstly conventional generation sources have previously competed with the distinct advantage of little to no restraints on their full environmental or social costs (Neuhoff 2005). The lack of internalisation of these externalities fully (Owen 2006), imposes the greatest challenge and has been the focus of much of the energy policy literature (Painuly 2001; Kenny, Law et al. 2010).

Secondly, the intergenerational gaps between different technology types present significant difficulties in the ability to expand into electricity markets. The intergenerational gaps between different technology types present significant difficulties in the ability to expand into electricity markets. The most mature generation are already cost-competitive with their fossil fuel based counter-parts which is certainly the key reason for their broad scale deployment of

Hydro and solar hot water systems. While these technologies enjoy acceptance in the generation portfolio mix, these plant types are generally only located in higher quality resource areas and have already accessed the most suitable sites for expansion. Furthermore these earlier generation technologies also have enjoyed shallower transmission/distribution network connection charges by comparison to their younger peers (Wolfe 2008).

Neuhoff (2005), identifies a second group of newer technologies whose development has now reached the precipice of competitiveness which include Wind, Solar PV and Solar Thermal. While these technologies have received a significant boost in development in the last 10 years, they still suffer from a failure in regulatory and market reforms to advantage of economies of scope and scale (El Fadel, Rachid et al. 2013). While the increase in their deployment of wind has been driven by renewable energy targets in the EU (Mondol and Koumpetsos 2013), China (Xin-gang, Yi-sheng et al. 2013), a variety of US states (Carley and Browne 2012) , there are still incumbency issues which detract from realising their full potential for deployment (Jacobsson, Bergek et al. 2009).

The costs associated with renewable energy have dropped significantly over the last ten years and the key example explored most by the literature is Solar PV. Solar PV has enjoyed a rapid rise in its deployment rate (IEA 2013), having enjoyed a wide variety of favourable policies such as feed-in tariffs developed countries. Incentive structures for consumers have produced an almost exponential rise in PV units amongst households internationally (Proença and Aubyn 2013). Furthermore the costs associated with PV have also dropped considerably, such that their cost structures have or are very close to reaching grid parity (Bazilian, Onyeji et al. 2013).

Given the examples and frameworks discussed above it is evident that the experiences associated with the broad scale deployment of renewable energy have been challenging (Effendi and Courvisanos 2012). While engineering challenges are naturally a consideration (Stoft 2002; Zhao, Dong et al. 2009), there core long term impacts can be overcome with research and development. Furthermore, it is clear that the economic, market design and regulatory frameworks which encompass electricity markets are the main barrier to higher renewables scale up to resource constraints (Unruh 2000; Neuhoff 2005).

1.3. Transmission Expansion

Transmission infrastructure has traditionally been operated by centrally planned vertically integrated government owned entities (Brunekreeft, Neuhoff et al. 2005). Planning has usually been formally been associated with strong demand forecasts underpinned by political interests aligned with maintain reliable supply (Simshauser 2002), while also enjoying a high rate of return (usually a regulated rate of return) on sunk capital (Haas and Auer 2006). The vertically integrated Leviathan planning model while waning in its prevalence in the developed world (and most certainly in the OECD-20), still maintains a significant influence in allocating investment (Rosellon 2007).

The timing and location of investment/expansion has also followed along the praxis of hegemony (David and Wen 2001). Expansion of transmission in the classical environment has provided access to cheap fossil fuel (mainly coal) resources (Ball, Ehmann et al. 2011; Foster, Froome et al. 2013). Further these resources are usually considered to be stranded assets (i.e. not linked to internationally traded prices) and thus provide a further advantage to utilities (Rosellon 2007). A new design and strategic implementation of optimal expansion is quite clearly needed to enable renewables expansion (Fang and Hill 2003).

Access and availability to connection for renewables is of deep concern to new entrants into electricity markets and poses the greatest hurdle for entry (Moreno, Strbac et al. 2010). Furthermore the depth of connection charge for large scale and distributed generation is also of concern (Bayfield, Wood et al. 2006; Rudnick, Ferreira et al. 2012).

Globally the scale efficient expansion of transmission infrastructure in light of renewables is clearly driven by incumbency issues (Reed, Paserba et al. 2003; Rudnick, Ferreira et al. 2012) and evidently linked to political factors (Fischlein, Wilson et al. 2013).

1.4. Re-leveling the playing field for Renewables:

This short review of the literature has highlighted several key points which will inform the future modelling to be undertaken by this project:

- Incumbency of Conventional Technology: Carbon and Technology Lock-in (Unruh 2000; Unruh 2002; van der Vleuten and Raven 2006; Foxon 2007)
- Incumbency of older generation renewables i.e. hydro (Jacobsson and Johnson 2000; Neuhoff 2005; Kalkuhl, Edenhofer et al. 2012)
- Incumbency of access to transmission (Baldick and Kahn 1993; Joskow 2005; Heiman 2006; Pollitt 2008)
- Market Structure, incentives and willingness to accept alternative new entrants (Blumstein, Friedman et al. 2002)
- Transmission expansion and regulatory frameworks (Fang and Hill 2003)
- Scale efficient expansion/investment under uncertainty (Zhao, Dong et al. 2009)

The modelling which will be undertaken throughout this project will posit a range of alternate futures based on difficulties associated with the aforementioned incumbency and policy barriers. Scenario analysis was originally developed to explore alternate futures (either economic and policy driven) and will form the basis for addressing these market challenges (Kahn and Aron 1962; Godet 1987; Baldick and Kahn 1993). Following data exchange and further literature reviews, this project will formulate draft scenarios for consultation and refinement which will actively pursue policies which can improve the likelihood of renewable energy deployment.

References:

Baldick, R. and E. Kahn (1993). "Transmission planning issues in a competitive economic environment." Power Systems, IEEE Transactions on **8**(4): 1497-1503.

Ball, B., B. Ehmann, et al. (2011). Delivering a Competitive Australian Power System. Part 1: Australia's Global Position, School of Economics, University of Queensland, Australia.

Bayfield, C., S. Wood, et al. (2006). "Planning for the integration of on-shore renewable generation for the gb transmission system." Proc. CIGRE.

Bazilian, M., I. Onyeji, et al. (2013). "Re-considering the economics of photovoltaic power." Renewable Energy **53**(0): 329-338.

Blumstein, C., L. Friedman, et al. (2002). "The History of Electricity Restructuring in California." Journal of Industry, Competition and Trade **2**(1-2): 9-38.

BP (2012). Statistical review of world energy.

Brunekreeft, G., K. Neuhoff, et al. (2005). "Electricity transmission: An overview of the current debate." Utilities Policy **13**(2): 73-93.

Carley, S. and T. R. Browne (2012). "Innovative US energy policy: a review of states' policy experiences." Wiley Interdisciplinary Reviews: Energy and Environment.

David, A. and F. Wen (2001). Transmission planning and investment under competitive electricity market environment. Power Engineering Society Summer Meeting, 2001, IEEE.

de Vries, L. and P. Heijnen (2008). "The impact of electricity market design upon investment under uncertainty: The effectiveness of capacity mechanisms." Utilities Policy **16**(3): 215-227.

Effendi, P. and J. Courvisanos (2012). "Political aspects of innovation: Examining renewable energy in Australia." Renewable Energy **38**(1): 245-252.

El Fadel, M., G. Rachid, et al. (2013). "Knowledge management mapping and gap analysis in renewable energy: Towards a sustainable framework in developing countries." Renewable and Sustainable Energy Reviews **20**(0): 576-584.

Fang, R. and D. J. Hill (2003). "A new strategy for transmission expansion in competitive electricity markets." Power Systems, IEEE Transactions on **18**(1): 374-380.

Fischlein, M., E. J. Wilson, et al. (2013). "States of transmission: Moving towards large-scale wind power." Energy Policy.

Foster, J., C. Froome, et al. (2013). Delivering a competitive Australian power system Part 2: The challenges, the scenarios, School of Economics, University of Queensland, Australia.

Foxon, T. J. (2007). "9 Technological lock-in and the role of innovation." Handbook of sustainable development: 140.

Godet, M. (1987). Scenarios and strategic management, Butterworths London.

Haas, R. and H. Auer (2006). "The prerequisites for effective competition in restructured wholesale electricity markets." Energy **31**(6): 857-864.

Heiman, M. K. (2006). "Expectations for renewable energy under market restructuring: the U.S. experience." Energy **31**(6–7): 1052-1066.

IEA (2012). World Energy Outlook 2012, OECD Publishing.

IEA (2013). World - Renewable and Waste Energy Supply (Ktoe).

Jacobsson, S., A. Bergek, et al. (2009). "EU renewable energy support policy: Faith or facts?" Energy Policy **37**(6): 2143-2146.

Jacobsson, S. and A. Johnson (2000). "The diffusion of renewable energy technology: an analytical framework and key issues for research." Energy Policy **28**(9): 625-640.

Joskow, P. L. (2005). "Transmission policy in the United States." Utilities Policy **13**(2): 95-115.

Kahn, H. and R. Aron (1962). Thinking about the Unthinkable, Horizon Press New York.

Kalkuhl, M., O. Edenhofer, et al. (2012). "Learning or lock-in: Optimal technology policies to support mitigation." Resource and Energy Economics **34**(1): 1-23.

Kenny, R., C. Law, et al. (2010). "Towards real energy economics: Energy policy driven by life-cycle carbon emission." Energy Policy **38**(4): 1969-1978.

Loock, M. (2012). "Going beyond best technology and lowest price: on renewable energy investors' preference for service-driven business models." Energy Policy **40**(0): 21-27.

Masini, A. and E. Menichetti (2012). "The impact of behavioural factors in the renewable energy investment decision making process: Conceptual framework and empirical findings." Energy Policy **40**(0): 28-38.

Mondol, J. D. and N. Koumpetsos (2013). "Overview of challenges, prospects, environmental impacts and policies for renewable energy and sustainable development in Greece." Renewable and Sustainable Energy Reviews **23**: 431-442.
Moreno, R., G. Strbac, et al. (2010). "Making room for the boom." Power and Energy Magazine, IEEE **8**(5): 36-46.
Neuhoff, K. (2005). "Large-Scale Deployment of Renewables for Electricity Generation." Oxford Review of Economic Policy **21**(1): 88-110.
Owen, A. D. (2006). "Renewable energy: Externality costs as market barriers." Energy Policy **34**(5): 632-642.
Painuly, J. P. (2001). "Barriers to renewable energy penetration; a framework for analysis." Renewable Energy **24**(1): 73-89.
Pollitt, M. (2008). "Foreword: Liberalization and Regulation in Electricity Systems-How can We get the Balance Right?', in." Competitive Electricity Markets: Design, Implementation, and Performance.
Proença, S. and M. S. Aubyn (2013). "Hybrid modelling to support energy-climate policy: Effects of feed-in tariffs to promote renewable energy in Portugal." Energy Economics.
Reed, G., J. Paserba, et al. (2003). "The FACTS on resolving transmission gridlock." IEEE Power and Energy Magazine **1**(5): 41-46.
Richter, M. (2012). "Utilities' business models for renewable energy: A review." Renewable and Sustainable Energy Reviews **16**(5): 2483-2493.
Rosellon, J. (2007). "An incentive mechanism for electricity transmission expansion in Mexico." Energy Policy **35**(5): 3003-3014.
Rudnick, H., R. Ferreira, et al. (2012). Transmission expansion in fast growing economies and the challenges of renewables integration. Power and Energy Society General Meeting, 2012 IEEE, IEEE.
Simshauser, P. (2002). Microeconomic reform of wholesale power markets : a dynamic partial equilibrium analysis of the impact of restructuring and deregulation in Queensland. PhD, The University of Queensland.
Stoft, S. (2002). Power Systems Economics: Designing Markets for Electricity, IEEE Press & Wiley-Interscience.
Unruh, G. C. (2000). "Understanding carbon lock-in." Energy Policy **28**(12): 817-830.
Unruh, G. C. (2002). "Escaping carbon lock-in." Energy Policy **30**(4): 317-325.
van der Vleuten, E. and R. Raven (2006). "Lock-in and change: Distributed generation in Denmark in a long-term perspective." Energy Policy **34**(18): 3739-3748.
Wolfe, P. (2008). "The implications of an increasingly decentralised energy system." Energy Policy **36**(12): 4509-4513.
Wüstenhagen, R. and E. Menichetti (2012). "Strategic choices for renewable energy investment: Conceptual framework and opportunities for further research." Energy Policy **40**(0): 1-10.
Xin-gang, Z., Y. Yi-sheng, et al. (2013). "International cooperation on renewable energy electricity in China–A critical analysis." Renewable Energy **55**: 410-416.
Zhao, J. H., Z. Y. Dong, et al. (2009). "Flexible Transmission Expansion Planning With Uncertainties in an Electricity Market." Ieee Transactions on Power Systems **24**(1): 479-488.

Project 3 work plan for 2013-2015.

Project title:

Research activity	**Expected completion date**	**Outcome**	**Corresponding Deliverable Number**
1. Literature Review	1/4/2013	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	1/4/2013	Transmission expansion • Incentive structures for TNSP's • Planning and expansion • Scale efficient expansion • "Build it and they will come"	1a
3. Literature Review	1/6/2013	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

4. Literature Review	1/6/2013	Electric vehicles (EV) and Plug-in Hybrid Electric Vehicles (PHEV)
		• Vehicle-to-Grid (V2G)
		• Deployment rates
		• Barriers to entry
		    o Liquid combustible fuel dominance/incumbency
		    o Battery life/Charge opportunities
		    o Capital cost requirements to meet growing charging station demand
			1b

Project 3 work plan for 2013-2015.

Project title:

Research activity	Expected completion date	Outcome	Corresponding Deliverable Number

5. Data Validation	30/6/2013	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

6. Data Validation	30/6/2013	Transmission topology agreement • USYD/UN IEEE 14 bus system • UQ representation • Discussion on transmission zone topology • CSIRO resource availability	2
7. Data Validation	30/6/2013	Gas price and availability forecasts to be shared with P2 for their gas network expansion model.	2
8. Protocols for model integration	30/9/2013	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
9. Protocols for model integration	30/9/2013	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
10. Benchmarking and Model Validation	30/9/2013	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
11. Benchmarking and Model Validation	30/9/2013	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**

12. Formal Scenario Development	30/9/2013	• 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

13. Reporting	30/9/2013	End of Financial Year Report	2
14. Modelling	30/3/2014	Modelling multi-node transmission network models in Plexos and ANEM for integration into cluster agreed scenarios.	3
15. Modelling	30/3/2014	Analysis of global gas markets and potential price and supply availability impacts for the NEM.	3
16. Modelling	30/3/2014	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