International experience with transformations in electricity markets: A Short Literature Review

by

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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 & Menichetti, 2012). However its future development is expected to have greater influence over electricity markets (Wüstenhagen & 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 (Foster et al., 2011; Molyneaux, Froome, Wagner, & Foster, 2013; 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 (Byrnes, Brown, Foster, & Wagner, 2013).

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, 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 & 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 et al., 2011; Foster et al., 2013; Institute, 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 (Kenny, Law, & Pearce, 2010; Painuly, 2001).

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, El-Samra, Bou Boutros, & Hashisho, 2013). While the increase in their deployment of wind has been driven by renewable energy targets in the EU (Mondol & Koumpetsos, 2013), China (Xin-gang, Yi-sheng, Tian-tian, & Yu-heng, 2013), a variety of US states (Carley & Browne, 2012) , there are still incumbency issues which detract from realising their full potential for deployment (Jacobsson 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 & 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 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 & Courvisanos, 2012). While engineering challenges are naturally a consideration (Stoft, 2002; Zhao, Dong, Lindsay, & Wong, 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 (Neuhoff, 2005; Unruh, 2000).

1.3. Transmission Expansion

Transmission infrastructure has traditionally been operated by centrally planned vertically integrated government owned entities (Brunekreeft, Neuhoff, & Newbery, 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 & 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 & Wen, 2001). Expansion of transmission in the classical environment has provided access to cheap fossil fuel (mainly coal) resources (Ball et al., 2011; Foster 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 & 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, Porrua, Mocarquer, & Bezerra, 2010). Furthermore the depth of connection charge for large scale and distributed generation is also of concern (Bayfield, Wood, Hiorns, & Trikha, 2006; Rudnick, Ferreira, Mocarquer, & Barroso, 2012).

Globally the scale efficient expansion of transmission infrastructure in light of renewables is clearly driven by incumbency issues (Reed, Paserba, & Salavantis, 2003; Rudnick et al., 2012) and evidently linked to political factors (Fischlein, Wilson, Peterson, & Stephens, 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 (Foxon, 2007; Lilley, Reedman, Wagner, Alie, & Szatow, 2012; Unruh, 2000, 2002; van der Vleuten & Raven, 2006; Wagner, Molyneaux, & Foster, 2014)
- Incumbency of older generation renewables i.e. hydro (Jacobsson & Johnson, 2000; Kalkuhl, Edenhofer, & Lessmann, 2012; Neuhoff, 2005)
- Incumbency of access to transmission (Baldick & Kahn, 1993; Heiman, 2006; Joskow, 2005; Pollitt, 2008)
- Market Structure, incentives and willingness to accept alternative new entrants (Blumstein, Friedman, & Green, 2002)
- Transmission expansion and regulatory frameworks (Fang & Hill, 2003)
- Scale efficient expansion/investment under uncertainty (Zhao 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 (Baldick & Kahn, 1993; Godet, 1987; Kahn & Aron, 1962). 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., & Kahn, E. (1993). Transmission planning issues in a competitive economic environment. *Power Systems, IEEE Transactions on, 8*(4), 1497-1503.

Ball, B., Ehmann, B., Foster, J., Froome, C., Hoegh-Guldberg, O., Meredith, P., . . . Wagner, L. (2011). Delivering a Competitive Australian Power System. Part 1: Australia's Global Position: School of Economics, University of Queensland, Australia.

Bayfield, C., Wood, S., Hiorns, A., & Trikha, C. (2006). Planning for the integration of on-shore renewable generation for the gb transmission system. *Proc. CIGRE*.

Bazilian, M., Onyeji, I., Liebreich, M., MacGill, I., Chase, J., Shah, J., . . . Zhengrong, S. (2013). Re-considering the economics of photovoltaic power. *Renewable Energy, 53*(0), 329-338. doi: http://dx.doi.org/10.1016/j.renene.2012.11.029
Blumstein, C., Friedman, L., & Green, R. (2002). The History of Electricity Restructuring in California. *Journal of Industry, Competition and Trade, 2*(1-2), 9-38. doi: 10.1023/a:1020822720063
BP. (2012). Statistical review of world energy.
Brunekreeft, G., Neuhoff, K., & Newbery, D. (2005). Electricity transmission: An overview of the current debate. *Utilities Policy, 13*(2), 73-93.
Byrnes, L., Brown, C., Foster, J., & Wagner, L. (2013). Australian Renewable Energy Policy: Barriers and Challenges. *Renewable Energy, 60*, 711-721.
Carley, S., & Browne, T. R. (2012). Innovative US energy policy: a review of states' policy experiences. *Wiley Interdisciplinary Reviews: Energy and Environment*.
David, A., & Wen, F. (2001). *Transmission planning and investment under competitive electricity market environment.* Paper presented at the Power Engineering Society Summer Meeting, 2001.
de Vries, L., & Heijnen, P. (2008). The impact of electricity market design upon investment under uncertainty: The effectiveness of capacity mechanisms. *Utilities Policy, 16*(3), 215-227. doi: http://dx.doi.org/10.1016/j.jup.2007.12.002
Effendi, P., & Courvisanos, J. (2012). Political aspects of innovation: Examining renewable energy in Australia. *Renewable Energy, 38*(1), 245-252.
El Fadel, M., Rachid, G., El-Samra, R., Bou Boutros, G., & Hashisho, J. (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. doi: http://dx.doi.org/10.1016/j.rser.2012.11.071
Fang, R., & Hill, D. J. (2003). A new strategy for transmission expansion in competitive electricity markets. *Power Systems, IEEE Transactions on, 18*(1), 374-380.
Fischlein, M., Wilson, E. J., Peterson, T. R., & Stephens, J. C. (2013). States of transmission: Moving towards large-scale wind power. *Energy Policy*.
Foster, J., Froome, C., Hoegh-Guldberg, O., Meredith, P., Molyneaux, L., Saha, T., . . . Ball, B. (2013). Delivering a competitive Australian power system Part 2: The challenges, the scenarios: School of Economics, University of Queensland, Australia.
Foster, J., Wagner, L., Wild, P., Bell, W. P., Zhao, J., & Froome, C. (2011). Market and economic modelling of the impact of distributed generation. *Energy Economics and Management Group, The University of Queensland, Brisbane, 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., & Auer, H. (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. doi: http://dx.doi.org/10.1016/j.energy.2005.02.014
IEA. (2012). *World Energy Outlook 2012*: OECD Publishing.
IEA. (2013). *World - Renewable and Waste Energy Supply (Ktoe).*
Institute, G. C. (2013). Delivering a Competitive Australian Power System Part 3: A better way to competitive power in 2035. *Energy Economics and Management Group Working Papers*.

Jacobsson, S., Bergek, A., Finon, D., Lauber, V., Mitchell, C., Toke, D., & Verbruggen, A. (2009). EU renewable energy support policy: Faith or facts? *Energy Policy, 37*(6), 2143-2146. doi: http://dx.doi.org/10.1016/j.enpol.2009.02.043

Jacobsson, S., & Johnson, A. (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., & Aron, R. (1962). *Thinking about the Unthinkable*: Horizon Press New York.

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

Kenny, R., Law, C., & Pearce, J. M. (2010). Towards real energy economics: Energy policy driven by life-cycle carbon emission. *Energy Policy, 38*(4), 1969-1978. doi: http://dx.doi.org/10.1016/j.enpol.2009.11.078

Lilley, W., Reedman, L., Wagner, L., Alie, C., & Szatow, A. (2012). An economic evaluation of the potential for distributed energy in Australia. *Energy Policy, 51*(1), 277–289.

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. doi: http://dx.doi.org/10.1016/j.enpol.2010.06.059

Masini, A., & Menichetti, E. (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. doi: http://dx.doi.org/10.1016/j.enpol.2010.06.062

Molyneaux, L., Froome, C., Wagner, L., & Foster, J. (2013). Australian Power: Can renewable technologies change the dominant industry view? *Renewable Energy, 60*, 215-221.

Mondol, J. D., & Koumpetsos, N. (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., Strbac, G., Porrua, F., Mocarquer, S., & Bezerra, B. (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. doi: 10.1093/oxrep/gri005

Owen, A. D. (2006). Renewable energy: Externality costs as market barriers. *Energy Policy, 34*(5), 632-642. doi: http://dx.doi.org/10.1016/j.enpol.2005.11.017

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., & Aubyn, M. S. (2013). Hybrid modelling to support energy-climate policy: Effects of feed-in tariffs to promote renewable energy in Portugal. *Energy Economics*.

Reed, G., Paserba, J., & Salavantis, P. (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. doi: http://dx.doi.org/10.1016/j.rser.2012.01.072

Rosellon, J. (2007). An incentive mechanism for electricity transmission expansion in Mexico. *Energy Policy, 35*(5), 3003-3014.

Rudnick, H., Ferreira, R., Mocarquer, S., & Barroso, L. (2012). *Transmission expansion in fast growing economies and the challenges of renewables integration.* Paper presented at the Power and Energy Society General Meeting, 2012 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, Brisbane. Retrieved from http://espace.library.uq.edu.au/view/UQ:157905

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., & Raven, R. (2006). Lock-in and change: Distributed generation in Denmark in a long-term perspective. *Energy Policy, 34*(18), 3739-3748.

Wagner, L., Molyneaux, L., & Foster, J. (2014). The magnitude of the impact of a shift from coal to gas under a Carbon Price. *Energy Policy, 66*, 280-291.

Wolfe, P. (2008). The implications of an increasingly decentralised energy system. *Energy Policy, 36*(12), 4509-4513.

Wüstenhagen, R., & Menichetti, E. (2012). Strategic choices for renewable energy investment: Conceptual framework and opportunities for further research. *Energy Policy, 40*(0), 1-10. doi: http://dx.doi.org/10.1016/j.enpol.2011.06.050

Xin-gang, Z., Yi-sheng, Y., Tian-tian, F., & Yu-heng, Y. (2013). International cooperation on renewable energy electricity in China–A critical analysis. *Renewable Energy, 55*, 410-416.

Zhao, J. H., Dong, Z. Y., Lindsay, P., & Wong, K. P. (2009). Flexible Transmission Expansion Planning With Uncertainties in an Electricity Market. *Ieee Transactions on Power Systems, 24*(1), 479-488. doi: 10.1109/tpwrs.2008.2008681