



CSIRO Intelligent Grid Cluster
Interim Report on whole project outcomes.
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1 Whole Project Outcomes

1.1 PROJECT PROGRESS

This project has provided a comprehensive understanding of the impacts of distributed energy in the Australian Electricity system. Over the last two years the Energy Economics and Management group have been constructing a variety of methodological frameworks for the analysis of Distributed Generation (DG) and its benefits to the Australian Electricity Supply Industry (ESI). In this report we shall briefly outline the progress of each of the project goals while also providing publications to show our significant progress.

Table 1: Summary of Research KPI's for Project 2

Journal Papers Published	7
Journal Papers Submitted	3
Journal Papers Currently in Progress (Final Draft)	4
International Conference Presentations	4

At the end of 2010 we have exceeded all publications KPI's as set out in the original contract establishing the iGrid Cluster (per Schedule 1 p.51 "Deliverables). Furthermore, with nine more publications in the submission process we expect to continue to contribute greatly to the research impact of this cluster.

Since the beginning of this cluster project we have been developing three modelling platforms to investigate the effects of DG in Australia's electricity markets which includes 2 whole market models and one power systems modelling framework. Namely:

- Plexos
- ANEMMarket
- Matpower.



Primarily these modelling frameworks have contributed to our knowledge of how DG will achieve the following objectives:

- Economic benefits due to deferral of network infrastructure
- Enablement of new investment in various aspects of the electricity and energy system
- Analysis of the flow on effects of a massive DE deployment on the greater economy
- Provision of support for the deployment of DE through recommendation on market structure and regulation
- Development of price response schemes for consumers and utilities, which will provide both system level and end-user economics benefits such as the cost reduction of delivered energy.

Economic benefits of investment in the energy system via Large Scale DE Deployment:

- Emissions reduction
- Deferral of transmission upgrades
- Reduction in wholesale spot market average prices
- Lowering spot price volatility
- Reduction in Transmission line losses (which normally attribute 8% of energy lost in the NEM)
- Integration of DG units as market scheduled (MS) dispatchable generation
- Network infrastructure deferral.
 - Wagner, L.D., and Reedman, L., "Deployment of distributed generation across the National Electricity Market"
 - Junhua Zhao and Prof. John Foster "Investigating the Impacts of Distributed Generation on Transmissions Expansion Cost: An Australian Case Study"
 - Junhua Zhao and Prof. John Foster "Flexible Transmission Expansion Planning Considering the Impacts of Distributed Generation"

Market Structure and regulation

- Development of policy strategies to enhance the deployment of DG into Australia
- Analysis of feed-in tariff structures and possible capacity payments for DG.
 - Froome, C., and Wagner, L., "Feed-in Tariffs for Commercial Solar Power Generation within Queensland"



Specifications for carbon trading

- Tender Price Allocation Mechanism: an alternate to carbon trading
 - Molyneaux, L., Foster, J., and Wagner, L. "Is there a more effective way to reduce carbon emissions?"
- Reassessment of the level of assistance provided to generators under the CPRS
 - Menezes, F., Quiggin, J.C., and Wagner, L.D., "Grandfathering and greenhouse: the role of compensation and adjustment assistance in the introduction of a carbon emissions trading scheme for Australia", *Economic Papers*, 2009 vol. 28, no. 2 pp.82-92

Cost/benefit analysis framework for investment decision making

- Levelised Cost of Energy (LCOE) framework to deliver thorough analysis of costs for investment and policy decision makers
 - Assessment of a range of centralised and DG options
 - Range of policy options integrated into modelling framework to inform decision makers ability to assess optimal investment strategies



2 Project Publications

Zhao, J., and Foster, J., "Flexible Transmission Network Planning Considering the Impacts of Distributed Generation" *IEEE Transactions on Power Systems* (A*) (In Press) <http://ideas.repec.org/p/qld/uqeemg/02.html>

The restructuring of global power industries has introduced a number of challenges, such as conflicting planning objectives and increasing uncertainties, to transmission network planners. During the recent past, a number of distributed generation technologies also reached a stage allowing large scale implementation, which will profoundly influence the power industry, as well as the practice of transmission network expansion. In the new market environment, new approaches are needed to meet the above challenges. In this paper, a market simulation based method is employed to assess the economical attractiveness of different generation technologies, based on which future scenarios of generation expansion can be formed. A multi-objective optimization model for transmission expansion planning is then presented. A novel approach is proposed to select transmission expansion plans that are flexible given the uncertainties of generation expansion, system load and other market variables. Comprehensive case studies will be conducted to investigate the performance of our approach. In addition, the proposed method will be employed to study the impacts of distributed generation, especially on transmission expansion planning.

Foster, J., Hinich, M.J., and Wild, P., "Randomly Modulated Periodic Signals in Australia's National Electricity Market," *The Energy Journal* (A), International Association for Energy Economics, (2008) vol. 29(3), pages 105-130.

In this article, we use half hourly spot electricity prices and load data for the National Electricity Market (NEM) of Australia for the period from December 1998 to August 2007 to test for randomly modulated periodicity. In doing so, we apply signal coherence spectral analysis to the time series of half hourly spot prices and megawatt-hours (MWh) load demand from 7/12/1998 to 31/08/2007 using the FORTRAN 95 program developed by Hinich (2000). We detect relatively steady weekly and daily cycles in load demand but relatively more unstable cycles in prices.



Other Publications

Simshauser, P. and P. Wild (2009), "The Western Australian Power Dilemma". *Australian Economic Papers (B)* 48(4), 342-369.

From 1984 gas-fired power generation had been gradually increasing its share of the electricity market in Western Australia (WA) starting at 1 per cent and rising to about 50 per cent by 2008. Had it continued on this trajectory, the WA power system would have made great advances in terms of cost and environmental efficiencies given the looming commencement of the Carbon Pollution Reduction Scheme in Australia from 2011. However, more recently the cost of natural gas has increased from \$3/GJ to \$7/GJ following the sudden collapse of the East Spar gas field in the North West Shelf. In this article, we analyse the impact of the gas price increase and demonstrate that despite being the most environmentally efficient conventional technology, natural gas combined cycle plant has been squeezed out of the market which in turn will increase forward electricity price risks to WA consumers through greater exposure to CO₂ pricing in the long run.

Wild, P. Hinich, M. J. & J. Foster (2010) "Identifying nonlinear serial dependence in volatile, high frequency time series and its implications for volatility modelling." *Macroeconomic Dynamics (A*)* 14(S1), 88-110.

In this article, we show how tests of nonlinear serial dependence can be applied to high-frequency time series data that exhibit high volatility, strong mean reversion, and leptokurtosis. Portmanteau correlation, bicorrelation, and tricorrelation tests are used to detect nonlinear serial dependence in the data. Trimming is used to control for the presence of outliers in the data. The data that are employed are 161,786 half-hourly spot electricity price observations recorded over nearly a decade in the wholesale electricity market in New South Wales, Australia. Strong evidence of nonlinear serial dependence is found and its implications for time series modeling are discussed.

Wild, P. Hinich, M.J. & J. Foster (in press) "Are Daily and Weekly Load and Spot Price Dynamics in Australia's National Electricity Market Governed by Episodic Nonlinearity?" *Energy Economics (A)* 32 (2010), pp. 1082-1091.

In this article, we use half hourly spot electricity prices and load data for the National Electricity Market (NEM) of Australia for the period from December 1998 to February 2008 to test for episodic nonlinearity in the dynamics governing daily and weekly cycles in load and spot price time series data. We apply the portmanteau correlation, bicorrelation and tricorrelation tests introduced in Hinich (1996) to the time series of half hourly spot prices and load demand from 7/12/1998 to 29/02/2008 using a FORTRAN 95 program. We find the presence of significant third and fourth



order (non-linear) serial dependence in the weekly load and spot price data in particular, but to a much more marginal extent, in the daily data.

Menezes, J., and Quiggin, J., and Wagner, L., "Grandfathering and Greenhouse: The Role of Compensation and Adjustment Assistance in the Introduction of a Carbon Emissions Trading Scheme for Australia," *Economic Papers (B)*, (2009) vol. 28(2), pages 82-92, 06.

The terms "grandfather clause" and "grandfathering" describe elements of a policy programme in which existing participants in an activity are protected from the impact of regulations, restrictions or charges applied to new entrants. In this paper, the role of grandfathering in the design of a carbon emissions trading scheme in Australia is assessed. It is argued that adjustment assistance policies such as those adopted in conjunction with previous microeconomic reform programmes are preferable to policies based on the free issue of emission permits. The suggestion that owners of capital assets should be compensated for changes in government policy that reduce the expected flow of income from those assets represents a radical, and undesirable, policy innovation.

Foster, J., "Energy, Aesthetics and Knowledge in Complex Economic Systems," *Journal of Economic Behavior & Organization* (in Press)

It is argued that the fact that economic systems are dissipative structures must be taken fully into account in economics if we are to understand the nature of the economic-ecological interface and how to deal with emergent environmental problems, such as global warming. Such problems are a product of economic growth, which is widely accepted to be the outcome of the acquisition and application of knowledge. Drawing upon disparate literatures within and outside economics, it is argued that economic growth should be more properly viewed as the outcome of a co-evolutionary process that involves the autocatalytic interaction of new knowledge and access of increasing amounts of free energy to do increasingly specialized forms of work. The conventional view is that energy is just a factor of production used increasingly as new knowledge is employed. The possibility of reverse causation is considered here. Specifically, the relevance of the 'energy hypothesis,' associated with Eric Schneider and his collaborators, is assessed. This hypothesis states that all dissipative structures have, as their primary objective, the reduction of accessible free energy gradients. It is concluded that such a hypothesis cannot be rejected in the context of economic behaviour and that this opens up an important research agenda for economists. It is argued that such research has to be interdisciplinary because our economic behaviour is driven by aspirational goals which are aesthetic constructions in the mind and strongly connected to our emotions. In this regard, recent neuropsychological literature,



arguing that certain emotional dispositions are necessary before we can employ our cognitive capabilities effectively, is important to digest. Thus, the possibility exists that it is in the emotional domain of the mind that the energy hypothesis is operative. Aesthetic constructions are, thus, connecting agents in the knowledge-energy co-evolutionary process. Some of the macroeconomic evidence concerning the relationship between free energy use and economic growth is considered and it is found that the energy hypothesis cannot be rejected in the economic domain. However, considerably more research needs to be undertaken before any firm conclusions can be drawn.

2.1.1 Submitted

Zhao, J., and Foster, J., "Investigating the Impacts of Distributed Generation on Transmission Expansion Cost: An Australian Case Study" *Renewable Energy* (A) (Submitted) <http://ideas.repec.org/p/qld/uqeemg/02.html>

Distributed generation (DG) is rapidly increasing its penetration level in Australia, and is expected to play a more important role in the power industry. An important benefit of DG is its ability to defer transmission investments. In this paper, a simulation model is implemented to conduct quantitative analysis on the effect of DG on transmission investment deferral. The transmission expansion model is formulated as a multi-objective optimization problem with comprehensive technical constraints, such as AC power flow and system security. The model is then applied to study the Queensland electricity market in Australia. Simulation results show that, DG does show the ability to reduce transmission investments. This ability however is greatly influenced by a number of factors, such as the locations of DG, the network topology, and the power system technical constraints.

Mullins, J., Wagner, L. and Foster, J., "Price Spikes in Electricity Markets: A Strategic Perspective" (Submitted to the *Journal of Industrial Economics* (A*)) <http://ideas.repec.org/p/qld/uqeemg/05.html>

This paper aims to analyze the issue of price spikes in electricity markets through the lens of noncooperative game theory. The case we consider is Australia's long established National Electricity Market (NEM). Specifically, we adapt von der Fehr and Harbord's multi-unit auction model to settings that more closely reflect the structure of the NEM, showing that price spikes can be related to a specifiable threshold in demand.



Molyneaux, L., Foster, J., and Wagner, L. "Is there a more effective way to reduce carbon emissions?" (Currently being submitted to the *Australian Journal of Resource Economics*) <http://ideas.repec.org/p/qld/uqeemg/04.html>

Whilst emissions trading systems are widely held to be able to deliver lowest-cost abatement, uncertainty reduces their effectiveness. We consider a new scheme, the Tender-Price Allocation Mechanism, which focuses carbon factor cost expenditure on abatement rather than just revenue transfers. It is a scheme that reduces uncertainty and the costs of uncertainty for both firms and regulators. It also incorporates a suite of incentives that compensates for the externalities associated with abatement investment.

2.1.2 In-Progress

Wagner, L.D., and Reedman, L., "Modeling the deployment of plug-in hybrid and electric vehicles and their effects on the Australian National Electricity Market." (In progress) <http://ideas.repec.org/p/qld/uqeemg/06.html>

The development of hybrid and fully electric vehicles could deliver significant reductions of emissions from the Australian transportation sector by shifting its major energy source from internal combustion to electricity. This shift towards the use of electricity shifts the point source emissions to one which has a lower emissions intensity. Changes in load behaviour as a result of the consumer uptake of these vehicles will have significant consequences for network and central planners for the future of Australia's electricity supply industry. This paper investigates the effects on the security of supply of energy during these previously unseen demand patterns, while also examining changes to spot market prices and changes in emissions rates. The simulation results indicate that wholesale prices during the off-peak period will increase slowly over time with controlled charging. While uncontrolled charging increases the incidence of extreme price events and a considerable number of hours with un-served energy within the network. This increase in spot prices may have consequences for regulated retail electricity tariffs. We also discuss the implementation of possible changes to the retail tariff structure to accommodate the charging of these vehicles.



Froome, C., and Wagner, L., “Feed-in Tariffs for Commercial Solar Power Generation within Queensland”

There has been ambivalence and contradictory policy positions in this area in Australia, yet the presence of predictable feed-in tariffs is an essential pre-requisite of a significant switch to DG, particularly in the absence of a significant carbon price or tax. We believe that the case for a gross feed in tariff in Queensland and in all other States is strong and that Federal leadership is necessary in this area. In our study, we focussed on a range of issues that pose obstacles to implementation. These issues have posed a range of reach questions that we shall seek to answer in the coming year. For example, the relative cost of conventional and solar energy sources need to be accurately measured (we identified this at the beginning of the project), we need to understand the interaction of a feed-in tariff regime and the prevailing institutional and regulatory environment in the electricity sector and elsewhere, there are technical issues relating to large scale adoption of DG in a favourable feed-in tariff regime that have to be considered from an economic standpoint, there is the problem of consumer awareness and understanding of tariff systems and, finally, the reactions of various stakeholders to such a regime.

Wagner, L., and Reedman, L., “Deployment of distributed generation across the Australian National Electricity Market.”

The deployment of Distributed Generation (DG) onto an electricity market could have many benefits for system regulators and policy makers across the developed world as a strategy to improve electricity generation efficiency and reduce emissions. With the impending introduction of the Australian Carbon Pollution Reduction Scheme (CPRS), and a greatly expanded Mandatory Renewable Energy Target (MRET), a low pollution future needs to be realised via significant cuts in emissions by stationary energy production. Deciding on the optimal mix of centralized power plant and DG to fulfil emission constraints and the desire for renewable generation will require long-term forecasts. Furthermore, to understand the full economic benefit of the deployment of DG, modelling must be performed at a market level to examine the behavioural consequences of such a wide spread deployment.



Wagner, L., and Foster, J., "Establishing the levelised cost of alternate electricity generation options for Australia" (In progress)

Because of the highly heterogeneous nature of electricity demand, no one individual energy source can effectively be used to serve demand. So an appropriate mix of generation assets is always required. So it is essential to know what the true costs of different generating technologies are. Each country is unique in this regard so it is necessary to provide a unique study of Australia. The platform that we have build has been successfully applied to the expected generation types currently under consideration. We have done this so that we can go on to apply screening curve to establish the optimal plant mix of generation asset types. The intention is to explore how best to embed different types of DG in an optimal mix in the face of assumptions concerning different level of carbon price, or tax.

2.2 CONFERENCE PRESENTATIONS

1. Froome, C., and Wagner, L., "Energy storage and its ability to add stability to intermittent generation and reduce distribution network costs" 29th USAEE/IAEE North American Conference, "Energy and the Environment: Conventional and Unconventional Solutions" October 14-16, 2010. Calgary, Canada
2. Wagner, L.D., and Reedman, L., "Modeling the Large Scale Deployment of Distributed Generation onto Electricity Markets" 29th USAEE/IAEE North American Conference, "Energy and the Environment: Conventional and Unconventional Solutions" October 14-16, 2010. Calgary, Canada
3. Wagner, L.D., and Reedman, L., "Modeling the deployment of plug-in hybrid and electric vehicles and their effects on the Australian National Electricity Market." Presented at 2010 IEEE Conference on Innovative Technologies for an Efficient and Reliable Electricity Supply, Boston, U.S.A., September 2010
4. Wagner, L.D., and Quiggin J., "Reassessing assistance for brown coal generators under the proposed CPRS." Presented at AARES '10, Adelaide Feb 2010
5. Wagner, L.D., "Modeling the Large Scale Deployment of Distributed Generation onto Electricity Markets". US Association for Energy Economics, 2010 Calgary, Canada