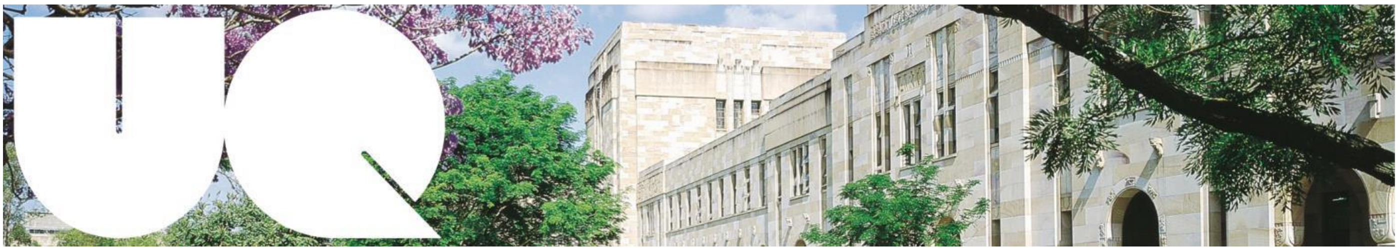

NEMLink: Augmenting the Australian National Electricity Market transmission grid to facilitate increased wind turbine generation and its effect on wholesale spot prices

EEMG Working Paper 10-2015 - Version 09

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As part of the project:

ARC Linkage Project (LP110200957, 2011-2014) - An investigation of the impacts of increased power supply to the national grid by wind generators on the Australian electricity industry

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Preface

This report investigates *'NEMLink: Augmenting the Australian National Electricity Market transmission grid to facilitate higher wind turbine generation and its effect on wholesale spot prices'.* NEMLink is a major augmentation of the Australian National Electricity Market's transmission grid outlined in the National Transmission Network Development Plan (AEMO 2010a, 2010b, 2011a, 2011b). This report is part of a research project titled: *An investigation of the impacts of increased power supply to the national grid by wind generators on the Australian electricity industry: ARC Linkage Project (LP110200957, 2011-2014).*

The aim of the project is to discover the most economical and effective way to accommodate large increases in wind power into the national grid and to understand the effects on the national electricity market. This is crucial to ensure stability of electricity supply and affordable prices in the transition towards a low carbon economy.

Significant increases in Australian power generation using wind are planned for the coming years. This project answers urgent questions concerning the capability of the existing power grid to cope with a volatile source of supply, required grid modifications, impacts on the national electricity market (NEM), the optimal placement of wind farms and the Large-scale Renewable Energy Target (LRET). This is, necessarily, an interdisciplinary project involving economists, electrical engineers and climate scientists with very strong support from the wind generators. A coherent government policy to phase in renewable energy in a cost effective manner will not be possible without high quality research of this kind.

The project's electricity market modelling tool is the *Australian National Electricity Market (ANEM) model version 1.10 (Wild et al. 2015). Wild et al. (2015)* provides extensive details of the version of the ANEM model used in this project. Table 1 provides a list of the project's interim and final reports.

Table 1: The project's publications

Journal publications:
Bell, WP, Wild, P, Foster, J, and Hewson, M (2015), Wind speed and electricity demand correlation analysis in the Australian National Electricity Market: Determining wind turbine generators' ability to meet electricity demand without energy storage, *Economic Analysis & Policy*, vol. 48, no. December 2015, doi:10.1016/j.eap.2015.11.009
Wild, P, Bell, WP and Foster, J, (2015) Impact of Carbon Prices on Wholesale Electricity Prices and Carbon Pass-Through Rates in the Australian National Electricity Market. *The Energy Journal*, vol. 36, no 3, doi:10.5547/01956574.36.3.pwil
Final reports:
Wild, P, Bell, WP, Foster, J, and Hewson, M (2015), *Australian National Electricity Market Model version 1.10*, EEMG Working Paper 2-2015, The University of Queensland, Brisbane, Australia.

Bell, WP, Wild, P, Foster, J, and Hewson, M (2015), *The effect of increasing the number of wind turbine generators on transmission line congestion in the Australian National Electricity Market from 2014 to 2025*, EEMG Working Paper 3-2015, The University of Queensland, Brisbane, Australia.

Bell, WP, Wild, P, Foster, J, and Hewson, M (2015), *The effect of increasing the number of wind turbine generators on wholesale spot prices in the Australian National Electricity Market from 2014 to 2025*, EEMG Working Paper 4-2015, The University of Queensland, Brisbane, Australia.

Bell, WP, Wild, P, Foster, J, and Hewson, M (2015), *The effect of increasing the number of wind turbine generators on carbon dioxide emissions in the Australian National Electricity Market from 2014 to 2025*, EEMG Working Paper 5-2015, The University of Queensland, Brisbane, Australia.

Bell, WP, Wild, P, Foster, J, and Hewson, M (2015), *The effect of increasing the number of wind turbine generators on generator energy in the Australian National Electricity Market from 2014 to 2025*, EEMG Working Paper 6-2015, The University of Queensland, Brisbane, Australia.

Bell, WP, Wild, P, Foster, J, and Hewson, M (2015), *NEMLink: Augmenting the Australian National Electricity Market transmission grid to facilitate increased wind turbine generation and its effect on transmission congestion*, EEMG Working Paper 9-2015, The University of Queensland, Brisbane, Australia.

Bell, WP, Wild, P, Foster, J, and Hewson, M (2015), *NEMLink: Augmenting the Australian National Electricity Market transmission grid to facilitate increased wind turbine generation and its effect on wholesale spot prices*, EEMG Working Paper 10-2015, The University of Queensland, Brisbane, Australia.

Interim reports:

Wild, P, Bell, WP and Foster, J (2014*), Impact of Transmission Network Augmentation Options on Operational Wind Generation in the Australian National Electricity Market over 2007-2012*, EEMG Working Paper 11-2014, School of Economics, The University of Queensland

Wild, P, Bell, WP and Foster, J (2014)*, Impact of increased penetration of wind generation in the Australian National Electricity Market,* EEMG Working Paper 10-2014, School of Economics, The University of Queensland

Wild, P, Bell, WP and Foster, J (2014), *Impact of Operational Wind Generation in the Australian National Electricity Market over 2007-2012*. EEMG Working Paper 1-2014, School of Economics, The University of Queensland.

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Abstract

This report compares the effect of increasing the number of wind turbine generators on wholesale spot prices in the Australian National Electricity Market's (NEM) under the existing transmission grid and an augmented version of the transmission grid called NEMLink (AEMO 2010a, 2010b, 2011a, 2011b). The comparison is made from 2014 to 2025.

We use a sensitivity analysis to compare the effect of five different levels of wind penetration on wholesale spot prices in the original NEM grid and NEMLink augmented grid. The five levels of wind penetration span Scenarios A to E where Scenario A represents 'no wind' and Scenario E includes all the existing and planned wind power sufficient to meet Australia's original 2020 41TWh Large Renewable Energy Target (LRET). We also use sensitivity analysis to evaluate the effect on wholesale spot prices of growth in electricity demand over the projections years 2014 to 2025 and weather over the years 2010 to 2012. The sensitivity analysis uses simulations from the 'Australian National Electricity Market (ANEM) model version 1.10' (Wild et al. 2015).

We find that NEMLink reduces the NEM's average wholesale spot price by 28% in Scenario A that is without any wind power. In comparison, without NEMLink but with the highest wind penetration Scenario E that is wind power alone reduces the NEM's wholesale spot prices by 51%. The combination of both introducing NEMLink and increasing the wind power penetration from Scenario A to E reduces the NEM's wholesale spot price by 65%.

These dramatic price reductions are beneficial for electricity consumers and will help fossil fuel generators exit the market but the long term viability of renewable energy generators needs considering with such low wholesale spot prices. Indeed, the feasibility of an energy only market consisting of an increasing proportion of renewable energy whose marginal costs are nearly zero becomes problematic for financing the ongoing renewal of the renewable energy fleet and the displacement of the fossil fuel fleet.

Contents

Tables

Abbreviations

ABS	Australian Bureau of Statistics
AEMC	Australian Electricity Market Commission
AEMO	Australian Energy Market Operator
AGL	Australian Gas Limited
ANEM	Australian National Electricity Market Model (from EEMG)
CER	Clean Energy Regulator
DC OPF	Direct Current Optimal Power Flow
EEMG	Energy Economics and Management Group (at UQ)
kV	Kilovolt
LNG	Liquid Natural Gas
LRET	Large-scale Renewable Energy Target
MW	Megawatt
MWh	Megawatt hour
NEM	National Electricity Market
NSP	Network Service Provider
NSW	New South Wales
PPA	Power Purchase Agreement
QLD	Queensland
SA	South Australia
TAS	Tasmania
TNSP	Transmission Network Service Providers
UQ	University of Queensland
VIC	Victoria
WTG	Wind Turbine Generator

1 Introduction

We identified constraints in the national electricity market (NEM) transmission grid affecting the beneficial deployment of wind turbine generation to reduce both wholesale spot prices and carbon dioxide emissions (Bell et al. 2015a, 2015b, 2015c, 2015d, 2015g). The higher penetration of wind turbine generation required to address climate change and reduce wholesale spot prices will require either energy storage or augmenting the NEM's transmission grid to overcome the limitations of grid that was primarily built to accommodate supply from a coal generation fleet. This coal generation fleet is a major source of carbon dioxide emissions in Australia and cause of climate change. The coal fleet is nearing the end of its economic life and the opportunity presents to phase out the coal fleet and replace with renewable energy but augmenting the existing transmission structure is required to ensure a smooth transition.

Our findings from a wind speed-electricity demand correlation analysis in the NEM shows that the greatest benefit from wind turbine generation comes from connecting the NEM's peripheral States: Queensland (QLD), South Australia (SA) and Tasmania (TAS) (Bell et al. 2015g). An improved peripheral connection would help both ameliorate the intermittency of wind turbine generation to improve system stability and improve wind turbine generators' ability to match changes in electricity demand. However, delivering these benefits requires improving the transmission capacity through both New South Wales (NSW) and Victoria (VIC).

This report primarily aims to investigate *augmenting the Australian National Electricity Market transmission grid to facilitate higher wind turbine generation.* Specifically we examine the effect of NEMLink on wholesale spot prices in the National Electricity Market. NEMLink is a proposed major augmentation of the transmission grid outlined in the National Transmission Network Development Plan (AEMO 2010a, 2010b, 2011a, 2011b). Wild et al. (2015, figs. 2-6) provides stylised topology diagrams of the transmission grid used in this project and those transmission lines that are part of NEMLink are coloured red. Wild et al. (2015, tbls. 2 & 3) provide the capacity of the lines augmented as part of NEMLink.

We consider the effect of NEMLink on wholesale spot prices under five different levels of wind penetration. The five levels of wind penetration span Scenarios A to E where Scenario A represents 'no wind' and Scenario E includes all the existing and planned wind power sufficient to meet Australia's 2020 41TWh Large Renewable Energy Target. The ANEM model report *(Wild et al. 2015)* provides a comprehensive explanation of the five levels of wind penetration.

Bell et al. (2015d) examine the effect of the five wind penetration levels on wholesale spot prices but without the NEMLink augmentation. We use this wholesale spot price analysis without NEMLink report as a baseline in this report.

The following outline provides a structure for the remainder of the report. Section 2 discusses the methodology for the sensitivity analysis and provides an outline of the *'Australian National Electricity Market (ANEM) model version 1.10' (Wild et al. 2015).* Section 3 presents the results from the sensitivity analysis. Section 4 discusses the results and Section 5 concludes the report.

2 Methodology: a sensitivity analysis using five levels of wind penetration

Wild et al. (2015) provides a detailed description of the ANEM model, justification for the five levels of wind penetration and the incrementing of the baseline electricity demand profile years 2010 to 2012 to form three demand projections from 2014 to 2025. This section provides a brief outline of the ANEM model, the five levels of wind penetration and the demand profiles before presenting the sensitivity analysis results in the next section.

2.1 Australian National Electricity Market Model

The following description provides a simplified computer input-output overview of the ANEM model.

The inputs of the ANEM model are:

- half hourly electricity “total demand” for 50 nodes in the NEM;
- parameter and constraint values for 68 transmission lines and 330 generators, albeit incorporating the de-commissioning of generation plant occurring over the period 2007-2014;
- carbon price, which is assumed zero in this project;
- fossil fuel prices; and
- network topology of nodes, transmission lines and generators.

The outputs of the ANEM model are:

- wholesale spot price at each node (half hourly),
- energy generated by each generator (half hourly),
- energy dispatched (sent out) by each generator (half hourly),
- power flow on each transmission line (half hourly), and
- carbon dioxide emissions for each generator (daily).

2.2 NEMLink sensitivity analysis

We analyse the sensitivity of wholesale spot prices to the introduction of the NEMLink augmentation. The transmission lines augmented for NEMLink (AEMO 2010a, 2010b, 2011a, 2011b) are shown in Wild et al. (2015, Sec. 2). The results in Bell et al. (2015d) form the baseline for the sensitivity analysis. Bell et al. (2015d) analyse the wholesale spot prices in the original NEM transmission grid configuration without NEMLink.

2.3 Five levels of wind penetration

We group existing and planned windfarms into five levels of wind penetration.

a. No wind generation
b. Operational and under construction
c. Advanced planning *(+all the windfarms above)*
d. Less advanced planning *(+all the windfarms above)*
e. Least advanced planning *(+all the windfarms above)*

Details of the windfarms within the five groups are in the project report *'ANEM model version 1.10'* (Wild et al. 2015, tbls. 4 & 5).

2.4 Baseline or weather years 2010-12 and projections years 2014-25

The project uses electricity demand profiles from three calendar years 2010, 2011 and 2012. Using the demand profiles from these three calendar years reduces the chances of modelling an unrepresentative weather year. Additionally, these weather years provide half-hourly correspondence between electricity demand for each node on the NEM and wind power generated for the five levels of wind penetration for each node on the NEM. The wind power generated is calculated from half-hourly wind climatology results for the years 2010 to 2012 (Wild et al. 2015).

The demand profiles in the three baseline-years are incremented to form projections for the years 2014 to 2025, making three projections. We simulated the five levels of wind penetration for each projection base year, making fifteen projections in all to allow sensitivity analysis.

Examining the three baseline years 2010 to 2012 considers the effect of differing annual weather systems on the dynamics of the NEM and the wholesale spot prices. In contrast, the projections years 2014 to 2025 consider the effect of growth in electricity demand on the dynamics of the NEM and the wholesale spot prices.

3 Results

This section presents the results, which should be read while viewing the diagrams in the project report *'Australian National Electricity Market model version 1.10'* (Wild et al. 2015, figs. 1-6). These diagrams relate the node numbers to the topology of the transmission network. Additionally, Wild et al. (2015, tbl. 5) relate the windfarms to their nodes on the NEM.

The congestion on transmission lines will induce wholesale price differentials between nodes on the network. We briefly review the change in transmission congestion induced by NEMLink to inform the change in average wholesale spot prices induced by NEMLink. The project's NEMLink transmission congestion report (Bell et al. 2015e, tbl. 2) summarises the effect of NEMLink on transmission network congestion. There are 68 transmission lines in the ANEM Model (Wild et al. 2015). Without NEMLink, we find 14 congested transmission lines, including 6 of the 8 interstate interconnectors and 8 intrastate transmission lines but only 3 of the intrastate transmission lines exhibited any significant congestion. The congestion on the interconnectors would induce price islanding by state, which we find in our wholesale spot price without NEMLink (Bell et al. 2015d).

With NEMLink, we find the number of congested transmission lines reducing from 14 to 10. For the interconnectors, NEMLink eliminates congestion in 3 interconnectors but induces mild congestion on a previously uncongested NSW-VIC interconnector and moderately increases congestion on 3 other interconnectors DirectLink, Heywood, and BassLink. Particularly, notable is NEMLink exacerbating Heywood's congestion under the highest wind power penetration Scenario E. For the intrastate transmission lines, NEMLink eliminates congestion on 1 NSW line, decrease congestion on 2 TAS lines, increase congestion on 1 NSW line and 1 SA line and produces mixed results on 1 SA line.

Given the aforementioned changes in congestion, we would expect NEMLink to reduce the price differential between states but the increase in congestion on BassLink could maintain or increase in price differential between TAS and the rest of the NEM. In contrast, the nodal prices within TAS would converge. Additionally, the nodes adjoining Heywood, DirectLink and the newly congested NSW-VIC interconnector could experience greater price differentials.

Table 2 presents the average wholesale spot prices for the states in the NEM to enable us to make interstate comparisons to identify system wide effects. Panels (a) and (b) show the average prices with and without NEMLink, respectively. Panels (c) and (d) show the absolute and percentage change in average prices, respectively. Table 2 allows us to examine system wide patterns using the lowest and highest wind penetration scenarios, A and E, and the first and last projection years, 2014 and 2025 for each of the baseline weather years 2010 to 2012. Three effects can explain the change in wholesale spot prices.

- Wind penetration effect shown between scenario A and E
- Weather effect shown between the baseline years 2010 to 2012
- Growth in demand effect shown between the projection years 2014 to 2025

The ANEM model's average wholesale spot prices in Table 2 for QLD are higher than that for the Australian Energy Market Operator (AEMO 2015). Our wholesale spot price report (Bell et al. 2015f, Sec. 3.1) discusses six factors explaining this disparity.

Table 2 shows that NEMLink reduces the NEM's average wholesale spot price across all scenarios from $49.57 to $35.40, shown in Panels (b) and (a) respectively, or by 29% shown in Panel (d). This reduction reflects averaging across demand growth, weather and wind penetration effects. In addition to the 29% reduction of the NEM's average wholesale spot price across all scenarios, Panels (a) and (b) also show the standard deviation in average wholesale spot prices between the states of the NEM with and without NEMLink at $8.59 and $22.88, respectively. Panel (c) shows the difference in standard deviation that Panel (a) less Panel (b) at -$14.30. There is considerable reduction in standard deviation of the average wholesale spot prices or convergence of prices. This is a further indication of the overall success of NEMLink in reducing congestion.

Next, we consider the combined effect of NEMLink and increased wind power penetration on wholesale spot prices. Without NEMLink shown in Panel (b), the increase in wind power penetration from Scenario A to E reduces average wholesale spot prices from $66.50/MWh to $32.65/MWh by 51%. With NEMLink shown in Panel (a), the increase in wind power penetration from Scenario A to E reduces wholesale spot prices from $47.76/MWh to $23.04/MWh or by 51%. The combined effect of NEMLink and increased wind power reduces average wholesale spot prices from $66.50/MWh to $23.04/MWh or by 65%.

However, the reduction in average wholesale prices is far from even across the NEM. For instance, Panel (c) shows the introduction of NEMLink causes an absolute reduction in average spot market prices for QLD, TAS and VIC across growth in demand, the weather effect and increases in wind power penetration. However, the introduction of NEMLink in Scenario A without any wind power causes the average wholesale spot prices to rise in NSW. Panel (b) shows NSW has the cheapest wholesale spot prices in the NEM and QLD the most expensive wholesale spot prices in the NEM. The introduction of NEMLink would allow some price equalisation. However, NSW will also benefit from reductions in average wholesale prices under the combined effect of NEMLink and increased wind power in Scenario E.

Panel (c) shows that SA experiences some small increases in wholesale spot prices under the combined effect of NEMLink and Scenario E wind power penetration. However, Panel (b) shows that SA has the cheapest wholesale spot prices in the NEM in Scenario E without NEMLink. SA experiences small increases from a very small base. Additionally, without NEMLink, SA experiences negative prices that contribute to the cheapest wholesale prices but these negative prices indicate the spillage of emissions free electricity generation. NEMLink allowing the export of this surplus electricity improves the economic viability of SA's wind generators and helps reduce CO_2 emissions elsewhere in the NEM. Further research is to evaluate the sensitivity of negative prices in SA to NEMLink.

Table 2: The average wholesale spot prices for wind penetration scenarios A and E, the projection year 2014 and 2025 and baseline years 2010 to 2012

Panel (a) Average prices with NEMLink

NEMLink	NSW	QLD	SA	TAS	VIC	NEM	Std. Dev.
a	**37.82**	**59.68**	**44.94**	**53.33**	**44.78**	**47.76**	**7.59**
2010	**39.37**	**61.84**	**44.66**	**54.11**	**44.43**	**48.73**	**8.04**
2014	27.30	34.86	30.59	42.11	30.29	32.93	5.14
2025	51.45	88.82	58.73	66.12	58.57	64.53	12.90
2011	**31.09**	**49.70**	**38.12**	**50.29**	**38.03**	**41.10**	**7.43**
2014	22.69	31.65	25.68	39.48	25.55	28.98	5.99
2025	39.49	67.75	50.56	61.11	50.50	53.22	9.74
2012	**42.99**	**67.51**	**52.04**	**55.60**	**51.88**	**53.43**	**7.93**
2014	30.00	37.04	35.74	42.90	35.48	35.83	4.12
2025	55.98	97.98	68.35	68.29	68.29	71.03	13.94
e	**14.63**	**36.69**	**13.83**	**32.41**	**15.24**	**23.04**	**9.89**
2010	**15.56**	**37.66**	**14.79**	**33.94**	**15.92**	**24.07**	**10.06**
2014	11.71	24.35	10.85	26.99	11.54	17.47	7.06
2025	19.41	50.96	18.73	40.89	20.31	30.67	13.35
2011	**12.13**	**33.16**	**11.50**	**32.13**	**12.82**	**20.83**	**10.05**
2014	9.03	23.55	8.60	25.81	9.34	15.64	7.72
2025	15.23	42.77	14.39	38.44	16.29	26.02	12.48
2012	**16.21**	**39.26**	**15.21**	**31.15**	**16.98**	**24.23**	**9.71**
2014	12.30	23.74	11.22	24.71	12.28	17.20	6.04
2025	20.12	54.78	19.19	37.60	21.69	31.27	13.80
Average	**26.23**	**48.19**	**29.39**	**42.87**	**30.01**	**35.40**	**8.59**

Panel (b) Average prices without NEMLink

Original	NSW	QLD	SA	TAS	VIC	NEM	Std. Dev.
a	**29.14**	**111.62**	**75.79**	**61.71**	**72.97**	**66.50**	**26.51**
2010	**30.89**	**113.97**	**73.24**	**61.31**	**69.61**	**66.55**	**26.64**
2014	23.21	60.04	44.45	47.39	41.65	41.81	11.87
2025	38.56	167.89	102.02	75.23	97.56	91.30	42.28
2011	**24.77**	**105.49**	**60.66**	**58.61**	**56.23**	**58.67**	**25.77**
2014	20.05	49.79	40.34	45.03	36.91	36.95	10.16
2025	29.48	161.19	80.97	72.19	75.55	80.40	42.78
2012	**31.76**	**115.41**	**93.46**	**65.22**	**93.07**	**74.27**	**28.81**
2014	23.84	64.99	54.63	51.04	51.30	46.67	13.64
2025	39.69	165.83	132.29	79.39	134.84	101.88	44.97
e	**16.80**	**74.31**	**13.37**	**34.20**	**19.81**	**32.65**	**22.45**
2010	**17.73**	**76.04**	**14.17**	**35.73**	**20.45**	**33.81**	**22.83**
2014	14.15	45.05	9.48	27.75	13.42	22.82	13.09
2025	21.31	107.04	18.86	43.70	27.47	44.80	32.84
2011	**14.89**	**65.62**	**10.59**	**33.25**	**15.81**	**29.07**	**20.33**
2014	11.94	32.71	7.13	26.18	10.86	18.53	9.89
2025	17.83	98.53	14.06	40.31	20.76	39.60	31.45
2012	**17.79**	**81.26**	**15.35**	**33.64**	**23.16**	**35.07**	**24.34**
2014	14.32	44.28	10.28	25.97	14.82	22.65	12.33
2025	21.26	118.24	20.41	41.32	31.51	47.48	36.65
Average	**22.97**	**92.96**	**44.58**	**47.96**	**46.39**	**49.57**	**22.88**

Panel (c) Change in average prices: Panel (a) less Panel (b)

NEMLink - Original	NSW	QLD	SA	TAS	VIC	NEM	Std. Dev.
a	**8.68**	**-51.94**	**-30.85**	**-8.38**	**-28.19**	**-18.74**	**-18.91**
2010	**8.49**	**-52.13**	**-28.58**	**-7.20**	**-25.17**	**-17.82**	**-18.60**
2014	4.08	-25.19	-13.86	-5.28	-11.35	-8.88	-6.73
2025	12.89	-79.07	-43.30	-9.11	-38.99	-26.76	-29.38
2011	**6.32**	**-55.79**	**-22.54**	**-8.32**	**-18.20**	**-17.57**	**-18.34**
2014	2.64	-18.13	-14.67	-5.56	-11.36	-7.97	-4.17
2025	10.01	-93.45	-30.41	-11.08	-25.05	-27.17	-33.04
2012	**11.23**	**-47.90**	**-41.42**	**-9.62**	**-41.18**	**-20.84**	**-20.88**
2014	6.17	-27.95	-18.90	-8.14	-15.82	-10.83	-9.52
2025	16.29	-67.85	-63.95	-11.10	-66.55	-30.85	-31.02
e	**-2.17**	**-37.62**	**0.46**	**-1.80**	**-4.57**	**-9.60**	**-12.56**
2010	**-2.17**	**-38.39**	**0.62**	**-1.79**	**-4.52**	**-9.74**	**-12.77**
2014	-2.44	-20.69	1.37	-0.76	-1.88	-5.35	-6.02
2025	-1.90	-56.08	-0.12	-2.81	-7.16	-14.13	-19.50
2011	**-2.76**	**-32.46**	**0.90**	**-1.12**	**-3.00**	**-8.24**	**-10.27**
2014	-2.91	-9.16	1.47	-0.36	-1.52	-2.89	-2.16
2025	-2.60	-55.76	0.34	-1.87	-4.47	-13.58	-18.97
2012	**-1.58**	**-42.00**	**-0.14**	**-2.49**	**-6.18**	**-10.84**	**-14.63**
2014	-2.02	-20.54	0.95	-1.26	-2.54	-5.46	-6.29
2025	-1.13	-63.46	-1.22	-3.72	-9.82	-16.21	-22.85
Average	**3.26**	**-44.78**	**-15.19**	**-5.09**	**-16.38**	**-14.17**	**-14.30**

Panel (d) Percentage change in average prices

% Change in average prices	NSW	QLD	SA	TAS	VIC	NEM	Std. Dev.
a	**30**	**-47**	**-41**	**-14**	**-39**	**-28**	**-71**
2010	**27**	**-46**	**-39**	**-12**	**-36**	**-27**	**-70**
2014	18	-42	-31	-11	-27	-21	-57
2025	33	-47	-42	-12	-40	-29	-69
2011	**26**	**-53**	**-37**	**-14**	**-32**	**-30**	**-71**
2014	13	-36	-36	-12	-31	-22	-41
2025	34	-58	-38	-15	-33	-34	-77
2012	**35**	**-42**	**-44**	**-15**	**-44**	**-28**	**-72**
2014	26	-43	-35	-16	-31	-23	-70
2025	41	-41	-48	-14	-49	-30	-69
e	**-13**	**-51**	**3**	**-5**	**-23**	**-29**	**-56**
2010	**-12**	**-50**	**4**	**-5**	**-22**	**-29**	**-56**
2014	-17	-46	14	-3	-14	-23	-46
2025	-9	-52	-1	-6	-26	-32	-59
2011	**-19**	**-49**	**9**	**-3**	**-19**	**-28**	**-51**
2014	-24	-28	21	-1	-14	-16	-22
2025	-15	-57	2	-5	-22	-34	-60
2012	**-9**	**-52**	**-1**	**-7**	**-27**	**-31**	**-60**
2014	-14	-46	9	-5	-17	-24	-51
2025	-5	-54	-6	-9	-31	-34	-62
Average	**14**	**-48**	**-34**	**-11**	**-35**	**-29**	**-62**

As noted in the introduction to Section 3, Bell et al. (2015e) find that NEMLink increases congestion on BassLink and BassLink is excluded from the NEMLink argumentation. We find the congestion on BassLink prevents TAS prices converging to the prices on the mainland NEM. For instance Panel (b) shows that TAS has the second most expensive average wholesale spot prices across all scenarios without NEMLink at $47.96 after QLD at $92.96. However, Panel (c) shows that TAS (-$5.09/MWh) has converged less to the NEM's average wholesale spot prices than QLD (-$44.78/MWh). The congestion on BassLink is causing a price islanding effect.

It should also be recognised, as with the case of the congestion results, the average price outcomes for TAS would also crucially depend upon the way TAS hydro was dispatched in the ANEM model simulations. Changes to these assumptions could affect the price results cited in this report.

4 Discussion

We have analysed the sensitivity of the Australian National Electricity Market wholesale spot prices to the introduction of NEMLink outlined in the National Transmission Network Development Plan (AEMO 2010a, 2010b, 2011a, 2011b). During this sensitivity analysis, we also considered the effect of increasing the number of wind turbine generators (WTG) on congestion from Scenario A that is no wind power to Scenario E that is sufficient wind power to meet the 2020 41TWh Large Renewable Energy Target. The sensitivity analysis also considered the effect of weather and electricity demand growth on congestion. We used simulations from the Australian National Electricity Market Model (Wild et al. 2015) to perform the sensitivity analysis.

The major results are:

- In Scenario A that is excluding any wind power, NEMLink reduces the NEM's wholesale spot price by 28%, see Table 2 Panel (d) Scenario A;
- without the NEMLink augmentation, increasing the wind power penetration from Scenario A to E reduces the NEM's wholesale spot prices by 51% that is calculated as the change in Table 2 Panel (b) from Scenario A at $66.50/MWh to Scenario E at $32.65/MWh; and
- the combination of both introducing NEMLink and increasing the wind power penetration from Scenario A to E reduces the NEM's wholesale spot price by 65% that is calculated as the change in Table 2 from Panel (b) Scenario A at $66.50/MWh to Panel (a) Scenario E at $23.04/MWh.

These dramatic price reductions are beneficial for electricity consumers and will help fossil fuel generators exit the market but the long term viability of renewable energy generators needs considering with such low wholesale spot prices. Indeed, the feasibility of an energy only market consisting of an increasing proportion of renewable energy whose marginal costs are nearly zero becomes problematic for financing the ongoing renewal of the renewable energy fleet and the displacement of the fossil fuel fleet.

Historically, generators have depended on Power Purchase Agreements (PPAs) with retail companies to ensure viability. More recently, however, the willingness of the three major vertically integrated retailers, in particular, to sign PPA's for new renewable energy projects has disappeared. Many commentators have seen this as part of a larger strategy on their part aimed at protecting their fossil fuel generation fleet.

We need a clearer picture of the electricity price and emissions reducing benefits of NEMLink in conjunction with renewable energy comprising projections up to 100% renewable energy to plan the optimal NEMLink and renewable energy portfolio and pathway toward 100% renewable energy. This would require extending the original NEMLink proposal (AEMO 2010a, 2010b, 2011a, 2011b) to incorporate emissions benefits and optimise in conjunction renewable energy portfolios and NEMLink configurations. The ensuing optimal renewable energy portfolio, that reduces electricity prices and maintains system stability, could provide the basis for determining subsidies or payments complementary to market based revenues to ensure the NEM maintains an optimal mix of renewable energy. Our NEMLink transmission congestion report (Bell et al. 2015e, Secs. 4 & 5) further discusses the optimal NEMLink and renewable energy portfolio. New LRET legislation post 2020 mapping a pathway to 100% renewable energy would make the dual NEMLink and renewable energy portfolio optimisation easier.

Another important step will be ensuring that retail companies cannot game the market by refusing to either underwrite PPA agreements with prospective new renewable energy projects or extend their own renewable portfolios if they are vertically integrated enterprises. Possible measures could include increasing the after-tax penalty rates payable by retailers if any shortfall in Large-scale Generation Certificates was because of their own strategic decision-making. Under such circumstances, they should also not be allowed to pass on these increased costs to their retail customers but should, instead, be required to absorb any increased cost internally. If gaming becomes entrenched amongst vertically integrated retail companies, consideration could also be given to splitting these companies up into separate retail and generation entities.

Our NEMLink transmission congestion report (Bell et al. 2015e) discusses addressing congestion emerging in the original NEMLink proposal under the wind penetration Scenario E. Notable is congestion on BassLink causing a price islanding effect that is TAS experiencing an extremely modest reduction in wholesale spot price compared to other states given its high wholesale spot prices. BassLink is excluded from augmentation in the original NEMLink proposal. A future revaluation of NEMLink that includes higher levels of renewable energy and values emissions reduction may find BassLink worth augmenting.

Our NEMLink transmission congestion report (Bell et al. 2015e) also discusses DirectLink as another contender for inclusion in a future NEMLink proposal. It also exhibits increasing congestion under both the introduction of NEMLink and higher penetrations of wind power. Despite QNI's augmentation under NEMLink, the congestion in DirectLink maintain a price differential between NSW and QLD making QLD's prices the most expensive under all scenarios in Table 2 relative to NSW and under most of the scenarios in Table 2 relative to the rest of the NEM.

Finally, a further benefit of NEMLink is the reduction of wholesale spot price variability and convergence around NEM's mean price. This will help retailers manage wholesale spot price volatility risk and potentially pass on the risk management savings to retail customers.

5 Conclusion

We find both increases in wind power and the introduction of NEMLink reduce average wholesale spot price. Combining NEMLink and wind power penetration amplifies the reduction in wholesale spot prices.

There is a requirement to re-evaluate the NEMLink proposal using alternative NEMLink structures and under higher penetrations of renewable energy to 100% renewable energy to find an optimal renewable energy portfolio and NEMLink configuration. LRET legislation mapping a pathway to 100% would also help develop an optimal renewable energy portfolio and NEMLink configuration pathway.

More immediately, we recommend three further NEMLink research topics using the original proposed NEMLink. (1) Evaluate the effect of NEMLink on carbon emissions. (2) Evaluate the effect of NEMLink on generator dispatch patterns, for instance, the change in generation by fuel type: gas, black coal and brown coal and by technology OCGT and CCGT. (3) Evaluate the effect of NEMLink on the total revenue for each generator and savings for electricity customers by state.

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