Attachment 1

AUGUST 2015

FUTURE NETWORK COST RECOVERY AND DEPRECIATION

Regulatory and policy options

We must use time as a tool,
not as a couch

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CONTENTS

Overview

Current regulatory approaches effectively presume future consumers will meet a substantial proportion of the capital costs of long-lived electricity and gas network investments made today.

Yet changes in demand, technology and cost conditions make this historic presumption less certain and the current approach potentially unsustainable. Continuation of the current path of not addressing the issue risks an avoidable regulatory failure with adverse outcomes for the long-term interest of consumers.

There are positive and proactive alternatives to a potentially risky 'wait and see' approach. There is a need for networks to move to more flexible depreciation approaches that will protect consumers from future regulatory failure arising from fundamental changes in energy markets.

The Australian Energy Regulator has rightly likened the regulatory asset base to the principal amount of a home mortgage, which is funded at an interest rate (the rate of return) and paid off over time. [1] Just as households can both save and have greater flexibility by paying off a home loan early, network customers as a whole may benefit by bringing forward the recovery of investment costs during the current phase of lower financing costs.

1. INTRODUCTION – THE CHALLENGES TO TRADITIONAL COST RECOVERY PATHS

Current economic regulatory approaches spread the recovery of long-lived capital investments in energy network assets over periods of between 30 to 50 years. This effectively defers the recovery of a substantial component of the costs of network infrastructure to future consumers that will be operating in future energy markets. These approaches presume future consumers will meet a substantial proportion of capital costs of major investments that are being made today.

Over the current determination cycle, for example, the Australian electricity and gas network sector is likely to need to make capital investments of approximately $600 million per month to connect and reliably serve households and businesses.[2]

The rapidly evolving energy market environment poses a significant challenge to this traditional paradigm of deferred recovery. Changes in demand, technology and cost conditions make the historic presumption of future consumers meeting a substantial proportion of today's capital investments less certain and the current approach potentially unsustainable. Continuation of the current 'wait and see' approach risks a regulatory failure with adverse outcomes for consumers. Modern risk management principles – and the logic of Pascal's wager[3] – suggest that where probabilities are uncertain, potential consequences should assume critical importance.

1 AER Issues Paper Victorian electricity distribution pricing review, 2016 to 2020, June 2015, p.10

2 Based on estimates in AER *State of the Energy Market Report* (2014), p.74 and Table 4.2

3 The seventeenth century mathematician Blaise Pascal formulated in his Pensées what came to be referred to as 'Pascal's wager'. The 'wager' is at its heart a pragmatic argument for the belief in a supreme being, derived by examining a matrix of potential consequences for beliefs for or against in the face of uncertainty before the fact. The key two potential outcomes in the hypothetical wager are salvation, or eternal damnation. It is commonly considered as an early forerunner to such modern concepts as game theory and risk management.

In this case, precaution should direct all stakeholders to understanding and discussing the risk mitigation options that are available to avoid costly regulatory failure. For exactly these reasons, this challenge is increasingly being recognised internationally by regulators and energy commentators as an area for assessment and early action.[4]

This paper discusses a number of regulatory and policy options to address this challenge, and examines their potential implications for the long-term interests of current and future consumers. It concludes that there are viable tools, in particular, the more flexible use of depreciation approaches, which can be used to address these challenges.

It is prudent and opportune to apply these more flexible approaches as part of the 'toolbox' of network regulation, and they should be progressed through active engagement with network customers and regulatory bodies about the benefits of these measures.

4 See for example, New Zealand Commerce Commission *Input methodologies: Invitation to contribute to problem definition*, 16 June 2015, p.29.and p.57-58, Frontier Economics Briefing *That Sinking Feeling*, July 2015 and COAG Energy Council Energy Working Group *Electricity network economic regulation; scenario analysis – Policy Advice*, June 2015

2. COST RECOVERY APPROACHES AND CHANGING MARKET CIRCUMSTANCES

2.1 EVOLVING MARKET ENVIRONMENT AND TRADITIONAL REGULATORY APPROACHES

The patterns and level of energy use and demand across Australian electricity and gas networks are currently undergoing a once in a generation shift. This is due to a combination of changing technologies and their impact on relative costs, past and current public subsidy arrangements for solar photovoltaic (PV) technologies, consumer responses to recent rises in energy charges and the cumulative impact of a suite of past energy efficiency measures.

For example, after around six decades of steady growth in total delivered electricity, peaking at total system demand just below 200 000 gigawatt hours in 2009, demand in the National Electricity Market connected electricity network has fallen 1.5 per cent on average over the past five years. Average annual residential and commercial consumption has fallen from around 8 000 kilowatt hours (Kwh) to around 6 000 Kwh per customer over the same period, a decline of approximately 30 per cent.[5]

This decline in the average volume of network demand does not significantly affect the costs of providing the network. Network costs are instead driven by the cost to reliably serve expected peak demand, obligations to offer new connections, and the costs to efficiently maintain assets and invest to deliver efficient services over the medium-term. Technology innovation or consumer behavior which lowers peak demand will generally put downward pressure on the cost of network services, but technologies and consumer behavior which only lower *average* energy demand will not lower the cost of network services and will tend to increase price per unit of energy.

The emergence of economic household level battery storage products, demonstrated by the launch in April 2015 of Tesla's 'Powerwall', represents a further transformative change to the energy delivery chain. The technology suites employed to deliver future network services are evolving rapidly to a greater mix of shorter-lived information technology and other network management assets, and average network demand is not growing predictably or steadily. In fact, it is possibly entering a long-term decline, with recent Australian Energy Market Operator forecasts encompassing scenarios ranging from continued decline, or a gradual recovery in demand.

The setting of the regulatory depreciation allowance decides who pays for network infrastructure services through time. Under current network regulatory rules a network business may propose a depreciation path, but the regulator has final discretion to set an allowance within the relevant *National Electricity Rules* and may also reject proposed depreciation proposals in some circumstances under the *National Gas Rules*.

Depreciation allowances to date have been a relatively uncontentious part of network revenue determinations. The previous steady growth in overall electricity demand, the largely stable technology for delivery of network services, and recognition of the typically long-lived nature of these investments contributed to this relative lack of regulatory policy attention.

The assumptions underpinning each element of this past regulatory approach to depreciation allowances are being challenged by changing technology, costs, demand patterns and emerging competitive forces impacting networks. The risk of a disjoint, between traditional regulatory approaches built on the historical conditions of yesterday and the emerging market circumstances of tomorrow, has arguably never been higher.

5 AEMO *National Electricity Forecasting Report Overview*, June 2015, p.8

2.2 LACK OF ACCESS TO NORMAL RISK MANAGEMENT AVENUES

Network owners and investors face the risks of these changing demands and conditions, but currently do not have access to the same risk management tools and strategies which would be used by normal commercial firms in comparable market circumstances.

These risk management tools include fully flexible pricing approaches to optimize efficient asset utilisation, a capacity to bring forward depreciation on assets at risk of being stranded, scope to set shorter depreciation schedules for new assets, a capacity to pause investment plans, or exercise the strategic 'option' to delay investment.

Under current network regulatory rules, however, the structure of prices is subject to approval and disallowance by the economic regulator. Similarly, depreciation allowances, while being proposed by each network business, are effectively determined by the regulatory body. In addition, electricity and gas networks commonly face statutory obligations to serve (with these obligations translating to requirements to make customer-specific investments), in contrast to normal market participants.

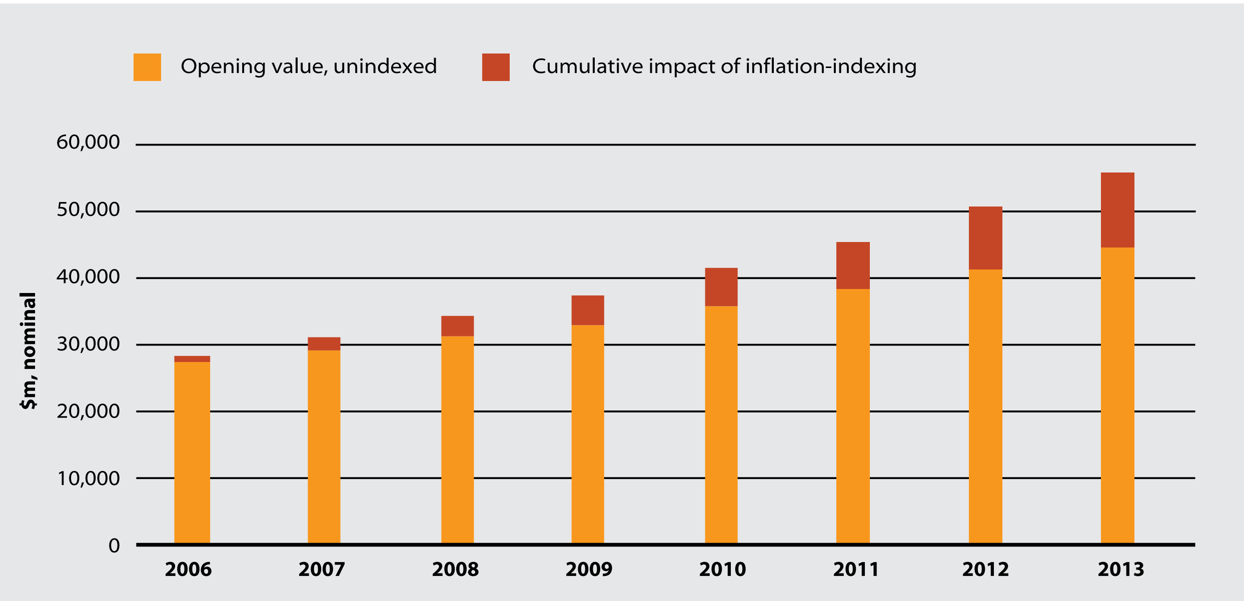
In fact, current regulatory approaches and regimes reflect an approach to cost recovery risks that runs directly counter to expected normal commercial practice.

For example, the annual indexation of the regulatory asset base (RAB) results in a deferral of recovery of part of the required return on capital, and its effective addition to (or capitalisation into) the capital base. This occurs because under the existing 'Post-Tax Revenue Model' of the Australian Energy Regulator (AER), the regulator reduces the amount of straight-line depreciation by the amount of inflation (or indexation) that is applied to the RAB.

That is, compensation for changes in inflation are capitalised into the RAB by decreasing the amount of depreciation provided to the business. This approach provides only the real element of the return in cash, and as such, has the impact of slowing the overall return of capital to the network business. This reduces cash flows in the short term relative to an approach where this indexation adjustment was not made.

Figure 1 sets out an illustrative example of the cumulative and compounding impact of this effect as a proportion of the 2006 regulatory asset base of all Australian electricity network businesses.

FIGURE 1 ILLUSTRATIVE EXAMPLE OF CUMULATIVE IMPACT OF RAB INDEXATION (2006-2013)



Applying current approaches has the effect of further back-loading the recovery of approved efficient network costs towards the end of the assets assessed lives. In practical terms, this means the deferral of recovery of regulator-approved revenues even further into the future than intended, and into periods in which greater uncertainty about market conditions and eventual recoverability exists. Perversely, this outcome artificially pushes investment recovery into a period in which the relevant assets are at proportionally *greater* risk of economic stranding or bypass.

Recent determinations affecting recovery of the costs of existing electricity meters provide a further example of how regulatory approaches can exacerbate approaches that are at odds with those observed in competitive markets.

In Queensland and New South Wales, AER electricity network determinations provide for the unrecovered value of existing meter assets which are replaced by new meters under a new competitive metering model to be added to the existing RAB for future recovery. This outcome avoids the necessity of any party bearing a lump sum payment, with the objective of facilitating metering competition and consumer choice. While there may be some positive features of this approach in the specific case, the practical impact of this approach, however, is to further add to the unrecovered asset base the value of assets which are in reality no longer in service.

Arguably, flexibility is also lacking in the other direction. Under the current *National Electricity Rules*, deferral of depreciation on electricity network infrastructure between regulatory periods beyond that implied by current 'straight-line' depreciation approaches is not currently permitted. This is despite there being some instances in which it is efficient for both networks and consumers to defer depreciation on a proportion or set of network assets into the future, so that the time profile of cost recovery will not unduly impact on network demand. Regulatory approaches and rules in electricity do not currently cater for this ordinary commercial practice.

2.3 CURRENT DEPRECIATION APPROACHES NOT DELIVERING ON PROMISED POLICY GOALS

The key rationales for the current dominant 'straight-line' depreciation approach have been that it promotes stable network prices overtime, and provides for all users of an asset to contribute to the capital costs which support their services.

In fact, network prices have varied significantly over the past decade, influenced by a variety of cost drivers, including changes to the cost of capital, labour and other input costs. In addition, significant capital expenditure programs in the first round of AER-determinations contributed to an associated increase in required depreciation allowances.

This means that in many cases the policy goal of stable network prices over time cannot be said to have been fully achieved. Lack of network pricing stability has been a major argument used by proponents of recently implemented network regulatory reforms to argue for these changes. In response to a similar set of concerns, the AER has recently sought to investigate the implications of the increasing profile of RABs as a driver for pricing outcomes in its current Queensland network revenue review.[6]

6 AER Issues paper *Queensland electricity distribution regulatory Proposals 2015–16 to 2019–20*, December 2014, p.19

2.4 NEED FOR REGULATORY POLICY INNOVATION IN A CHANGING MARKET ENVIRONMENT

Areas of regulation that are relevant to the emerging technologies, new services and competitive forces transforming the environment of networks are increasingly being re-examined in Australia and internationally. Policy makers are considering the need for regulatory change through processes such as the Australian Energy Market Commission's review of competition in metering, and the Energy Council's current policy review process around the implications of new energy services for customer protection frameworks and regulation.

The past five years has also seen major regulatory reforms to how regulators set a number of the core revenue 'building blocks' that make up regulated network revenues. Changes to rules, and detailed AER guidelines, have significantly reformed how rates of return are determined and operating and capital expenditures are estimated. New investment tests and incentive schemes to drive greater capital investment efficiency, as well greater assurance and oversight around the efficiency of past investments, have been introduced.

Building on these changes, electricity network pricing rule changes finalised by the Australian Energy Market Commission in November 2014 are designed to progressively allow for the introduction of improved pricing signals to network customers from 2017 onwards. This should in turn progressively help drive more efficient investment and usage decisions, improving the utilisation of network infrastructure.

All of this reform activity has occurred, however, without any substantial re-examination or alteration to one of the key drivers of network charges – the setting of regulatory depreciation allowances. Regulatory depreciation provides for the return <u>of</u> capital invested, and typically constitutes between 10 to 20 per cent of final network charges, equivalent to over $3.0 billion per year for Australian electricity and gas networks.[7]

Declining average network demand, and largely fixed network costs, creates a risk of locking in steadily increasing network charges over time. This potential is exacerbated by network pricing structures that rely heavily on the recovery of fixed costs through volume-based charges, and the potential emergence of battery storage and distributed generation technologies that could allow a significant proportion of existing customers to entirely disconnect from networks over the coming decade. This possibility, commonly referred to as the 'utility death spiral' hypothesis, has been widely canvassed in utility sector commentary both internationally and in Australia.[8]

A number of commentators and the AER have identified the growth in network asset bases as an issue for potential concern.[9] However, to date there has been insufficient recognition that under the building blocks model a growing RAB is synonymous with the proposition that the total of regulator-approved charges being paid by today's consumers are less than the sum total of deferred future returns on and of capital. This is characteristic of the phase of significant network investments made over 2008-2012, and it highlights the importance of sustainably addressing this challenge.

Networks, consumers and regulators may have differing perspectives on how quickly network investments can or should be depreciated (that is, the economic lives of the assets). It is uncontroversial, however, that the regulatory framework is specifically designed to ensure both a reasonable opportunity to recover efficient future costs, and a high degree of assurance over the recovery of past investments.[10] This reasonable opportunity and assurance underpins investors' willingness to provide relatively low cost capital for long-lived investments made in the common network, which directly benefits consumers by lowering network charges. This is practically achieved through the regulatory framework by providing for a commercial risk-adjusted rate of return on the RAB and a depreciation allowance based on the economic lives of the assets forming the RAB.

An important factor in progressing discussion on this issue is that changes to depreciation allowances, unlike operating or capital cost estimates, or the rate of return, do not result in absolute changes in required revenues. That is, they are revenue neutral. They simply change the *time profile* of cost-recovery – put simply, they decide how much current versus future consumers should pay.

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7 Estimate based on AER *State of the Energy Market Report* (2014), p.71, Figure 2.2 and Table 4.1.

8 See for example, EEI *Disruptive Challenges: Financial Implications and Strategic Responses to a Changing Retail Electric Business*, January 2013

9 AER *Issues Paper - Queensland electricity distribution regulatory proposals 2015–16 to 2019–20*, December 2014, p.19

10 See *National Electricity Law*, Section 7A(2), *National Gas Law*, Section 24(2), COAG Energy Council Energy Working Group *Electricity network economic regulation; scenario analysis – Policy Advice*, June 2015, p.iii and Standing Committee of Officials of the Ministerial Council on Energy *Explanatory Material - Changes to the National Electricity Rules to establish a national regulatory framework for the economic regulation of electricity distribution*, April 2007, p.44

3. RESPONDING TO THE CHALLENGE – ASSESSING POTENTIAL OPTIONS

3.1 POTENTIAL OPTIONS TO ADDRESS EVOLVING ENERGY MARKET IMPACTS

There are a set of alternative options which relevant regulatory economic literature and practice suggests could help in addressing the issue of promoting sustainable cost recovery in a way that maintains the integrity of the regulatory compact and the building blocks approach.

Options to meet the challenge of the impacts of evolving market circumstances on historical depreciation approaches which are not longer 'fit for purpose' could include, for example:

Option 1

Increased new grid connection fees – increased grid connection fees would reduce the magnitude and risk of future stranded costs, by bringing forward cost recovery and sharing risks with new consumers. Both infrastructure providers and users can benefit from these revised arrangements, as evidenced by the significant role that similar 'take or pay' contracts play in competitive infrastructure service provision.

Option 2

Network exit fees – an exit fee on customers choosing to leave the grid could be developed, which provided for the recovery of a cost which recognises the historic share of network capacity dedicated to that customer (which could, for example, be based on relative share of coincident demand as a proportion of the RAB).[11]

Option 3

Compulsory 'rates' style network access levies – movement to charging based not on usage, but on access to the grid would recognise the broad community benefit of a ubiquitous grid to all (whether individual users take advantage of the opportunity to connect or not), and potentially avoid inequitable outcomes where some users sought to 'exit' the grid, placing an increased burden on those customers remaining connected.

Option 4

Providing explicit compensation for stranding risks – alternatively network revenues could be adjusted to compensate for future stranding risks. This could occur through adjustments to regulatory cash-flows or an addition to the existing cost of capital (which does not currently include compensation for stranding risk).[12]

Option 5

Greater flexibility in depreciation approaches – providing greater scope for networks to better manage cost recovery risks by addressing the back-loading of depreciation under current models and approaches, addressing the impacts of RAB-indexation, bringing forward recovery where appropriate, or allowing scope for the deferral of the return of capital across multiple regulatory periods.

A number of these options obviously would face profound implementation challenges. Options of new grid connection fees or network exit fees (*option 1* and *option 2*), while economically well-founded, would be likely to encounter significant consumer resistance and there are issues about how they could be applied in practice.

Higher connection fees for new customers present difficult equity and hardship issues, while exit fees can be represented as an unfair barrier to emerging competitive technologies. In part, these options are likely to encounter resistance because they affect only a subset of readily identifiable and specific customers, rather than network customers as a whole. This sits uneasily with the fact that the grid has characteristics of a shared 'public good'. Different perspectives on these mechanisms highlight the potential tensions between the interests of individual customers and collective customers, when determining fair, efficient cost recovery frameworks for network infrastructure.

11 Commercial Economics *Consulting Memorandum - NSP Asset Stranding Risk – Optimum Whole of Economy Outcome* (2014)

12 Kolbe, A. and Tye, W. 'Compensation for the risk of stranded assets' in *Energy Policy*, Vol.24, No.12 pp.1025-1050, 1996

An option which explicitly recognises and is based on this shared 'public good' character of utility networks is a compulsory 'rates' or 'land tax' style charge (*option 3*). This could be incurred based on the grid being available to the user, rather than actual connection or usage. This model is used in the water utility sector in a number of Australian states and territories. Despite this, a flat charge based merely on potential access to a service (even where that potential access may be of material value to the consumer) would be likely to face substantive challenges on the grounds of customer acceptance, inter-customer equity, and impacts on emergent competing technologies.

Adjustments to the cost of capital or cash flows to compensate for network stranding risks (*option 4*) are established theoretical options for addressing similar cost recovery issues. However, there remain a range of outstanding and complex issues regarding how they could be assessed and applied in practice.[13] Compensation for future stranding risk may be impractical, contentious and difficult to calibrate to the conditions of individual networks, and compensation following stranding would also be complex and problematic.[14] These outstanding issues have limited their application in practice.

By contrast, providing greater flexibility to bring forward or deferring depreciation (*option 5*) better recognises the common contribution of all past and present network customers to the existing network. In a recent report to the AER, University of Sydney Chair of Finance Associate Professor Graham Partington observed:

> *The appropriate way to adjust to for disruptive technology is therefore to adjust the cash flow. To the extent that the result of disruptive technology is stranded assets, then the effective economic life of the asset is reduced and/or its residual value is less than originally assumed. Consequently, one way to allow for the impact on cash flow is to increase the regulatory depreciation allowance.*[15]

The AER has recently confirmed that its preferred approach to addressing issues relating to changing market conditions and the risk of technological disruption from such technologies as solar PV and battery storage is by adjusting network firms' cash flows. Recently, the AER advised that:

> *Further, we recognise the development of disruptive technologies in the Australian energy sector may create some non-systematic risk to the cash flows of energy network businesses. We consider these can be more appropriately compensated through regulated cash flows (such as accelerated depreciation of assets).*[16]

Such measures would affect all customers in a more manageable way, impacting customer network charges only marginally. They could be achieved by either pre-defined adjustments to forward depreciation paths, or effected via a revision (and shortening) of assumed asset lives under the Post-Tax Revenue Model. New Zealand's Commerce Commission, in recent exploratory work in this area, has identified modification of assumed asset lives as a primary potential means of addressing this issue in a way that is consistent with the principle of providing adequately for cost recovery.[17]

How to implement either of the flexible approaches mentioned under *option 5* above should be the subject of broad and informed discussion between industry, consumers and regulators. In the mean time, removal of the impact of the deferral of returns on capital that arise solely as a function of the operation of inflation-indexed RAB should be pursued to ensure the issue does not continue to compound.

13 Discussed, for example, in the Productivity Commission *Review of the National Access Regime* (2002)

14 See Professor Paul Kerin 'What would an Efficient Regulatory Contract Look Like?' in *Network*, Issue 55, June 2015

15 Partington, G. *Report to the AER – Return on Equity – Updated*, April 2015, p.77-78

16 AER *SA Power Networks preliminary decision – Attachment 3: Rate of return*, April 2015, p.376

17 New Zealand Commerce Commission *Input methodologies: Invitation to contribute to problem definition*, 16 June 2015, p.53-58

4. CONSUMER BENEFITS FROM REFORMING DEPRECIATION AND COST RECOVERY APPROACHES

Any changes to cost recovery or depreciation approaches should ultimately be considered based on whether the outcomes will promote the long term interests of consumers. Reforming depreciation approaches, by adopting more flexible approaches to accelerated depreciation will benefit consumers in a number of critical ways.

4.1 BETTER REFLECTING 'USER PAYS' PRINCIPLES

If current customers are expected to use the network more heavily than future customers are likely to, current customers should pay relatively more than future customers. This contributes towards intergenerational equity because it avoids future consumers from bearing an undue proportion of costs for services which they do not utilise as intensively as past consumers, and instead provides for the recovery of the costs of assets from their beneficiaries

If this approach is not adopted, there is a risk that tomorrow's electricity consumers could be penalised by being required to contribute to the return of capital of a proportion of assets which they do not derive benefits from. An example of this scenario arising is circumstances in which distributed generation and storage provides a significant proportion of network customers with an option to fully or partially bypass the grid. In this case, the existing regulatory approach would suggest the recovery of total depreciation charges from remaining grid customers. This would effectively represent a 'double penalty' likely to fall mostly upon customers with fewer options to bypass the grid.

4.2 LONGER-TERM PRICE STABILITY CONSISTENT WITH ECONOMIC EFFICIENCY AND CONSUMER PREFERENCES

Flexible depreciation approaches also have the potential to better promote long-term stability in the path of network pricing over future investment cycles.

For example, greater capacity to bring forward, or defer depreciation allowances would enable a network business to propose a 'smoother' revenue path into the future. In the current environment of historically low risk-free rates, for example, there would be a capacity to bring forward depreciation allowances. This capacity would have particular value in providing more stable pricing outcomes in current capital market conditions (this is discussed further in *Section 5*).

Customers consistently report that they value pricing stability and certainty over time.[18] Flexible depreciation approaches are a tool for delivering this, through the capacity of the return on and the return of capital to respond to evolving capital and energy market drivers.

Improving price stability over time would also facilitate economically efficient investments by household and business network users. Greater stability over time is more likely to foster efficient investments from users (either in complimentary technologies and service elements, or grid substitutes) than unstable network pricing paths over time. In addition, it is likely to result in more equitable treatments of grid-dependent investments made by consumers and distributed energy owners in the past.[19]

18 See for example Panchal, S. and Jha, A. 'Fairness and Reciprocity of Consumers' in Voice of Research, Vol.3, December 2014 and ENERGEX *Your network, your choice: Customer assumptions report*, December 2014, drawing on residential and small business consumer survey by TNS Australia.

19 Biggar, D. 'Is Protecting Sunk Investments by Consumers a Key Rationale for Natural Monopoly Regulation?', *Review of Network Economics* 8(2): 128–53, 2009

4.3 FLEXIBLE DEPRECIATION WOULD REPLICATE THE OUTCOMES OBSERVED IN COMPETITIVE MARKETS

Flexible depreciation would also promote outcomes in the energy network sector which would occur in a competitive market subject to a similar pace of market and technological change. Facing the potential risks of market or technological changes leading to an economic stranding of a portion of investment, investors in a competitive market recognise the potential shortened asset lives in their investment evaluation. Investors in these circumstances will only make investments where they assess that a reasonable opportunity to recover the costs of these investment within a shortened economic life exists.

Similarly, a commercial firm which faces the potential risk of market 'disruption', or a deterioration in its capacity to recover costs in future market conditions will seek to bring forward its cost recovery on undepreciated assets.

4.4 POSITION NETWORKS TO BEST SERVE CUSTOMERS IN THE EMERGING MARKET FOR ENERGY SERVICES

Implementing faster depreciation in response to changing market and technological conditions would also have the benefit of lowering the growth of network firms' individual regulatory asset bases, and therefore reduce the total amount of future network revenues that would be linked to the size of the RAB.

The direct connection between the RAB and projected revenues is commonly identified as a potential distortion in network investment and operational decision-making.[20] Reducing the overall level and connection between regulatory allowances and the RAB would materially lessen this potential impact. In particular, faster depreciation resulting in smaller future RABs would lower the potential for either the network firm, or consumers, competitors and other energy market participants to view the primary commercial driver as being the maximisation of the future value of the RAB.

4.5 AVOIDING HIGHER COSTS AND DISINCENTIVES TO INVEST BY DE-RISKING FUTURE CASH FLOWS

Providing for accelerated depreciation for network assets would also contribute to 'de-risking' future cash-flows, by making the undepreciated component of the RAB smaller, and therefore at less risk of being economically non-recoverable. Undertaking this through a more flexible depreciation allowance that was not based on the current 'straight-line' indexed approach would provide existing and potential network investors greater confidence around the regulatory treatment of new and existing assets. This would mitigate potential incentives for underinvestment compared to circumstances where alternative higher risk or 'do nothing' approaches were adopted.

For example, network capital providers, anticipating a risk of future uncompensated stranding, could require higher future returns and/or reduce the scale of network investments to minimise their exposure to future stranding risks. This could lead to current and future consumers paying higher financing and operating costs through network charges than necessary, and reduced quality of service through underinvestment in long-lived network assets. Distorted network charges of this type would also promote a potential costly and inefficient over-investment by customers in distributed generation and storage technologies.

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20 COAG Energy Council Energy Working Group *Electricity network economic regulation; scenario analysis – Policy Advice*, June 2015, p.6

5. A 'WINDOW OF OPPORTUNITY' IS OPEN NOW TO LOWER THE RISK OF REGULATORY FAILURE LATER

Collectively, consumers, regulators and networks have an unusual opportunity to take advantage of a historically low interest rate environment to embrace more flexible regulatory depreciation approaches. By providing an option, where market conditions allow, for the timely recovery of existing investments such an approach would serve to increase the capacity and resilience of networks to efficiently meet the needs of future consumers and avoid the creation of a potential regulatory failure.

5.1 LOWER FINANCING COSTS PROVIDE AN OPPORTUNE 'WINDOW' TO ADDRESS COST RECOVERY

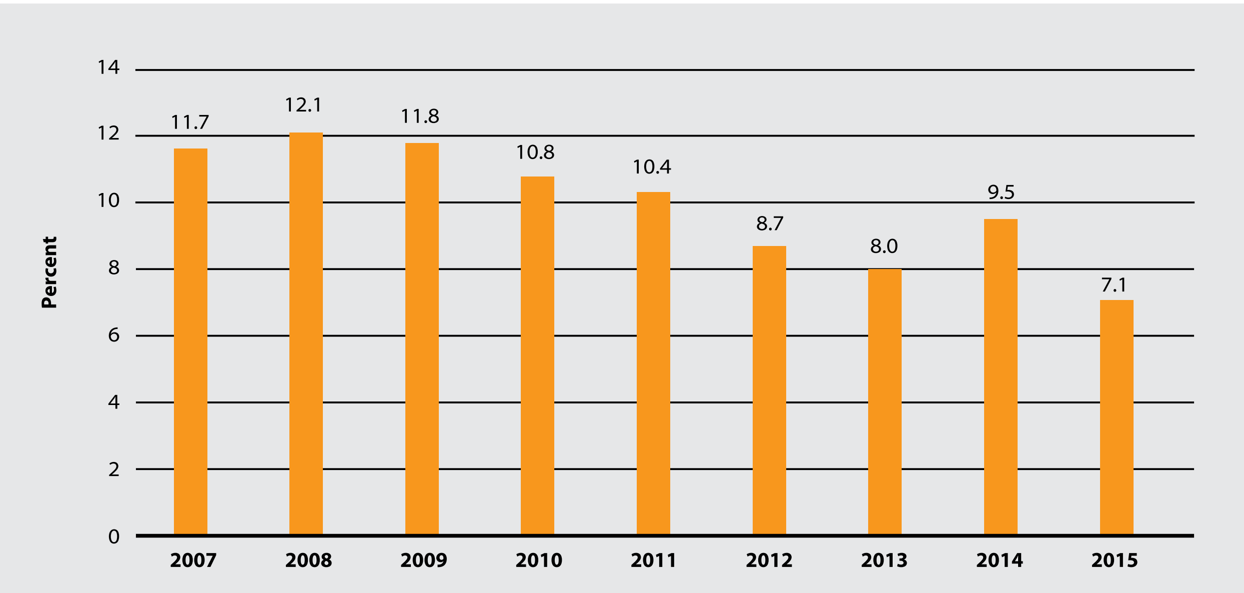
There is currently a valuable opportunity to address long-term cost recovery risks created by the significant falls in financing costs for network companies.

Since 2009, the median AER-approved cost of capital has fallen approximately 300 basis point, or 3 per cent (See Figure 2). Further reductions over the next twelve months are possible, due to the Commonwealth bond rate declining from around 4 per cent to 2.5 per cent in the past year.

Under current cost of capital approaches, declines in interest rates feed directly into future estimates of the required return on equity and debt creating a substantial downward pressure on regulated network charges. These declines have been partially reflected in some recent network determinations. For illustrative purposes, a decline of 1.5 per cent in the Commonwealth bond rate, like that which has occurred, lowers future required revenue by just over $1.5 billion per annum on a whole of industry basis.

The reduction in return on capital flowing from less costly access to debt finance, and the fall in the Commonwealth bond rate provides Australian energy regulators (such a the AER and WA Economic Regulation Authority) with a rare opportunity to deliver both real reductions in network charges, and allow for more neutral or even front-loaded, depreciation approaches than have been applied to date.

FIGURE 2 MEDIAN AER APPROVED RETURN ON EQUITY (2007-2015)



This opportunity can be considered as analogous to the opportunity presented to a home owner to take advantage of low interest rates to make further payments against the principal. As home loan rates fall during the economic cycle, many Australian households maintain fixed nominal contributions, effectively repaying the principal faster. In total, Australian mortgage holders prepayments are estimated to have built up a prepayment 'buffer' which is the equivalent of 1.5 years of scheduled repayments, with over 40 per cent of mortgage holders estimated to maintain a buffer of greater than a year.[21]

Lower cost of capital estimates in the network sector today provide a similar community opportunity to reduce the outstanding depreciation (which can be viewed as the 'debt' owed by future consumers for today's assets).[22]

Lower cost of capital estimates in the network sector today provide a similar community opportunity to reduce the outstanding depreciation

5.2 POTENTIAL RISKS OF INACTION – A 'REGULATORY FAILURE' FOR CONSUMERS

If the current opportunity is not taken advantage of, and unless alternative approaches are adopted, the interaction of market, technology and inflexible regulatory approaches create the material risk of a regulatory failure in the cost recovery framework established under the regulatory regime. This regulatory failure would arise from a lack of flexible adaption to the changed circumstances.

Two broad scenarios are possible.

» **Tomorrow's electricity consumers could be penalised by being required to contribute to the return of capital of a proportion of assets which they do not derive benefits from.**

  An example of this scenario arising is circumstances in which distributed generation and storage provides a significant proportion of network customers with an option to fully or partially bypass the grid. In this case, the existing regulatory approach would suggest the recovery of total depreciation charges from remaining grid customers. This would effectively represent a 'double penalty' likely to fall mostly upon customers with fewer options to bypass the grid.

» **Network capital providers, anticipating the risk of future uncompensated stranding, could require higher future returns and/or reduce the scale of network investments to minimise their exposure to future stranding risks.**

  This could lead to current and future consumers paying higher financing and operating costs through network charges than necessary, and reduced quality of service through underinvestment in long-lived network assets. Distorted network charges of this type would also promote a potential costly and inefficient over-investment by customers in distributed generation and storage technologies.

Both of these scenarios result in significant harm to the long-term interests of consumers, and so should be avoided. Either outcome would represent a 'first order' regulatory policy failure that would be likely to be avoidable through a proactive use of the mix of existing regulatory tools. The risks and costs of a potential regulatory failure of this scale make it prudent to consider more flexible depreciation techniques in the 'toolbox' of network regulation, which can be progressed in active engagement with network customers, and regulatory bodies, about the benefits of these measures.

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21 RBA *Financial Stability Review,* September 2012, Box B

22 This is an analogy the AER has itself used. For example, the AER recently noted in its Issues Paper for the Victorian electricity distribution pricing review: "*The Regulatory Asset Base is just like the balance on a mortgage, or on a credit card…..Each year, any new capital expenditure is added to the RAB. This new capital expenditure is like any new borrowings on your mortgage, or any new charges on your credit card…. any repayments of principal are subtracted from the RAB. In the building block model the repayments of principal are called 'depreciation'. This term is a little misleading, since it doesn't refer to any actual wear-and-tear on the assets—it is purely the repayment of the amount borrowed. This is just like the repayments of principal on your mortgage or the repayments of the borrowings on your credit card.*" (p.10)

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He holds a graduate qualification in law and postgraduate qualifications in regulatory economics and trade and has worked as a regulatory economic consultant advising firms in the energy, rail and telecommunications sectors.

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The opinions in this report are those of the author and do not necessarily represent the views of the ENA or its members, individual board members or committee members.

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Attachment 2

Outclassed

How Queensland’s schools and social services are affected by mining industry assistance and lobbying

June 2015

Rod Campbell

Policy Brief

The Australia Institute

Research that matters.

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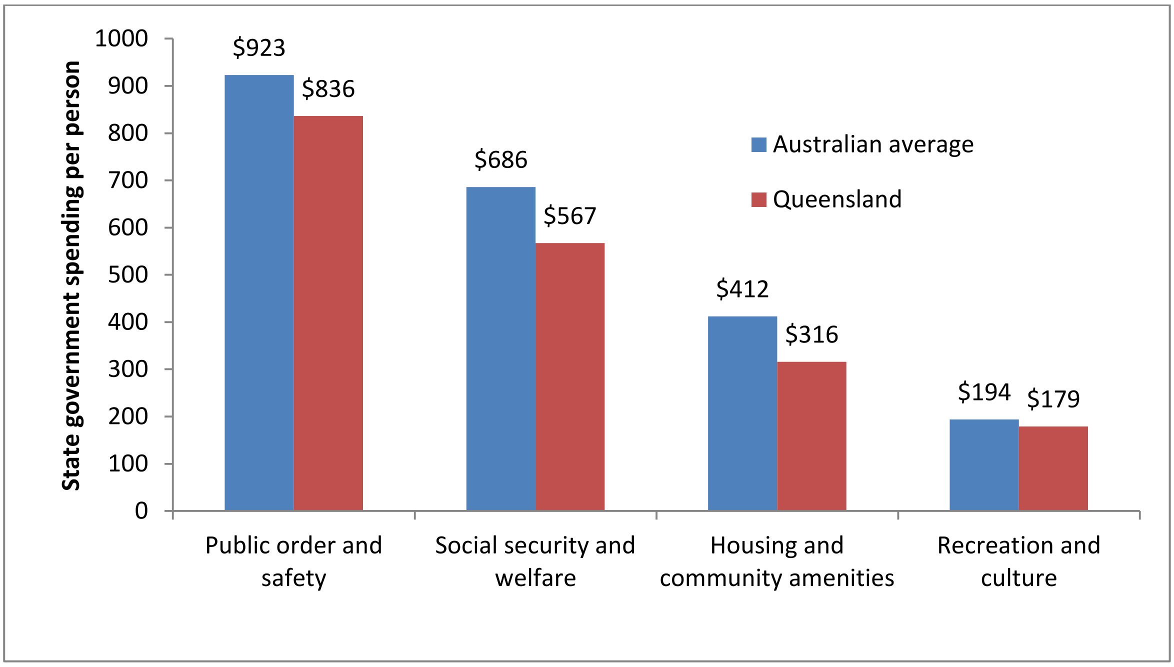
TAI

Summary

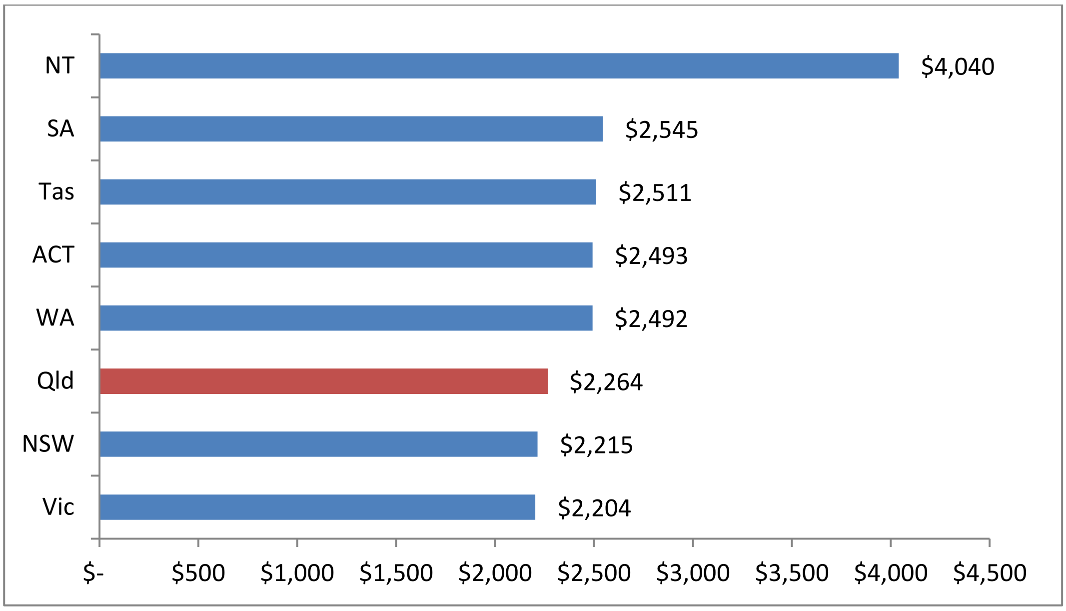
Queensland spends less on social services than the rest of Australia in per capita terms, despite being a large state with a growing population:



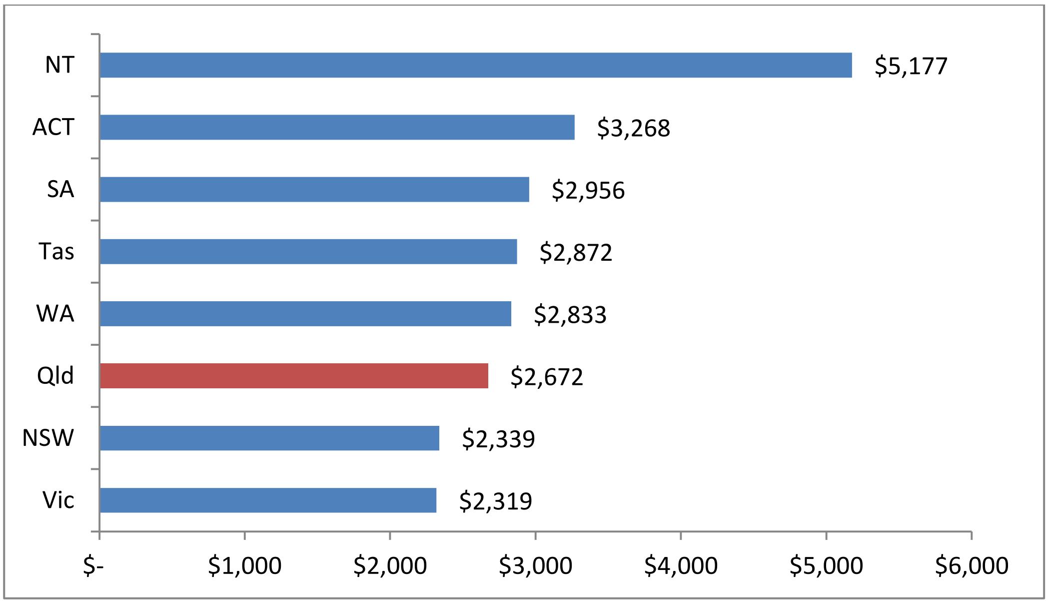
Source: ABS (2015) *Government Finance Statistics, Australia, 2013-14*, Cat no 5512.0, 13 May and ABS (2015) *Australian Demographic Statistics, Sep 2014*, Cat no 3101.0, 26 March.

In the major areas of health and education, Queensland spends less per person than any other state except NSW and Victoria – both of which benefit from large populations in relatively small, easily serviceable areas:

Per capita spending on education by state



Per capita spending on health by state



Source: ABS (2015) *Government Finance Statistics, Australia, 2013-14*, Cat no 5512.0, 13 May and ABS (2015) *Australian Demographic Statistics, Sep 2014*, Cat no 3101.0, 26 March.

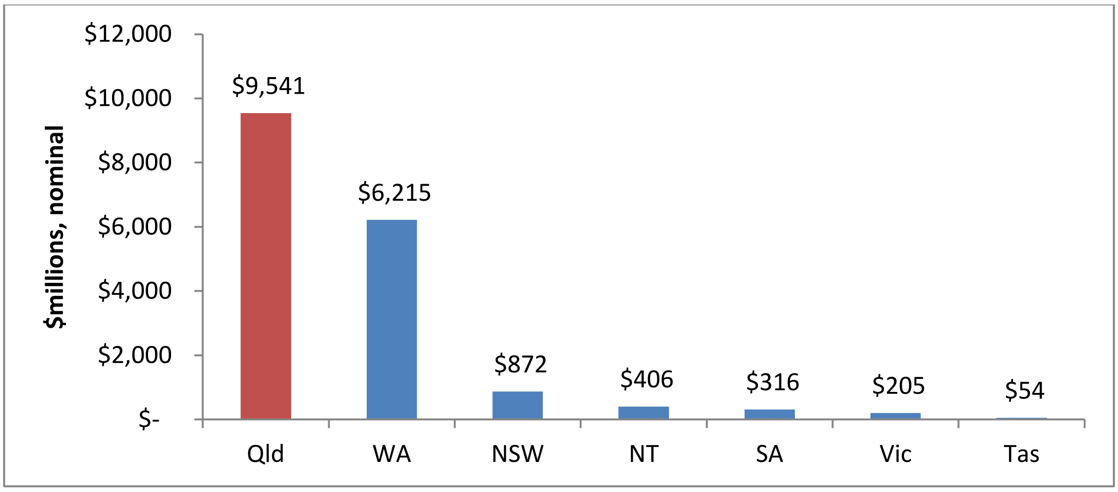
The consequence of this spending shortfall is obvious in parts of the health and education sectors. The Queensland Audit Office points out in recent audits:

- Queensland's public schools face a $268 million maintenance backlog
- The ability of the Queensland Ambulance Service to maintain current service levels is "at risk" due to budget constraints and growing demand.

Demand is growing for many services. For example, in the next 15 years Queensland's school student numbers are forecast to grow by 257,000, 110 new schools worth $3.8 billion, and many others will need expansion. To teach these extra students nearly 14,000 extra teachers and support staff will be required, earning an extra $1.1 billion in wages.

In contrast to the state's low social spending, the Queensland Government spent $9.5 billion assisting the mining and fossil fuel industry between 2008-09 and 2013-14, more than any other state, as shown below:

State government assistance to mineral and fossil fuel industries 2008-09 to 2013-14



Source: State budget papers, compiled in (Peel et al. 2014)

Queensland Treasury makes it clear that this spending reduces the amount the government can spend on social services:

> *Governments face budget constraints and spending on mining related infrastructure means less infrastructure spending in other areas, including social infrastructure such as hospitals and schools.*

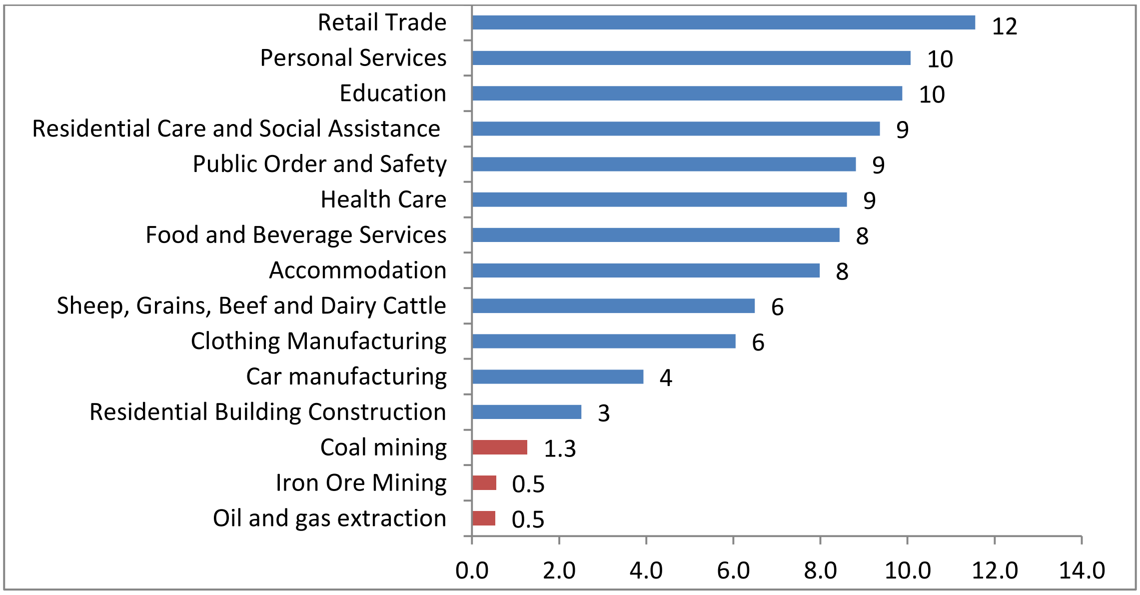
The Palaszczuk Government has made commitments to reduce the taxpayer funding of controversial mining projects. However, there are still a large number of proposals and budget measures that are being pursued, many with existing approvals and the support of state departments and state-owned corporations. The value of some of these assistance measures is summarised below:

Potential and budgeted mining industry assistance spending

Rail projects	$2.2 billion
Port projects	$1.8 billion
Water supply projects	$3 billion
Royalty holiday	$1 billion
Existing budget measures	$1 billion
Clean up costs	$1 billion
Total	**$10 billion**

This spending cannot be justified as employment creation. Mining is among the most capital intensive industries, producing less jobs per million dollars than almost any other industry:

Australians employed by industry per million dollars output



Source: ABS 2013 *Australian National Accounts: Input-Output Tables*

The message for the Queensland Government is that if it wants to increase employment through government spending, the worst industry to spend money on is the mining industry. In contrast, education and social services offer some of the highest rates of employment.

The mining industry's $10 billion assistance wish list, outlined above, is aggressively pursued by its lobby groups, such as the Queensland Resource Council, the Minerals Council of Australian Petroleum Production and Exploration Association. These groups have revenue of around $50 million per year to spend on lobbying for such assistance measures.

Queensland's underfunding of social services has no silver bullet. However, reducing the state's largesse to the mining industry could provide substantial funding to health, education and other services.

Introduction

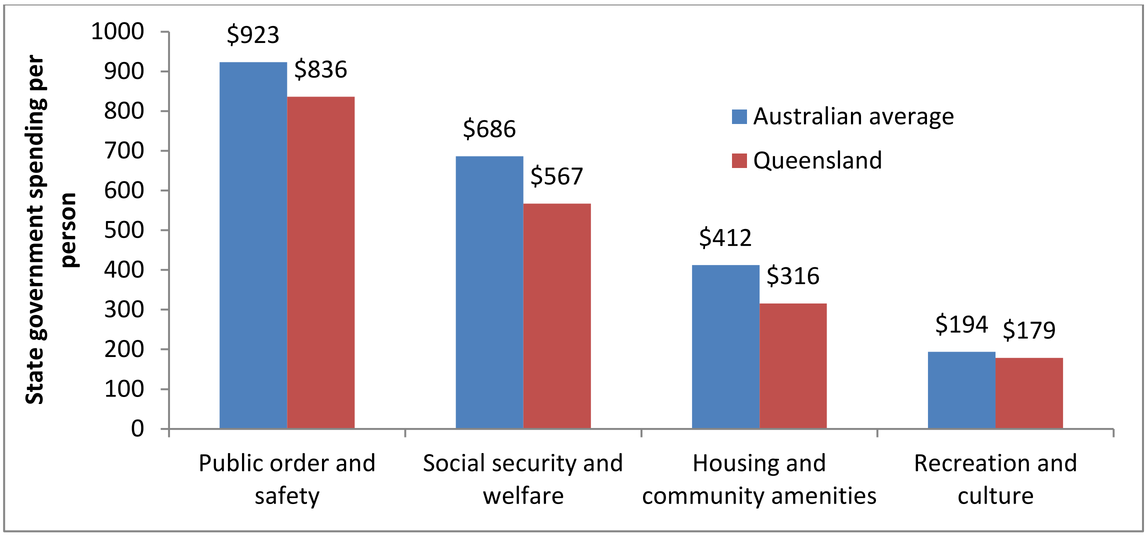
Like all Australian Governments, Queensland is grappling with how to better fund services that the community requires and expects at a time when budgets are being challenged. Queensland's budget is in reasonable shape – while it will run a deficit of around $2.3 billion this year, this is largely due to borrowing to invest for the state's growth. Under this, Queensland will experience net cash flows from operating activities worth $3.38 billion or 6.6 per cent of state revenue for 2014-15, a healthy surplus on operating activities.[1]

However, Queensland's social services are poorly funded. Education and health are funded at levels lower than most states in per capita terms. Other areas such as public safety and social assistance are some of the worst funded in Australia. In stark contrast, Queensland's mining industry receives some of the highest levels of assistance in the nation. Redressing this imbalance should be a priority for the Palaszczuk Government.

Social spending in Queensland

Queensland's social spending is some of the lowest in Australia on a per person basis. It spends below the Australian average on public order and safety, social security and welfare, housing and community amenities and recreation and culture, as shown in Figure 1 below:

Figure 1: Social spending per person – Queensland and Australian average



Source: ABS (2015) *Government Finance Statistics, Australia, 2013-14*, Cat no 5512.0, 13 May and ABS (2015) *Australian Demographic Statistics, Sep 2014*, Cat no 3101.0, 26 March.

For *Public order and safety*, Queensland ranks second last of all states and territories. Only Tasmania spends less per person, spending $835 per person, a dollar less than Queensland. Tasmania of course has far less ground to cover than Queensland, the second largest state. Starved of funding, Queensland's public order and safety organisations seek sponsorship, including from the gas industry. For example, gas company Santos sponsors Queensland Police vehicles.[2]

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[1] ABS (2014) *Government Financial Estimates, Australia, 2014-15*, Cat no 5501.0.55.001, 18 November.

[2] http://www.brisbanetimes.com.au/queensland/mining-company-santos-logo-used-on-queensland-police-vehicles-20141208-122zo9.html

Queensland has the lowest per person spending in the country on *social security and welfare*, $567 per person per year, more than a hundred dollars per year below the Australian average of $686. Next lowest is the ACT, which spends $584, likely due to it having the highest average incomes in Australia.

Queensland has the second lowest funding of *Housing and community amenities* per person, spending $316 per person, 25 per cent lower than the Australian average of $412 per person. Only NSW spends less, with $298 per person per year.

Queensland's spending on recreation and culture is slightly lower than the national average - $179 per person compared to $194 per person. New South Wales and Victoria spend less.

Queensland spends less per person on health and education than all states and territories except NSW and Victoria, as shown in Figures 2 and 3 below:

Figure 2: Per capita spending on education by state

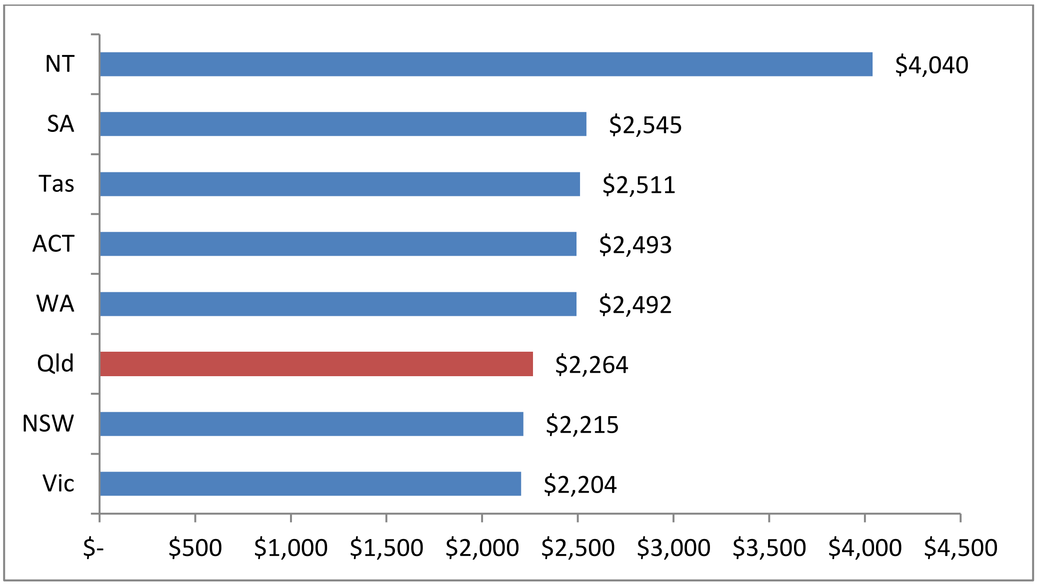
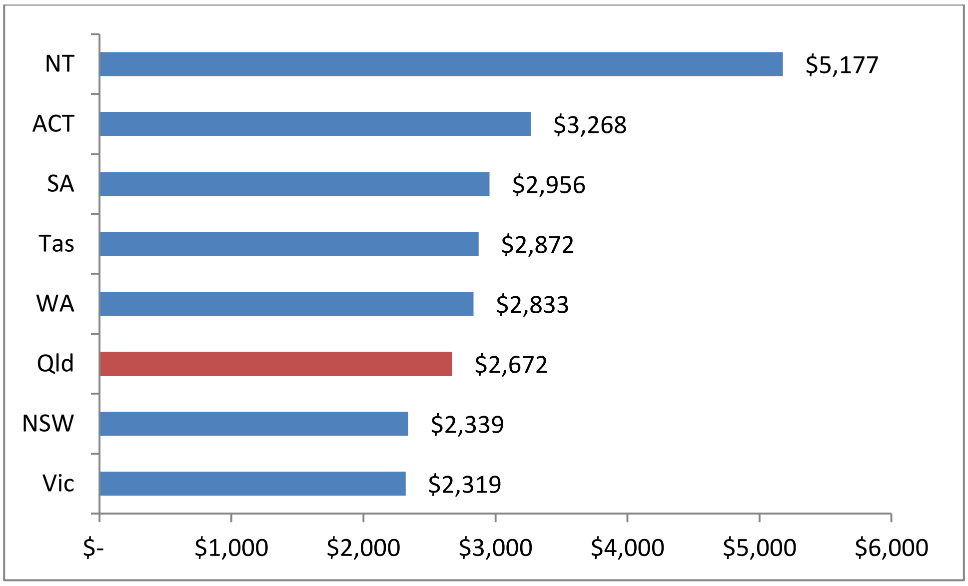


Figure 3: Per capita spending on health by state



Source: ABS (2015) *Government Finance Statistics, Australia, 2013-14*, Cat no 5512.0, 13 May and ABS (2015) *Australian Demographic Statistics, Sep 2014*, Cat no 3101.0, 26 March.

Figures 2 and 3 show that NSW and Victoria have the lowest spending on education and health in per person terms. However, they are able to spend less due to their relatively large populations in relatively small, easily serviceable areas. This is emphasised by the Commonwealth Grants Commission that says Queensland should spend more than average and more than NSW and Victoria per person across most elements of public health spending.[3]

Queensland's health and education services are under considerable strain at their present funding levels, as is clear from reports by the Queensland Audit Office.

The Queensland Audit Office estimates that the state's public schools are facing long-term maintenance pressure:

> *[Queensland] is not maintaining its schools to its own standards and requirements. The root cause of this has been the historical underfunding of maintenance, and this situation continues today. Underfunding has created backlogs of repairs and other corrective maintenance tasks, which consume almost all available recurrent funds set aside for maintenance.*[4]

The Audit Office estimates that public schools have a maintenance backlog of $268 million as of October 2014, despite a recent program spending $300 million on addressing the issue.

On health, the Audit Office finds that the Queensland Ambulance Service (QAS) is a high-performing service, which has coped well with the recent increases in demand due to an increasing and aging population. The Service operates across a large geographic area, with highly qualified staff and a low reliance on volunteers relative to other states. Because of these challenges and high standards, the service needs to be well funded. The Audit Office finds:

> *…[In] a fiscally constrained future the ability of QAS to continue to provide its current standards of emergency and pre-hospital care for patients is at risk. A whole-of-government response is required to address these challenges for QAS.*

Increases in population and expected standards are a common theme through all public services.

Future spending – Case study on schools

According to the Queensland Schools Planning Commission, in the next 15 years Queensland's student population will grow by 257,000 students. Many schools will need to be expanded and around 110 new schools will need to be built. Contracts signed by the former Queensland Government indicate construction cost for a new school is around $35 million.[5] This suggests that Queensland needs to spend around $3.8 billion on building new schools over the next 15 years, not including expenses associated with the expansion of existing schools.

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[3] (CGC 2015) See p209

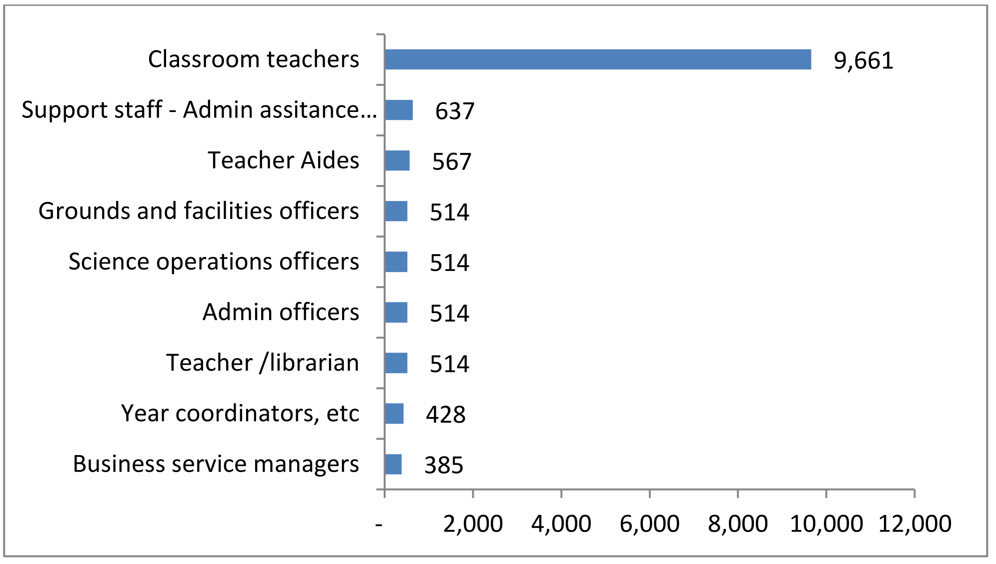
[4] (Queensland Audit Office 2015) p1

[5] Based on announcement by Treasury: https://www.treasury.qld.gov.au/projects-infrastructure/projects/queensland-schools/ The construction firm involved in the successful tender was to receive $350 million for the construction of the ten schools. https://www.treasury.qld.gov.au/projects-infrastructure/projects/queensland-schools/

Schools need to be maintained. Based on data from the Queensland Audit Office, Queensland's current 1,333 public schools require around $200 million per year in maintenance, or around $150,000 per school per year. Queensland's additional schools would require at least $16 million per year.[6]

Schools also need to be staffed, not only by teachers but by support and administrative staff. Based on Queensland's school staffing allocation guidelines this will require an extra 13,734 classroom teachers and school support staff, as shown in Figure X below:

Figure 4: Extra school staff required to 2031 in Queensland



Source: Based on data and formulas in (Queensland Schools Planning Commission 2014; Queensland Department of Education Training and Employment 2014) Note all staff numbers are full-time equivalent.

Assuming that staff earn the average education sector full time wage of $80,153 per year, Queensland needs to budget for an extra $1.1 billion in education wages by 2031. Currently the state budgets for 61,388 staff, with an estimated wage bill of $4.9 billion per year.[7]

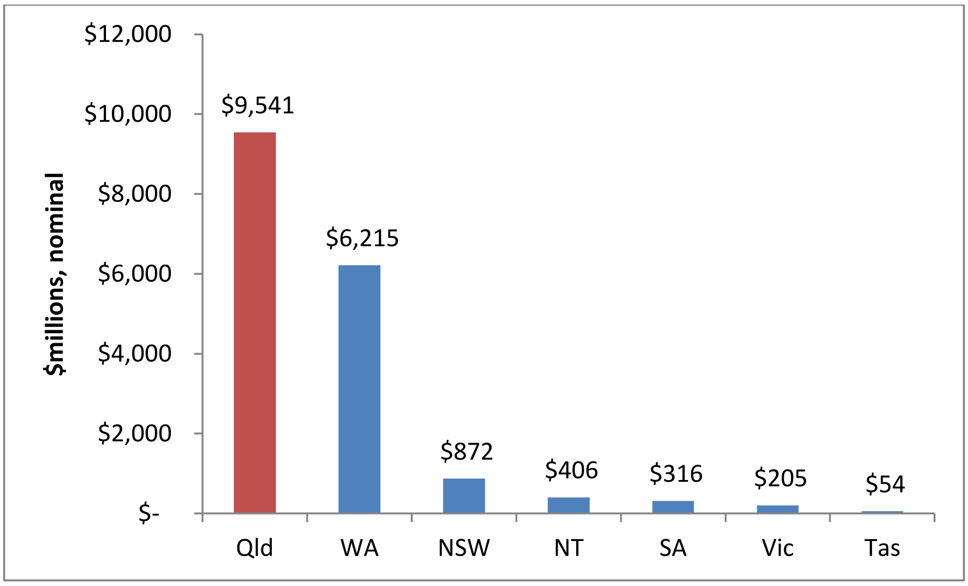
It is clear that Queensland's spending on health and education needs to be prioritised. However, in recent years successive Queensland Governments have put considerable emphasis on funding not social services, but assistance to the mining and fossil fuel industries.

Queensland assistance to the mining and fossil fuel industries

Queensland Governments of both sides of politics have spent billions of dollars in recent years on measures that largely assist the mining and gas industries. Research by The Australia Institute, based on Queensland Budget Papers, shows that Queensland taxpayers spent $9.5 billion on items which benefited these industries, far more than any other state, as shown in Figure 5 below:

[6] (Queensland Audit Office 2015) see p2. Note that the higher expenditure years of 20012-13 to 2014-15 are used here as in these years maintenance spending kept pace with requirements.
[7] http://www.budget.qld.gov.au/budget-papers/2014-15/bp5-dete-2014-15.pdf

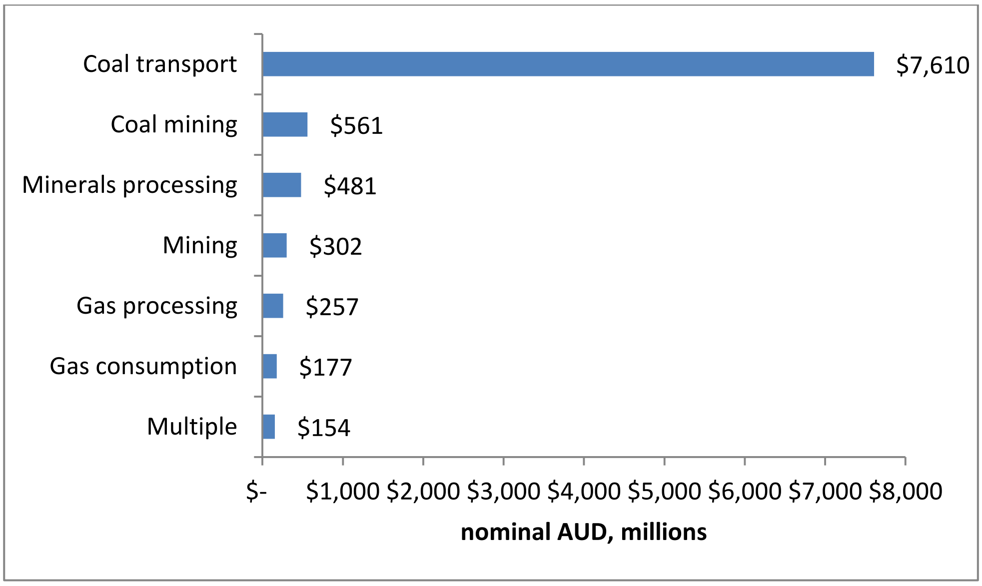
Figure 5: Queensland spending on mining and gas industry 2008-09 to 20013-14



Source: State Budget Papers and (Peel et al. 2014)

The vast bulk of this expenditure, $7.6 billion, has been on transport infrastructure for the coal industry such as railways and ports, as shown in Figure 6 below:

Figure 6: Queensland spending by industry segment 2008-09 to 20013-14



Source: State Budget Papers and (Peel et al. 2014)

The justification for this spending is usually that the coal industry pays royalties and user charges back to government. As former Premier Campbell Newman put it:

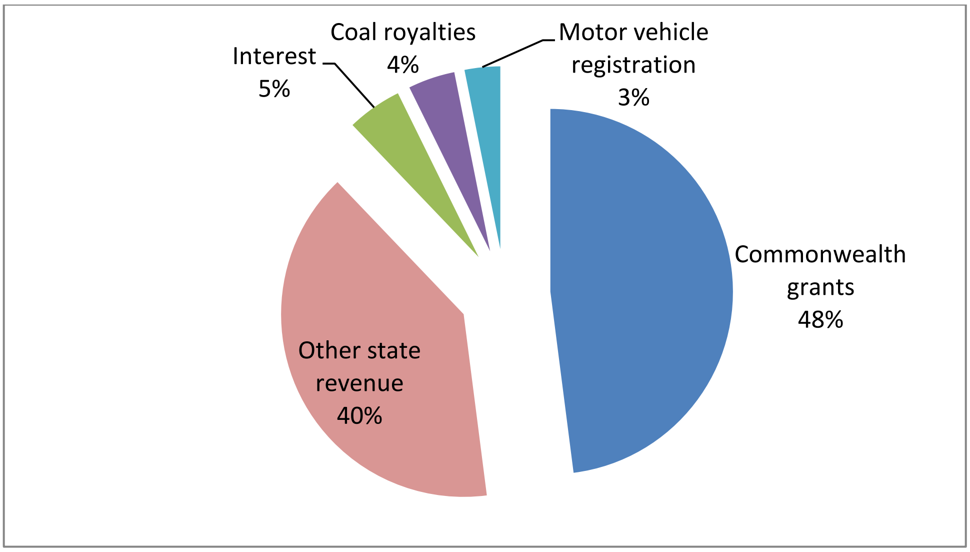
> *We are in the coal business. If you want decent hospitals, schools and police on the beat we all need to understand that.*[8]

While Queensland has a large export coal industry, Queensland budget papers contradict Mr Newman's claim that health, education and emergency services in Queensland are in some

[8] News.com.au (2012) *"We're in the coal business": Campbell Newman slams UNESCO Great Barrier Reef warning*

way dependent on the coal industry. Coal royalties make up only four per cent of the Queensland Government's revenue, as shown in Figure 7 below:

Figure 7: Queensland state government revenue 2014-15 (A$50.1 billion in total)



Source: Queensland Treasury (2014) *Queensland State Budget 2014-15 Budget Paper 2, see also* (Campbell 2014)

Figure 7 shows that in Queensland, services such as hospitals, schools and police are 96 per cent funded by sources other than the coal industry. The state's budget receives around the same amount from motor vehicle registration and interest payments.

Mr Newman is not alone in thinking the coal industry is more important to the provision of services in Queensland than it actually is. Polling results in other research by The Australia Institute show that on average Queenslanders think coal royalties make up 19 per cent of state revenue, almost five times greater than is actually the case.[9] This impression is fostered by the mining industry which rarely misses an opportunity to paint itself as a "pillar" of the Queensland economy.

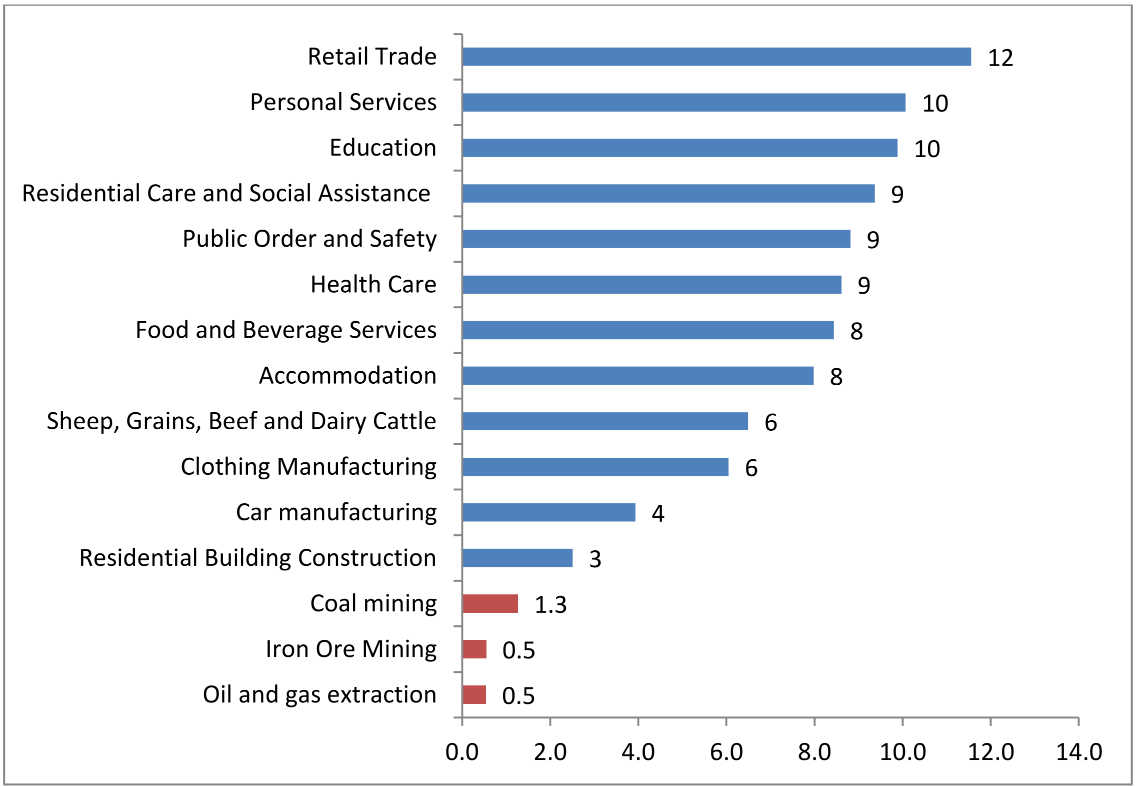
Assistance of mining does not create jobs

Similarly, mining is a small employer in Queensland. Despite the volumes of coal Queensland produces, only 24,000 people worked in coal mining at the last census – a number that has probably fallen since the downturn in coal prices. This represents just 1.2 per cent of Queensland's workforce. In contrast, on average Queenslanders think that 13 per cent of the workforce is employed in coal mining, ten times greater.

Mining employs few people as it is capital intensive – it uses a lot of machines and has large revenues relative to the amount of people employed. National accounts figures show that for every million dollars that is put into an industry, mining employs far fewer people than almost every other industry, as shown in Figure X below:

[9] (Campbell 2014)

Figure 8: People employed per million dollars output



Source: ABS 2013 Australian National Accounts: Input-Output Tables

The implication of this for Queensland Governments is that if it wants to increase employment through government spending, the worst industry to spend money on is the mining industry. In contrast, education and social services offer some of the highest rates of employment.

Queensland Treasury confirms cost of mining assistance

The perception that Queensland's services can be funded by the mining industry brings great concern to Queensland's Treasury. Treasury is less concerned by the public's misunderstanding than by the opinions held by the Commonwealth Grants Commission (CGC). The CGC is the body that oversees the allocation of GST funding from the Commonwealth to the states. If the CGC decides that a state can raise more of its own revenue than the others, less GST money goes to that state.

While the CGC no doubt understands the relative value of coal royalties in the Queensland budget, Queensland Treasury goes to great lengths to emphasise to the CGC that the coal royalties the state receives do not come without a heavy price tag in government spending. Treasury explains that spending on mining infrastructure and other forms of assistance have a serious effect on the state's ability to provide essential services. It is worth quoting Treasury at length on this point:

> ***Governments incur costs in the development of the mining industry***
>
> *The development and regulation of mining in Queensland has proceeded as a partnership of industry and government, with government playing an important role in the provision of economic and social infrastructure. The cost to government of*

> *providing economic and social infrastructure can manifest itself in the forms of direct expenditure, opportunity cost and risk.*
>
> *The Queensland Government incurs significant direct expenditures in mining regions and areas that have linkages to mining regions. This includes the construction and improvement of roads and bridges which directly service the mining industry, as well as social infrastructure to provide for regional population growth.*
>
> *These costs are not temporary and are likely to continue as long as the mining industry has a strong presence in Queensland. For example, the Queensland Government has announced a 'Royalties for the Regions' program to give back to the communities that support resource projects through the Resource Community Building Fund, Roads to Resources and the Floodplain Security Scheme.*
>
> *Some costs may also be recovered by the government over time if they are directly industry related. However, there is a real opportunity cost for governments in undertaking the initial capital expenditure.* ***Governments face budget constraints and spending on mining related infrastructure means less infrastructure spending in other areas, including social infrastructure such as hospitals and schools.*** *For many projects directly related to assisting mining industry development, such as land acquisitions for state development areas, the expected timeframes for cost recovery are extremely long (sometimes decades). The opportunity cost of this use of limited funds is a real cost to government and the community.*
>
> *There are also risks associated with expenditure on infrastructure that must be borne by government. The continuation of the mining boom is not guaranteed. World demand for Australian resources is dependent on a number of factors, including international economic conditions and the development of alternative suppliers. The risk faced by the large mining states is that the assumptions on which infrastructure planning was based fail to eventuate, leading to an over-allocation of resources to the mining regions and under-utilisation of infrastructure.*[10]

To summarise Treasury's key points:

- The Queensland Government spends large amounts of money on the mining industry, particularly relating to provision of infrastructure.
- This spending has opportunity cost – it reduces the government's ability to spend money on hospitals, schools and other services.
- This spending is risky – return on mining infrastructure spending is dependent on international markets and many other factors.

This last point is further emphasised by Treasury:

> *One view expressed during the GST Distribution Review submission process was that infrastructure costs borne by government in support of the mining industry should not be recognised in the [GST allocation] process because the majority of these expenditures are cost recovered from industry. However, little evidence has been presented to support this assertion, and Queensland has substantial costs that are not recovered from industry, particularly in the area of roads construction. It seems likely that other mining states have similar expenditures.*[11]

[10] (Queensland Treasury 2013) p15-16, bold added
[11] (Queensland Treasury 2013) p16

Treasury's concerns seem to be shared by parts of the new Palaszczuk Government. Ms Palaszczuk has been referenced in the media as saying:

> *State Opposition Leader Annastacia Palaszczuk said mining projects must show they were viable without government support and ruled out funding for projects such as a rail line linking Adani's mine near Rockhampton to the Abbot Point coal terminal in north Queensland.*[12]

While State Development Minister Anthony Lynham has formally announced:

> *We will ensure that approvals costs will be met by Galilee Basin proponents, with capital dredging costs to be paid for by the proponents to the Galilee Basin projects*[13]

While the new Labor Government's pledges to avoid taxpayer subsidy of the North Galilee Basin Rail Project and capital dredging at Abbot Point are welcome, reducing subsidisation of Queensland's coal and gas industry will not be easy – a range of capital projects and tax breaks are, or were until recently, official government policy. Other assistance measures are already written into the state budget or being borne by Queensland's natural environment.

Future assistance to the mining and fossil fuel industries

Under the Newman Government a wide range of policies were adopted that offered billions in assistance to the mining and gas industries. It is unclear which of these will be maintained by the Palasczuk Government. Many of these measures have strong support from state government departments and government-owned corporations, which have been involved in their planning and would be involved in their construction and operation.

The 2013 Galilee Basin Development Strategy set out a range of policies and projects that the government would support:

- Rail infrastructure
- Port construction
- Water infrastructure
- Royalty discount

While the status of the Strategy is uncertain, many of the projects that it set in train are still actively being pursued. Table 1 summarises the value of the assistance measures sought by industry with support from Queensland governments, departments and state-owned corporations:

[12] http://www.abc.net.au/news/2015-01-21/adani-underlines-commitment-to-galilee-basin-coal/6031288
[13] http://statements.qld.gov.au/Statement/2015/3/11/palaszczuk-govt-charts-new-course-for-abbot-point

Table 1: Future industry assistance spending

Rail projects	**$2.2 billion**
Port projects	$1.8 billion
Water supply projects	$3 billion
Royalty holiday	$1 billion
Existing budget measures	$1 billion
Clean up costs	$1 billion
Total	**$10 billion**

Rail infrastructure

A range of rail options have been proposed for the Galilee Basin. Different proponents with mines in different locations have plans for coal railways to different destinations and even of differing gauge widths. The most advanced proposal is the North Galilee Basin Rail Project, proposed by Indian conglomerate Adani. The project has approval from the state government but requires around $2.2 billion in capital.[14]

Adani has been unable to raise capital for this project to date. This is why the Newman Government agreed to subsidise it, although the extent of the funding and the degree to which it is required is uncertain.[15]

Port infrastructure

From 2008-09 to 2013-14 Queensland Governments spent $2.7 billion on expanding coal port capacity through its Public Non-Financial Corporations. Major expenditure items included Gladstone's RG Tanna coal terminal expansion ($780 million) and Abbot Point X50 expansion ($818 million).[16] Most of Queensland's coal ports are running at well below their nameplate capacity, with further expansions proposed.[17]

Despite this, there are proposals for major expansions to the Abbot Point coal terminal, which would be necessary if the Galilee Basin coal projects are developed. While Abbot Point is owned by the Queensland Government through the North Queensland Bulk Ports Corporation, Abbot Point's Terminal 1 (T1) is leased by Adani. Adani is planning to expand capacity through the Terminal 0 (T0) project, while GVK Hancock is proposing further expansion through the construction of the Terminal 3 (T3) project.

Both of these expansion proposals would require major dredging and construction. There has been controversy over plans to dump dredge spoil either at sea in the Great Barrier Reef

[14] See North Galilee Basin Rail Project Environmental Impact Statement chapter 22, section 22.3

[15] http://www.brisbanetimes.com.au/queensland/queensland-government-quiet-on-how-much-it-will-invest-in-galilee-basin-20141125-11tuxv.html

[16] (Peel et al. 2014)

[17] (Eadie 2013), http://www.qca.org.au/getattachment/95609fc7-914b-4ca5-baea-8b0e287ca406/Blackwater-System-Coal-Railings-Forecast.aspx

Marine Park, or on land on the state significant Caley Valley Wetlands. The current Abbot Point Growth Gateway proposes to dump dredge spoil on the site of T2 – another expansion proposal, now abandoned.[18] The new Labor government has declared that:

> *We will ensure that approvals costs will be met by Galilee Basin proponents, with capital dredging costs to be paid for by the proponents to the Galilee Basin projects* [19]

It should be noted that this seems to refer only to capital dredging costs at Adani's T0 proposal, with no discussion of maintenance dredging and where a line may be drawn between capital and maintenance dredging. There are many other costs involved in Abbot Point Port expansion that the Queensland Government and North Queensland Bulk Ports Corporation may be asked to subsidise around disposal of dredge spoil and capital construction costs of the T0 and T3 projects.

While there are no published estimates of capital costs of the T0 and T3 projects, Abbot Point's earlier X50 expansion, which cost the Government $818 million, was to "effectively duplicate the existing terminal infrastructure".[20] Building two more terminals with associated infrastructure could be expected to cost a comparable amount, around $1.6 billion.

The main dredging proposal for Abbot Point involves the dredging and disposal of 1.7 million cubic meters of spoil for T0 and T3. Using estimates commissioned by the port owner, made by engineering firm Aurecon, dredging and disposing this amount of spoil within the terminal area could be expected to cost around $265 million. Net of capital dredging for one berth, this would cost around $215 million.

Water infrastructure

The Queensland Government spent around $150 million on water projects that assisted the mining and fossil fuel industry between 2008-09 and 2013-14. Importantly, most of this expenditure related to proposals, business cases and environmental impact statements for stalled projects, particularly those owned by the state-owned Sunwater. Sunwater has around $3 billion in planned developments over the next five years, most of which service the mining industry to a large degree.[21]

Water has been a key problem for Galilee Basin proposals. Coal mines need significant amounts of water for coal washing, processing and dust suppression. Several supply options have been proposed for the Galilee Basin projects, although it is currently unclear which proposal is favoured. The Galilee Basin Development strategy commits the Government to:

- *Support proponents developing localised water solution, including off-stream storage schemes*
- *Make an allocation of water supplies available from the Burdekin Resource Operations Plan at prices intended to facilitate the development of local supply and management solutions*.[22]

While the details are unclear, the Strategy could be used as justification to finance several projects at "prices intended to facilitate development", i.e. heavily subsidised.

[18] http://www.statedevelopment.qld.gov.au/major-projects/abbot-point-growth-gateway-project.html
[19] http://statements.qld.gov.au/Statement/2015/3/11/palaszczuk-govt-charts-new-course-for-abbot-point
[20] http://statedevelopment.qld.gov.au/resources/project/abbot-point-stage-3/abbot-point-stage-3-cg-report-aug-07.pdf
[21] http://www.sunwater.com.au/__data/assets/pdf_file/0003/7284/Industry_Briefing_-_Moranbah_to_Alpha_Pipeline_Project.pdf
[22] (Queensland Government 2013) p9

The Connors River Dam proposal has a capital cost of $1.2 billion.[23] The project was a central part of a series of water supply projects for Galilee Basin and other coal mines. The project was shelved in 2012 due to high capital costs and state government budget constraints, but Sunwater remains "firmly committed" to this and other projects such as the Mooronbah to Alpha pipeline.[24]

The Mooronbah to Alpha pipeline is another proposal to supply Galilee Basin mines, particularly GVK's Kevins Corner and Alpha mines. Sunwater estimates the 200 kilometer pipeline would cost $600 million.[25]

The Nathan River Dam is further south and would service the Bowen and Surat Basin mining areas as well as various other users. The capital cost of the dam is estimated by Sunwater and their consultants at $1.4 billion. Proposals for the controversial dam have been considered for many years and have been the subject of legal action over environmental impacts. The project is still being pursued and has an active EIS.[26]

A more recent development known as the Galilee Water Project proposes to divert water from the Cape and Campaspe rivers into water storages to supply the Galilee Basin. No information is available about its capital costs or how the project might be financed. The project is being proposed by a former Labor Treasurer of Queensland, Keith De Lacy. Given Mr De Lacy's political connections and the need most Galilee Basin projects have for government assistance, it seems highly likely the company will request some form of assistance from the Queensland Government.[27]

In summary, there are at least $3 billion dollars' worth of water infrastructure projects proposed by the state-owned water company Sunwater and well-connected proponents, which mainly benefit the mining industry. All of these projects appear to be economically marginal and dependent on significant government assistance. All of these projects carry significant risk and exposure to the coal industry and it is unlikely that they would provide a return to the Queensland community comparable with required investment in core services such as health and education.

Royalty holiday

A key part of the Galilee Basin Development Strategy is a discount on royalties payable by mining companies to the state in return for the right to sell the coal. The Strategy states that the Government may offer developers:

> *A ramp-up to full royalty for an initial period, on the normal coal royalty payable and based on a sliding scale.*[28]

No details are provided on how many companies the discount may be available to, how big the discount may be, or how long it will last. Regardless, the policy could cost Queensland taxpayers billions of dollars.

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[23] http://www.statedevelopment.qld.gov.au/resources/project/connors-river-dam-pipelines/connors-report-summary.pdf

[24] http://www.sunwater.com.au/about-sunwater/media-room/latest-news/latest-news/2012/sunwater-discontinues-work-on-connors-river-dam-and-pipelines-project

[25] http://www.sunwater.com.au/__data/assets/pdf_file/0003/7284/Industry_Briefing_-_Moranbah_to_Alpha_Pipeline_Project.pdf

[26] http://www.sunwater.com.au/__data/assets/pdf_file/0006/8745/Chapter-00-Executive-Summary.pdf, http://www.sunwater.com.au/future-developments/nathan-dam/overview, http://envlaw.com.au/nathan-dam-case/

[27] http://www.galileewater.com.au/

[28] (Queensland Government 2013) p2

For the purpose of illustration, Adani's Carmichael Coal project is expected to operate for 60 years. In the recent Land Court challenge to the project's approval, Adani claimed the project would pay $2.058 billion in royalties in the project's first ten years. A discount of 50 per cent on the first five years and a 25 per cent discount on the second five years would result in a loss to the Queensland Government of $677 million.[29] If such a subsidy were extended to other proponents, it could easily reduce royalties received by over $1 billion.

Assistance measures in the current budget

Assistance to the resource industry in the current budget has been analysed by the Queensland Competition Authority (QCA) in its draft report 'Industry Assistance in Queensland'. The QCA estimates the mining sector will receive assistance worth $700 million dollars over the 5 year budget period:

Table 2: Mining assistance measures in QCA analysis

Measure	Value of assistance to the mining industry
Gladstone Port concessions	$ 244,900,000
Payroll tax - exemption threshold and deduction scheme	$ 236,610,000
Area discounts for mineral development licences	$ 97,658,000
Trade and Investment Queensland	$ 45,708,600
Payroll tax - exempt employees	$ 29,469,000
Future resources program (excluding collaborative drilling initiative)	$ 22,000,000
Leases of port land at concessional rates	$ 12,420,000
Contracted Air Services	$ 7,630,500
Collaborative drilling initiative	$ 3,000,000
Other	$ 783,160
Total	**$ 700,179,260**

The QCA's analysis underestimates the value of state assistance to the mining industry due to its methodology which focuses on the incidence of assistance rather than its effect. In other words, the QCA assesses where a form of assistance starts rather than what industry it actually assists. Other measures the QCA leaves unallocated are where data is unavailable or further research would be required.

Examples of such measures which deliver government assistance to the mining sector, but that are not allocated to mining in the QCA analysis are the *Rail Network and Infrastructure Financing* concession and *Commercial Access to National Parks, Regional Parks, State Forests and Marine Parks.*

Rail Network and Infrastructure Financing

This is a contract between the government and Queensland Rail (QR) to pay for maintenance and some new projects of QR's rail network. The Budget Papers Concession Statement point out that part of this concession accrues to all users, including public transport users. The QCA estimates the amount which accrues to industry, however, as its "inquiry is primarily focused on benefits provided to freight customers."[30] The QCA makes it

[29] based on data in (Fahrer 2015)
[30] (Queensland Competition Authority 2015a) p46

clear who these freight customers are, as it focuses on QR's "Regional rail network for the purpose of operating freight services (mainly livestock and coal) by rail."[31]

However, under the QCA's analysis none of the $1.1 billion Rail Network and Infrastructure Financing assistance measure is included as assisting either agriculture or mining, but is considered a service as it initially accrues to freight rail companies that service these industries. The QCA ignores to what extent this assistance is passed on to livestock and coal producers. While this approach makes the QCA's research task simpler, it distorts its results. For example, if the government spent money to build flour mills, making flour cheaper, the main beneficiary would be the bread industry. The QCA's methodology considers that only the flour industry has gained any assistance. The Australia Institute's approach is to include this concession as accruing to the industry affected and to note that the benefit is partially accruing to the industry rather than dedicated to it.

Clearly a substantial amount of this concession accrues to the mining industry. QR has eight main freight networks. The West Moreton system and the Mt Mount Isa system are dominated by mining, while the North Coast system and South East systems are partly used by the industry. The Western, Central Western, South West and Tablelands systems are predominantly used by other industries. Based on QR's description of the freight on these lines, between a quarter and a third of freight is related to mining, suggesting that around $300 million of the $1.1 billion industry concession accrues to mining.[32]

Commercial Access to National Parks, Regional Parks, State Forests and Marine Parks

Mining and gas companies receive access to state-owned and managed land at rates that do not reflect costs to the state. As the QCA puts it:

> *Queensland Parks and Wildlife Services provides and manages commercial access to national parks, regional parks, state forests and marine parks. Commercial access is generally underpriced and is provided for mining (e.g. mineral and gas exploration and extraction), agricultural (e.g. grazing and beekeeping) and commercial tourism (access to iconic sites) activities...*[33]

The QCA estimates this measure at $206 million over the 5 year forward estimates. This is an underestimate, however, as it only considers the costs involved in facilitating access and does not consider how much industries would be willing to pay for access and how much a private landholder might charge for this cost. This benefit would largely accrue to the mining industry, as it is unlikely bee keepers, graziers or tourism operators would be willing to pay the amounts that mining companies could. Estimation of this assistance is beyond the scope of this paper.

Environmental costs

Where mines are abandoned or not fully rehabilitated mines can contaminate soil, groundwater and surface water and represent a safety hazard. The community bears a cost through either having to pay to clean up the site or through accepting the degradation of environmental assets.

The Queensland Audit Office has estimated the cost of rehabilitating Queensland's abandoned mines and is concerned that recent increases in mining activity have the potential to add to this cost:

[31] (Queensland Competition Authority 2015b) p205
[32] http://www.queenslandrail.com.au/NetworkServices/DownloadsandRailSystemMaps/Freight/Pages/freight.aspx
[33] (Queensland Competition Authority 2015a) p59

> *This growth comes with increased risk of environmental harm and the possibility of adding to an estimated 15 000 abandoned mines and up to $1 billion estimated cost if all mines were to be rehabilitated.*[34]

This substantial cost that the community and taxpayers are left with represents a considerable subsidy to the mining industry, one that is not recognised by industry assistance estimates such as the QCA. The Australia Institute's assessments of state government assistance to the mining industry also overlook this environmental subsidy unless specific rehabilitation measures appear in budget papers. Queensland's budget papers do not contain such references, only South Australia makes mention of taxpayer funded rehabilitation of abandoned mines.

Support from State Government Bureaucracy

Mining industry assistance measures have strong support within parts of the Queensland public service and state-owned corporations. These officials are influential as they advise the government on policies relating to the mining industry.

For example, the Department of State Development states on its website:

> *The Port of Abbot Point expansion is the gateway to Queensland's economic development for many years to come. Jobs, royalty-funded social services, research and training and development opportunities from Galilee Basin projects will ensure that Queensland families continue to prosper.*[35]

As discussed above, coal mining is a small part of the Queensland economy and funds a tiny fraction of Queensland's public services. The Department's willingness to published poorly-researched information on its website demonstrates its support for Galilee Basin development.

The North Queensland Bulk Ports Corporation (NQBP), a state-owned entity states in its annual report that it is assisting Galilee Basin Development, rather than assessing its merits objectively:

> *NQBP is assisting both the Adani Group and Hancock Coal Infrastructure Pty Ltd (GVK Hancock Coal) to facilitate new coal terminal developments at the Port of Abbot Point.*[36]

NQBP also writes regular blog posts and tweets in support of these private developments.

State-owned water infrastructure company, Sunwater, is also supportive of taxpayer funded investment in projects that predominantly assist the mining industry:

> *SunWater is disappointed to announce that it will not be proceeding with the Connors River Dam and Pipelines Project at this time.*
>
> *SunWater acknowledges that while the State Government is supportive of the $1.3 billion Connors River Dam and Pipelines Project, SunWater cannot continue to undertake project activities without financial support and commitment of customers.* [37]

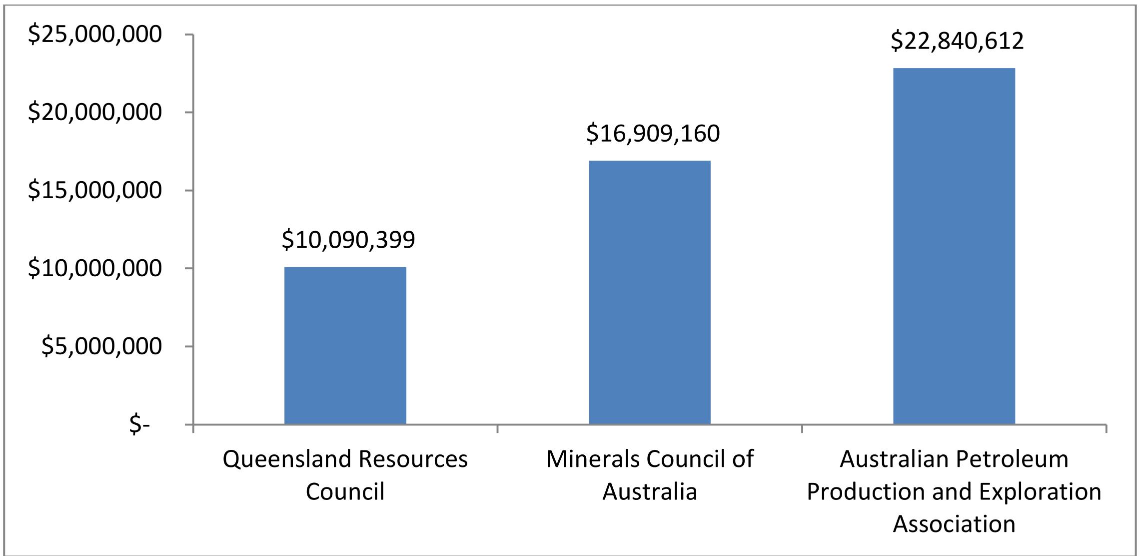
[34] (Queensland Audit Office 2013) p1
[35] http://www.statedevelopment.qld.gov.au/major-projects/expanding-the-port-of-abbot-point.html
[36] http://www.nqbp.com.au/wp-content/uploads/2015/04/Annual-Report-2013-2014.pdf, p4

Commitment to these projects, and disappointment when they are interrupted, shows the political and bureaucratic momentum behind them. While project benefits are emphasised, there is little discussion that these projects should be strictly considered on a user-pays basis to ensure returns on these investments exceed those available elsewhere. This approach is further assisted by the well-funded lobbying of the mining industry.

Mining industry lobbying

The mining industry lobbies actively for government-funded assistance such as the projects outlined in Table 1. Lobby groups such as the Queensland Resource Council, the Minerals Council of Australia and the Australian Petroleum Production and Exploration Association are well resourced to access Queensland's officials and decision makers. These three organisations have a combined budget of $50 million in 2013-14 to spend on lobbying for projects such as these:

Figure 9: Revenue of major Queensland resource industry lobby groups 2013-14



Sources: Annual reports and financial statements to the Australian Securities and Investments Commission. Note that Minerals Council of Australia figures are for the calendar year eg in 2011/12 column the figures are for the 2012 calendar year.

These groups are only the most visible part of the Queensland mining lobby. Companies also engage professional lobbying firms and employ in-house lobbyists to campaign for benefits to industry such as the projects listed in this report.

Conclusion

The Queensland State Budget is in a fairly sound position. This should come as no surprise as the State has a diversified, modern economy and generally well-functioning institutions. Yet despite Queensland's overall financial health, social spending lags behind the rest of Australia. Even in health and education, which are funded at around national averages, Queensland's size and characteristics are putting pressure on services like schools and ambulances.

[37] http://www.sunwater.com.au/about-sunwater/media-room/latest-news/latest-news/2012/sunwater-discontinues-work-on-connors-river-dam-and-pipelines-project

Queensland's Treasury makes it clear that part of this problem is the state's continual spending on assistance for the mining industry. State-funded mining infrastructure comes at the expense of schools and hospitals.

The mining industry has a $10 billion wish list that it wants from the Queensland Government and it has a $50 million per year lobbying budget that it uses to get what it wants.

Queensland's underfunding of social services has no silver bullet. However, reducing the state's largesse to the mining industry could provide substantial funding to health, education and other services.

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Attachment 3

Submission by

Alternative Technology Association

on

QCA's Issues Paper on Solar Feed-in Tariffs:

'Estimating a Fair and Reasonable Solar Feed-in Tariff for Queensland'

14th September 2012

By Email to: electricity@qca.org.au

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1.0 Introduction

The Alternative Technology Association (ATA) welcomes the opportunity to provide comment on QCA's Issues Paper on *Estimating a Fair and Reasonable Solar Feed-in Tariff for Queensland* ("the Issues Paper").

ATA is a national, not-for-profit organisation representing consumers and communities in the renewable energy and energy efficiency marketplace. The organisation currently provides service to 5,500 members nationally who are actively engaged with small, medium and large scale renewable energy projects, energy efficiency and the national electricity market (NEM).

ATA provides an 'independent' consumer advice role, both to our members in Queensland and throughout Australia, and also more broadly to the public general in Queensland. As we are not funded by, and do not have direct links with industry or government, the ATA is a trusted source of advice for our membership and the general public in regards to the economics and environmental benefits of energy technologies.

A key specialist area of the ATA's in this regard is the economic impact, both at the customer level and with respect to the dynamics of the electricity market, of solar investment. Through our work as consumer advocates on broader issues within the NEM, ATA has developed a solid understanding of the optimal role of distributed generation technologies such as solar photovoltaic (PV) in the energy market.

ATA has been actively involved in development of feed-in tariff (FiT) policy across all Australian jurisdictions over the last four years and more recently has submitted to following state-based solar FiT reviews:

- May 2012 –Victorian Competition and Efficiency Commission's (VCEC) *'Inquiry into Feed-in Tariff Arrangements and Barriers to Distributed Generation'*;
- January 2012 – NSW Independent Pricing and Regulatory Tribunal's (IPART) *'Setting a fair and reasonable value for electricity generated by small-scale solar PV units in NSW'*;
- May 2011 – Review of the South Australian feed-in tariff.

1.1 Overview

Properly designed and implemented, FiTs offer the best opportunity to address the substantial market failures that exist in the NEM with respect to the cost effective utilisation of solar PV.

As a policy mechanism, FiTs also offer the greatest potential for investment certainty for consumers and industry players in the relevant technology space.

To date, Australia has primarily used FiTs to drive small solar photovoltaic (PV) generation. In Queensland the Solar Bonus Scheme, beginning in mid-2008, had the aims of supporting the solar industry and making solar power more affordable[1] when the installed price of PV technology was high – in the order of $10 – $12 per watt (pre- incentives).

[1] http://www.cabinet.qld.gov.au/documents/2011/may/queensland%20solar%20bonus%20scheme/queensland%20solar%20bonus%20scheme.doc

There has been a rapid reduction of installed prices for solar PV systems over the last four years and as such, FiTs in both Queensland and nationally have required adjustment to ensure that those objectives have been maintained whilst preventing over-incentivisation of the market.

The adjustment of FiT mechanisms nationally has led in some quarters to a perception that FiT policies are problematic – when their continued adjustment is entirely appropriate in the context of the overall policy objective.

In 2012, the levelised cost of energy from solar PV systems is now lower than the average levellised cost (at the retail level) of energy from the electricity grid. As such, the primary issue for FiT design going forward is not one associated with providing a 'subsidy' or 'incentive' to potential solar proponents, but how to remunerate the pure economic value of any solar electricity exported into the energy market.

2.0 Fair and Reasonable

In considering the term 'fair and reasonable' it is important to carefully consider the objectives of the FiT policy that is being assessed.

The focus on FiT policy in Australia on primarily deploying solar PV technology has led to the misconception that the objective of FiT policy is primarily associated with the delivery of emissions reductions. This has in turn led to assertions that FiTs themselves are a high cost policy mechanism to deliver carbon abatement.

In reality, it is not the policy mechanism itself but the technology choice (e.g. solar) that leads to the relative cost of abatement. And emissions reduction is only one of the market benefits provided by solar technology. However the primary objective of investing in solar PV from a societal-wide perspective is not to deliver emissions reductions.

ATA contends that ***the primary objective of a well designed and structured FiT mechanism is to correct market failure*** – and to capture cost benefits and other potential benefits (e.g. carbon) of a particular technology choice, where the market alone cannot realise those benefits, or indeed is actively preventing them from occurring[2].

2.1 Principles for FiT Policy Design

The management of FiT policy going forward requires a principled approach, upon which a long term policy can be established for Queensland. ATA proposes the following principles to guide forthcoming Queensland FiT policy:

- To address market failure – where the Queensland energy market cannot capture, or is actively preventing the realisation of the cost benefits that solar generation can provide to all electricity consumers.
- To require no subsidy by other consumers, with particular attention to low-income or disadvantaged consumers. 'Subsidy' in this context refers to when a payment is made by electricity consumers where the benefit they receive is lower than the value of that payment (e.g. if a 44c/kWh FiT is paid when the benefit or value of that exported electricity is 20c/kWh, then a 'subsidy' of 24c/kWh would exist within that payment).
- To support innovation and ongoing development of the solar industry.

[2] A classic example of the NEM preventing benefits from being realised is the fact that distributed solar cannot trade directly into the wholesale market – thereby preventing the monetisation (to the solar proponent) of merit order wholesale price reductions that occur from reduced demand on supply side generators at times of peak demand. FiTs redress this situation by offering part of the wholesale price savings back to solar owners.

2.2 'Value Stack' Approach

In keeping with the principles outlined above, ATA suggest that fair and reasonable value for solar and other distributed generation technology be based on a value stack – i.e. the components of value that distributed generation offer to the market.

A number of energy market economists recognise that net exported energy from solar has an inherent value within the energy market. As an example, SKM MMA in a recent report[3], attribute the following value components to solar generation:

- *"Energy value, comprising the value that the net exports would earn if it was traded on the wholesale market or if the equivalent amount of electricity had to be purchased from the wholesale market. This value comprises not only the spot value on the wholesale market but, at low levels of installation within a region, the avoided losses from central supply sources and any costs incurred by retailers in contracting for wholesale energy.*

- *"Network savings mainly in the form of deferred investment in fixed cost assets. The magnitude of this value depends on the correlation between PV generation and peak demand at the regional level.*

- *"Ancillary savings, such as avoided market fees."*

SKM MMA go on to state that:

> *"Other benefits are also possible such as a reduction in the wholesale price to other customers during peak periods, reduced network losses faced by customers in regions with a high level of uptake, and environmental benefits through reduced emissions and reduced water use."*

Given that typically solar PV generation and residential load curves are not aligned, ATA do not believe that the deferral of distribution network assets represents sufficient value to warrant recognition within a FiT rate.

In areas with a higher penetration of commercial and industrial development, where generation and load curves do more closely match, asset deferral is likely to be an economic benefit provided by solar that warrants remuneration through a FiT.

ATA do contend that the energy value, avoided distribution and transmission losses and avoided market fees, as described by the SKM MMA analysis, are absolutes economic values that are delivered by solar PV generation and should be remunerated through any FiT arrangement.

ATA also contend that the reduction in the wholesale price to other customers during peak periods – known as the *merit order effect* – is a material economic benefit that is delivered by distributed solar.

[3] SKM MMA, 2011. '*Value of Generation from Small Scale Residential PV Systems*'. A Report to the Clean Energy Council, Melbourne.

In line with the above, a 'value stack' can then be developed upon which the design of ongoing FiT arrangements in Queensland should be based:

Figure 1: Value Components of Solar PV

c/kWh	Wholesale energy value
	Avoided distribution and transmission losses
	Avoided market fees
	Reduction in wholesale prices – 'Merit Order Effect'

In recognising this value stack, the question then becomes, by what methodology to quantify the value of each of these benefits, and to ensure that part of their value is returned to all electricity consumers in the form of lower retail prices.

Wholesale Energy Value

The approach taken by QCA for the calculation of wholesale energy value in their retail electricity price determinations has more recently been a market-based approach including hedging costs. This approach has merit in reflecting the value of energy purchase costs by retailers and ATA agrees that it is an appropriate method for calculating the value of wholesale energy.

ATA is also comfortable with the methodology put forward by a number of energy market economists in attributing wholesale energy value in the form of a regulated FiT – that is, broadly based on a volume weighted price of energy for Queensland, which based on a recent study[4] is expected to fall in the range of 8c to 10c/kWh.

Avoided Distribution and Transmission Losses

The value of avoided transmission and distribution losses also needs to take into account, and at the time at which net exports from a solar generator are taking place.

Electricity from solar PV is often exported at times when network elements are likely heavily loaded, meaning that customers in a region may benefit from lower network loss factors. This should be taken into account when appropriating a value using standard network loss factors.

Further, ATA would highlight the approach taken in the Western Australian Market (WEM) with respect to avoided losses from distributed generation. In WA, a higher value is attributed within the FiT to distributed generation systems that are installed in more remote parts of the electricity network. Given Queensland's significant geographic area, ATA would suggest this is a logical economic basis upon which to incorporate values within a future FiT to remunerate for avoided losses.

[4] SKM MMA, 2011. '*Value of Generation from Small Scale Residential PV Systems*'. A Report to the Clean Energy Council, Melbourne.

Avoided Market Fees

ATA is also comfortable with typical energy market estimates of the value of avoided market fees and costs. This generally represents a value less than 1c/kWh.

Reduction in Wholesale Prices – Merit Order Effect

Solar generation at or near the location of demand reduces the demand for electricity from the wholesale market. This in turn translates into downward pressure on wholesale electricity prices.

This effect is known as the 'merit-order effect' (MOE) and it results in a benefit for all electricity consumers through lower wholesale electricity prices.

The downward pressure on energy prices due to the MOE occurs through the following mechanisms:

- A reduction in the need to dispatch the next (more expensive) market generator which sets the price for wholesale energy traded on the spot market.

  This effect occurs immediately after each new DG system starts to generate, the value of which is generally considered to slowly reduce in magnitude over the course of a number of years as market bidding behaviour is adjusted in response to the reduction in energy spot prices.

- The lowering of the value of price hedging instruments, and thus the retail cost of energy, in the medium to longer term.

  This comes in to effect as existing hedging arrangements expire and are renewed, typically over the course of three years following the installation of new system, and is also generally considered to slowly reduce in magnitude over the course of a number of years.

The MOE occurs for all energy generated by solar PV, regardless of whether it is used on site or exported as surplus. The reason for this is that all of the solar PV generation is seen by the wholesale market as a reduction in demand.

It should also be noted that while the MOE can occur for all distributed generation technologies, the value of the MOE produced by solar PV is higher than for most other distributed generators. This is because solar generation lowers the demand from the wholesale market during periods of higher electricity use and higher wholesale prices – being during the daytime and during the hotter and sunnier seasons.

Therefore, it is important to recognise, and furthermore remunerate, a value in recognition of the MOE that is provided by solar PV generators as a benefit to all other electricity consumers in the form of lower electricity prices.

Ignoring this benefit, on any basis, would be short-changing solar PV and other distributed generation owners, and therefore cannot be considered to be fair and reasonable.

Estimating the MOE for Solar PV Generation

While it may be difficult to confidently predict or accurately measure the value of the MOE in the longer term, the MOE caused by solar PV is generally agreed be of a material value – to the extent that concern over this materiality has previously been raised by coal fired generators[5].

Research[6] by the Melbourne Energy Institute (MEI) at the University of Melbourne has estimated the installation of solar PV above the current installation penetrations would have been worth, all other factors being equal, 'in excess of $1.8 billion over 2009 and 2010'. This amount represents potential savings to all consumers brought about by the effect solar PV has on the wholesale market.

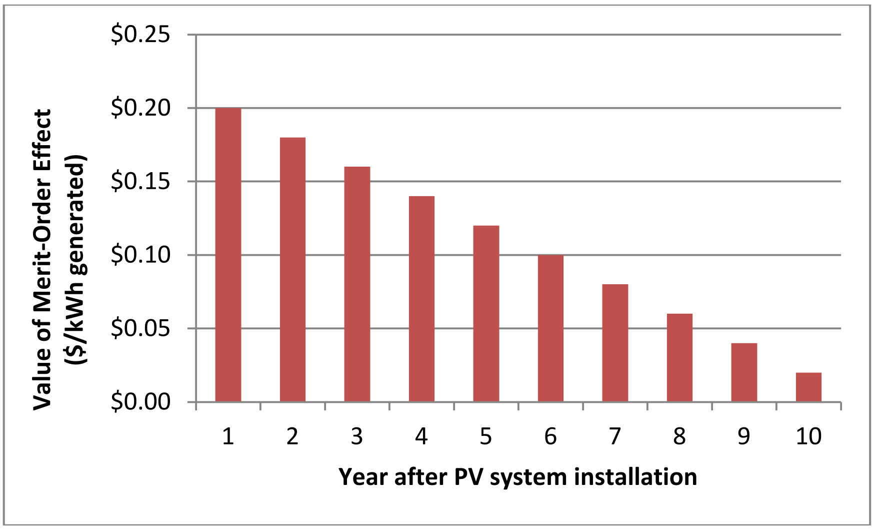
Based on this wholesale market estimated saving of the $1.8 million, energy from solar PV generation is worth 20c per kWh in the first year after installation.

Over a number of years, the value of the MOE from a particular installation would be expected to reduce in magnitude, eventually nearing zero. From our own investigations and understanding of the energy market, ATA are of the view that the period over which the MOE for new solar PV reduces to zero is likely to be in the order of 5 to 15 years.

After this time, the value of solar PV generation would continue to include the average volume weighted wholesale electricity price at the times of solar generation, as well as avoided network losses and market fees, as outlined above.

ATA suggest that for the purposes of estimating the value of the MOE over time, it would be appropriate that the MOE reduces linearly from 20c/kWh generated down to 0c over the course of 10 years, as shown in **Figure 2** below.

Figure 2: Value of the Merit-Order Effect for Solar PV Generation over 10 years



5 During considerations of an expansion to the former Victorian Renewable Energy Target (VRET), brown coal generators expressed concern that a larger share of renewable energy, including distributed systems in the electricity market, would negatively impact their revenue due to downwards pressure on the wholesale price.

6 http://energy.unimelb.edu.au/index.php?mact=News,cntnt01,detail,0&cntnt01articleid=112&cntnt01returnid=22

Apportioning the Merit Order Effect

In light of the benefit that the solar PV provides to all electricity consumers through the MOE, ATA are of the view that it should be remunerated as part of FiT arrangements.

In keeping with the lessening of the effect with time, the remuneration in the FiT based on merit order value should apply a for fixed time period following the installation of each new system, after which FiT remuneration reverts to the value of the remaining energy market components identified earlier in this submission.

As noted earlier, the merit order effect is caused by all energy generated by a solar PV generator, regardless of whether it is exported by the generator or used on site. This also needs to be considered in the calculation of the MOE for a net feed in tariff.

ATA are of the view that at the household scale it is reasonable to assume that the value of the MOE for all energy generated be monetised via the FiT. For a net FiT, this requires the value of MOE for the portion of generation used on site (i.e. not exported) to be applied to the FiT for exported energy.

If we assume:

- an average system export rate of approximately 50%;
- a ten year merit order effect as described above; and
- 2012 value of money (i.e. non-discounted cash flows);

then ATA recommend that a value of:

- 20c/kWh be remunerated in any net FiT; or
- 10c/kWh be remunerated in any gross FiT;

for 10 years from the installation of each new system up to 5kW, after which time the system qualifies for a FiT simply based on the value of the remaining energy market components as identified earlier.

ATA's proposed methodology aims to achieve this sharing of benefits, the 20c/kWh value included in the FiT value stack is below the estimated value of the MOE for solar PV on the NEM.

ATA also believe this is an emerging area of understanding within the energy market, and through the course of this review, QCA and the Queensland Government should seek to work closely with those academic institutions and energy market consultants who have developed comprehensive modelling to analyse and assess the benefits of the MOE for solar PV.

2.3 Completed Value Stack for Solar PV

Taking into account all of the benefits of solar PV outlined above, the value stack under a net metering arrangement results in the remuneration values outlined in **Table 1**:

Table 1: Complete Value Stack for Solar PV under a Net Metering Arrangement

Wholesale energy value	8c to 10c/kWh
Avoided distribution and transmission losses	Needs calculation
Avoided market fees	0c to 1c/kWh
Reduction in wholesale prices – 'Merit Order Effect'	20c/kWh for 10 years

This results in a minimum FiT payment of 29 cents to 34 cents per kWh for the first 10 years after installation, falling to 9c to 14c per kWh after that.

The above analysis represents a fair and reasonable value for solar PV payment, taking into account the economic benefits of solar PV and passing back to this form of generation some of the benefit that it produces in the wholesale electricity price for all consumers.

3.0 Form of Regulation and Reviewing FiT Value

The Issues Paper requested feedback on the how the term 'fair and reasonable' should be interpreted (section 3.1, p9).

In relation to this, the Issues Paper discusses the first principal in COAG's set of national principles to apply to feed-in tariff schemes and reviews:

> "Governments agree that residential and small business consumers with small renewables (small renewable consumers) should have the right to export energy to the electricity grid and require market participants to provide payment for that export which is at least equal to the value of that energy in the relevant electricity market and the relevant electricity network it feeds in to, taking into account the time of day during which energy is exported."

Specifically ATA would like to draw attention to the phrase "... and ***require market participants to provide payment for that export which is at least to the value of that energy***...".

The phrase from COAG's national principles indicates that under no circumstance could the payment for solar energy be zero when it is clear that the exported energy has value to the energy market.

As an initial point, ATA would state that for a future Queensland feed-in tariff to be fair and reasonable, it must have a legislated minimum rate that is higher than zero cents per kilowatt-hour.

The need for any future rate to be legislated, as opposed to market driven, is outlined below.

3.1 The Market alone will not provide Fair and Reasonable FiTs

Further to COAG's principles, an important reason to put in place a legislated minimum rate is the current abuse of market power by electricity retailers in the distributed generation market, and as evidenced in NSW.

The majority of electricity retailers around the country now have some level of vertical integration – i.e. they own some degree of centralised generation assets that trade directly into the wholesale market.

As vertically integrated businesses, part of their vested interest is to ensure that the wholesale market trades as high as possible (with respect to price) to ensure that they get the best return for their generation assets as is possible.

As the evidence from 2009 now suggests, the prevalence of solar PV in the NEM is leading to demand reductions and a lowering of wholesale electricity prices. As such, the increasing prevalence of distributed generation such as solar is in direct conflict or competition with gen-tailers business models – and will ensure that as solar proliferates, gen-tailers will become increasingly resistant towards offering fair and reasonable FiT rates.

As a primary example, it is clear to see the current behaviour of retailers in NSW since IPART released the recommended range for FiT rates on 27 July 2012.

Currently, the FiT range recommended by IPART to retailers is from 7.7 to 12.9 cents per kilowatt-hour[7]. ATA has performed an analysis of the FiT rates offered by NSW retailers and there is very little evidence of fair and reasonable in their offered tariffs, as outlined in **Table 2**.

Table 2: Feed-in Tariff Rate offers for NSW Retailers

Retailer	Feed-in Tariff Offered[8]	Residential Customers[9]
ActewAGL Retail	-	24,449
AGL Sales	8.0 c/kWh	406,358
Australian Power and Gas	-	35,065
Country Energy	-	0
Dodo Power and Gas	-	0
Energy Australia	7.7 c/kWh	0
Integral Energy	-	0
Lumo	7.7 c/kWh	1,721
Momentum	-	2
Origin Energy Electricity	6.0 c/kWh	1,372,793
Power direct	7.7 c/kWh	5,852
QEnergy	-	0
Red Energy	5.0 c/kWh	18,467
TRUenergy	-	1,041,125

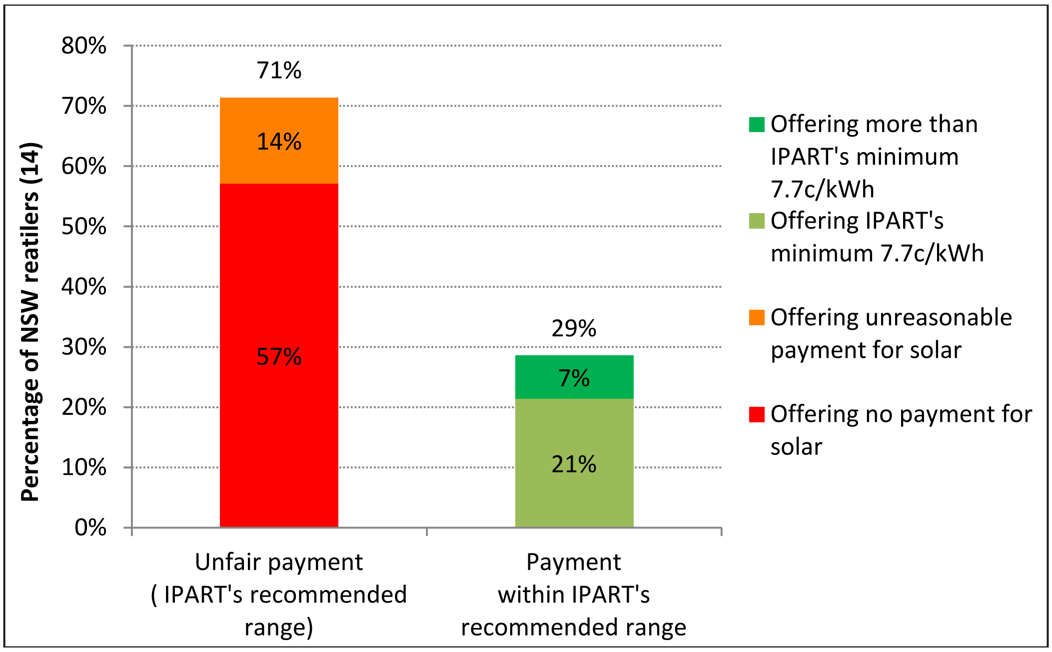
Out of the 14 retailers in NSW:

- 8 retailers (57%) are not offering a FiT payment to new solar customers at all; and
- only 4 retailers (29%) are offering a FiT payment within IPART's recommended range.

[7] http://www.ipart.nsw.gov.au/Home/Industries/Electricity/Reviews/Retail_Pricing/Solar_feed-in_tariffs_-_2012-2013/27_Jun_2012_-_Media_Release_-_A_fair_and_reasonable_solar_feed-in_tariff_for_NSW/Media_Release_-_A_Fair_and_Reasonable_Solar_Feed-In_Tariff_for_NSW_-_June_2012
[8] http://www.myenergyoffers.nsw.gov.au/useful-information/solar-feed-in-tariffs.aspx
[9] http://www.ipart.nsw.gov.au/files/43f052df-c49c-4cd9-a315-9f5c00bcdc32/InformationPaper-ElectricityRetailbusinessesperformanceagainstcustomerserviceindicatorsinNSW.pdf

Figure **3** below shows these FiT offers in relation to IPART’s recommended range.

Figure 3: Solar FiT offers for NSW Retailers



Further to this, it is estimated that more than 80% of residential electricity customers in NSW are not offered a solar FiT rate within the range recommended by IPART.

The above offers can hardly be considered fair or reasonable.

NSW is the only market in Australia so far where FiT rates have been left to the market to determine – i.e. there is no legislated minimum rate. On the basis of this market, there is little evidence to suggest that retailers will offer fair and reasonable solar FiT rates without a legislated minimum rate in place.

3.2 Reviewing the Value of FiT Rate

In their response[10] to VCEC's *Power from the People, Inquiry into distributed generation*[11], the Victorian Government has recently decided to legislate a minimum FiT rate, reviewed annually, for the years 2013 to 2016.

In South Australia the price regulator ESCOSA, has also determined that a regulated minimum FiT rate is appropriate, with annual increases that are currently determined and published for each final year until 2013-14.

ATA supports this approach as by having annually determined, legislated minimum FiT rates, the government can ensure that Queensland FiT policy has the ability to react to changing market conditions, and in particular changing wholesale energy prices.

[10] http://www.vcec.vic.gov.au/CA256EAF001C7B21/WebObj/Victoriangovernmentresponse-Aninquiryintodistributedgeneration%28PDF%29/$File/Victorian%20government%20response%20-%20An%20inquiry%20into%20distributed%20generation%20%28PDF%29.pdf
[11] http://vcec.vic.gov.au/CA256EAF001C7B21/WebObj/PowerfromthePeople-FinalReport/$File/Power%20from%20the%20People%20-%20Final%20Report.pdf

4.0 Responses to Specific Questions

Defining fair and reasonable	
(b) Should the Authority include the benefits associated with PV exports to other parties (all customers and distribution entities) in setting the fair and reasonable value? Why? **(c) Are there any other issues that the Authority should consider in interpreting the term fair and reasonable value?**	The merit order effect described above in section 3.2.5 outlines the benefit of lower electricity prices provided to all electricity consumers through solar generation.

Geographical considerations and the Uniform Tariff Policy	
(e) Is it fair and/or reasonable to have different FIT based on geographical locations in a market with the Uniform Tariff Policy in place? What are some of the benefits or complications of creating geographically based FIT?	ATA broadly supports this approach where it can be reasonably and independently determined.

Form of regulation	
(c) What evidence is available of the number of solar PV customers receiving voluntary feed-in tariff premiums in Queensland? Does the level of these tariffs represent a fair and reasonable value for the electricity exported by solar PV customers?	As shown above in section 3.1 there is no evidence to suggest that the market alone will deliver a fair and reasonable FiT payment. Indeed the evidence from the only market where this is currently occurring is that it will not.
(e) Are there any other factors (besides the competitiveness of the retail electricity market) that the Authority should consider in determining an appropriate form of regulation to apply in Queensland?	As described in section 3.1 there is considerable disregard by retailers for recommended ranges for payments.

Review of the fair and reasonable value	
(d) What are the implications for the current review of a potential transition to a national feed-in tariff established through COAG processes?	Our involvement in FiT policy in all jurisdictions over the past five years has left us with little confidence that there is a concerted move towards a national FiT arrangement. As such, ATA's view is that it would be inappropriate to leave Queensland consumers without FiT policy certainty in the short to medium term.

5.0 Further Contact

Thank you for the opportunity to provide comment to this process and please do not hesitate to contact us at Damien.Moyse@ata.org.au or on (03) 9631 5417.

Yours sincerely

Damien Moyse
Energy Projects and Policy Manager

Attachment 4

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Retrospective modeling of the merit-order effect on wholesale electricity prices from distributed photovoltaic generation in the Australian National Electricity Market

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HIGHLIGHTS

- ► We model the impact of photovoltaic generation on the Australian electricity market.
- ► Photovoltaic generation depresses electricity prices, particularly in summer peaks.
- ► Over the course of a year, the depression in wholesale prices has significant value.
- ► 5 GW of solar generation would have saved $1.8 billion in the market over two years.
- ► The depression of wholesale prices offsets the cost of support mechanisms.

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ABSTRACT

In electricity markets that use a merit order dispatch system, generation capacity is ranked by the price that it is bid into the market. Demand is then met by dispatching electricity according to this rank, from the lowest to the highest bid. The last capacity dispatched sets the price received by all generation, ensuring the lowest cost provision of electricity. A consequence of this system is that significant deployments of low marginal cost electricity generators, including renewables, can reduce the spot price of electricity. In Australia, this prospect has been recognized in concern expressed by some coal-fired generators that delivering too much renewable generation would reduce wholesale electricity prices. In this analysis we calculate the likely reduction of wholesale prices through this merit order effect on the Australian National Electricity Market. We calculate that for 5 GW of capacity, comparable to the present per capita installation of photovoltaics in Germany, the reduction in wholesale prices would have been worth in excess of A$1.8 billion over 2009 and 2010, all other factors being equal. We explore the implications of our findings for feed-in tariff policies, and find that they could deliver savings to consumers, contrary to prevailing criticisms that they are a regressive form of taxation.

1. Introduction

The design of policies to assist the transition to low emission electric power production presents significant challenges. Any new generation necessarily incurs significant up-front cost, and this is particularly the case for renewables such as solar photovoltaic (PV). On a levelised cost basis, solar PV is currently an expensive way to produce electricity. However, solar PV has a well-established and demonstrated learning curve that is producing significant cost reductions, reducing at about 22% for each doubling in deployment (Breyer and Gerlach, 2010). Many analysts anticipate that solar PV will reach retail grid parity in this decade (Breyer and Gerlach, 2010; EPIA, 2011; Gerardi and Stevens, 2011), at which time it will become cost competitive with residential electricity tariffs. An objective of policy measures, such as guaranteed feed-in tariffs, is to help realize grid-parity in the near-term.

However, policies such as feed-in tariffs that are designed to accelerate deployment of renewable energy remain controversial. They have been criticized for the impact they have on consumer

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electricity prices, as well as the method by which such costs are distributed across the consumer base. In Australia, the NSW Independent Pricing and Regulatory Tribunal (IPART) has suggested that the State and Federal Government renewable energy schemes added 6% to retail prices in 2010/11 (IPART, 2011). Nelson et al. (2011) argued that current NSW feed-in tariffs cost consumers 0.5 cents per kW h, and that the costs are unequally distributed amongst different sectors of the community. There is particular concern amongst the welfare sector that the costs associated with feed-in tariffs have been unfairly borne by households unable to participate in the scheme, such as renters. Because these costs are likely to impact disproportionately on low income groups, some have argued that feed-in tariffs may constitute an unwelcome form of regressive taxation (Nelson et al., 2011).

However, there are other mechanisms by which renewables can potentially impact electricity prices which may offset the feed-in tariff impost levied across consumers. For example, the low marginal cost of renewables means that they can significantly impact the "merit order", which plays a crucial role in the determination of the wholesale electricity spot price. Furthermore, distributed renewable energy generation may potentially mitigate network expansion and upgrades by alleviating loads that need to be carried through the transmission and distribution networks. With generation typically accounting for about only 30% of retail electricity costs in the Australian market, there may be hidden benefits of renewable generation that offsets the costs of feed-in tariffs. There may also be hidden network cost, should excessive localized generation required grid augmentation for export, or two way flow.

The key offset for renewable generation addressed in this paper is through the so-called merit order effect. The addition of significant levels of renewable generating capacity into electricity grids has been shown internationally to markedly reduce wholesale spot prices for electricity (Ray et al., 2010).

In Germany, Sensfuss et al. (2008) estimated that the savings from the merit order effect from renewable generation in 2006 were about €5 billion, while the money spent on feed-in tariffs was €5.69 billion. This gave a net total cost of €0.69 billion for 52 TW h of renewable electricity, which would have otherwise had a wholesale market value of €2.5 billion, representing a net saving to consumers. The merit order effect has also been quantified specifically for wind power in Germany (Weigt, 2009), Denmark (Munksgaard and Morthorst, 2008; Jónsson et al., 2010), Spain (Sáenz de Miera et al., 2008) and a combination of European countries (Ray et al., 2010).

In Australia, renewable generation is demonstrably impacting wholesale spot prices in jurisdictions such as South Australia where wind accounts for some 24% of generation capacity (AEMO, 2011). In South Australia, negative wholesale spot price events are increasingly common during periods of high wind power generation (Boerema et al., 2010; Cutler et al. 2009), and now account for about 1% of market time. The potential of renewables to impact via the merit order effect has been recognized in the purported concerns of some coal-fired generators about the rate of introduction of renewable generation. For example, in 2011,

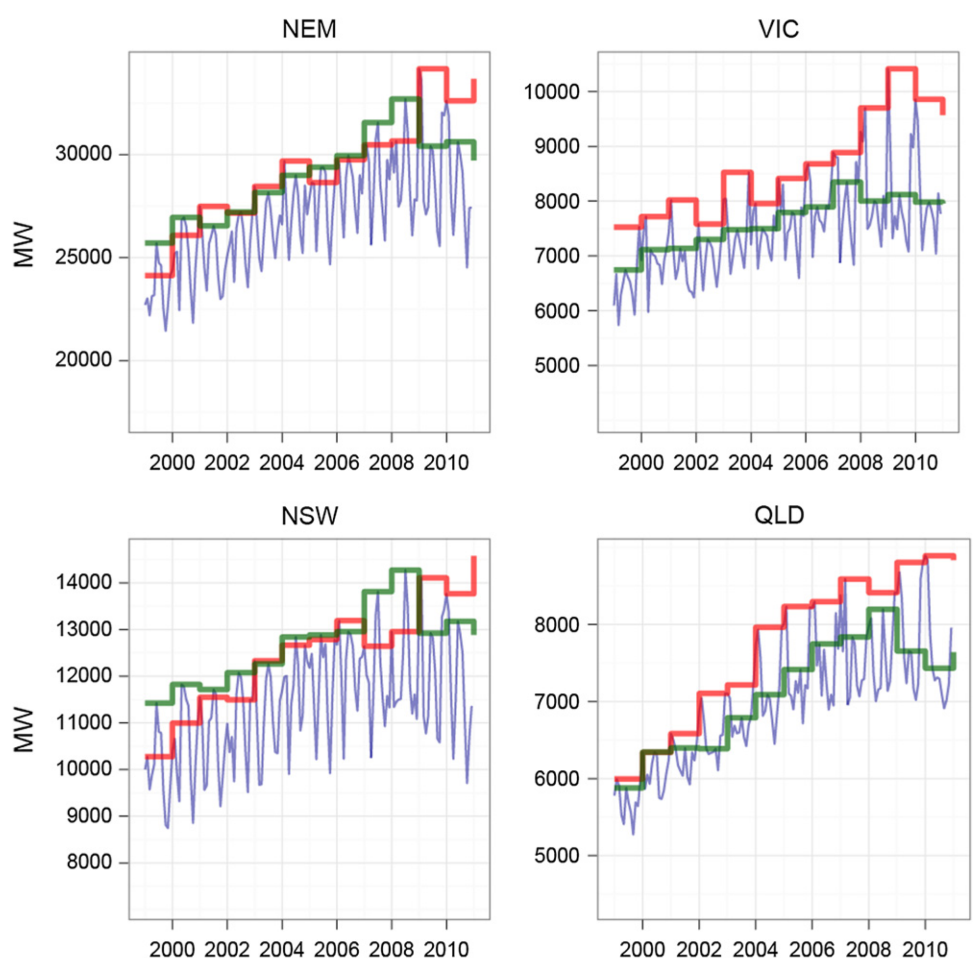

Fig. 1. Annual summer (red) and winter (green) peak demands and monthly (blue) peaks in each of the three main National Electricity Market (NEM) regional jurisdictions (VIC—Victoria, NSW—New South Wales, QLD—Queensland) and the entire NEM, for years 1999–2011 (up to and including August 2011). Data from AEMO. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the Victorian Auditor-General reported (Pearson, 2011) on the reasons behind relaxation of mandates for introduction of renewable capacity in 2007, when the time frame for increasing the share of Victoria electricity consumption from renewable energy sources to 10% was extended from 2010 to 2016. The Auditor-General concluded that this extension occurred "primarily to alleviate the concerns of brown coal generators that the 10% target would deliver too much renewable energy too quickly which would reduce wholesale electricity prices and adversely affect existing generators".

PV is expected to impact wholesale electricity spot prices more than wind power (Bode and Groscurth, 2010), per unit of electricity generated in the Australian National Electricity Market (NEM). This is because power production from PV generally correlates more strongly with electricity demand than wind. In markets such as the NEM in which peak demand has recently been dominated by summer peaks (Fig. 1), when PV will be generating the most power, the impact of PV on the merit order may be anticipated to be particularly effective.

In this paper we investigate the potential impact of PV on the wholesale electricity spot price in the Australian NEM over the 2009 and 2010 calendar years, as a preliminary investigation into assessing the extent to which the merit order effect may offset the costs associated with PV incentives. Our primary objective is to estimate the value of the purported concern of coal-fired generators, as expressed in the Victorian Auditors-General's report (Pearson, 2011), that meeting renewable energy targets too quickly would depress wholesale prices. This concern motivates the method of our analysis. Over time we expect the market to adapt to any new generation capacity, adjusting via changes in the amount of capacity overhang, for example. However, in the short term there is little capacity for the market to respond in such ways. We are therefore motivated to calculate the "static" response of the market as if PV generation were instantaneously added. We begin with an outline of some of the relevant characteristics of the Australian NEM, followed by an outline of the models we use for solar generation and price demand dispatch to evaluate the potential impact of PV generation on the NEM wholesale spot prices.

2. The Australian National Electricity Market

The Australian NEM spans the eastern states of Queensland, New South Wales, Victoria, Tasmania and South Australia, and is broadly divided into those 5 regions, with interconnectors between. All electricity in the NEM is traded through a central pool, and the NEM is currently largely dominated by fossil fuel energy sources, particularly black coal (Queensland and New South Wales) and brown coal (Victoria). The NEM peak demand is around 35 GW, with a mean annual demand of 23 GW.

Peak demand is typically in January or February in the Austral Summer, in each of the main jurisdictions (Table 1), as illustrated in Fig. 2. Summer peaks now typically exceed winter peaks by more than 1 GW in each of the three main regional jurisdictions of the NEM (New South Wales, Queensland and Victoria), and the current trend is for more rapid growth in the summer peak compared to the winter peak demand. Summer demand tends to peak in periods during the afternoon when PV is able to supply some load.

Table 1
Summer maximum demand and winter maximum demand (MW). Data from AEMO.

	Winter max demand		Summer max demand	
	2009	2010	2009	2010
NSW	12,922	13,176	14,106	13,765
QLD	7655	7313	8804	8891
SA	2362	2505	3331	3121
TAS	1679	1694	1358	1300
VIC	8119	7981	10,415	9858

In the normal operation of the NEM, enough generation capacity is scheduled to meet the demand. This demand is met by starting at the lowest price offer and then additional capacity is added in order from the lowest to the highest price. That is, electricity is scheduled on an economic basis in order of merit (AEMO, 2010).

The dispatch price of electricity is determined every 5 min on the basis of bids by the participating generators. The dispatch price is set at the value where the most economic combination of competitive bids meets the demand. All electricity generated within a region receives that price for the 5 min period, and the 5 min prices are averaged over each half an hour period to produce the half-hourly spot price (AEMO, 2010).

With a total generating capacity in excess of 45 GW and a peak demand of 35 GW, the NEM is characterized by a significant "capacity overhang" of almost 30%. One consequence is that volume weighted spot prices are typically below that of long run marginal costs, even for the cheapest generation. In the financial year 2010–11, the volume weighted wholesale price was $\sim$3.2 c/kW h, compared to average retail prices in the range of 16–24 c/kW h.

At the end of 2009, there was about 121 MW of PV capacity installed in Australia, which increased to 385 MW by the end of 2010 (ORER, 2011). As such, over the period we analyzed, installed PV would already have an impact on the NEM. We consider the impact of adding additional capacity over and above this existing deployment. The '0 GW' and '5 GW' scenarios referenced in the following discussion therefore refer to additional installation over and above this existing installed PV base.

3. Solar PV power generation model

To attribute the value of PV generation we consider a scenario in which PV generation is confined to the capitals of the four largest NEM regions, Brisbane (QLD), Sydney (NSW), Melbourne (VIC) and Adelaide (SA), where the bulk of the population is located. The model assumes a PV panel oriented at 30° slope facing directly north, in each of the cities. We consider that the number of PV installations is equally partitioned in these locations. While we could consider distributions more aligned to the population distribution, the absence of interconnect constraints in our model, as discussed below, means that the actual partitioning of PV distribution will have relatively little price impact. Furthermore the range in PV annual capacity factors for the four capital cities is small, with Adelaide having the highest at around 19.5% for 2010 and Sydney having the lowest at around 17.1% for 2010.

Our solar generation model calculates the solar radiation received by a solar panel on an hourly time-step using basic inputs of longitude and latitude, measured Global Horizontal Irradiation (GHI) from 2009 and 2010, measured local air temperature and solar panel orientation.

We use hourly GHI Solar data from the Geostationary Meteorological Satellite and MTSAT series operated by the Japan Meteorological Agency sourced from the Australian Bureau of Meteorology (BOM, 2011), and local ambient temperature data taken from Australian Bureau of Meteorology station readings from within the cities. Temperature data was averaged over relevant stations on an hourly basis.

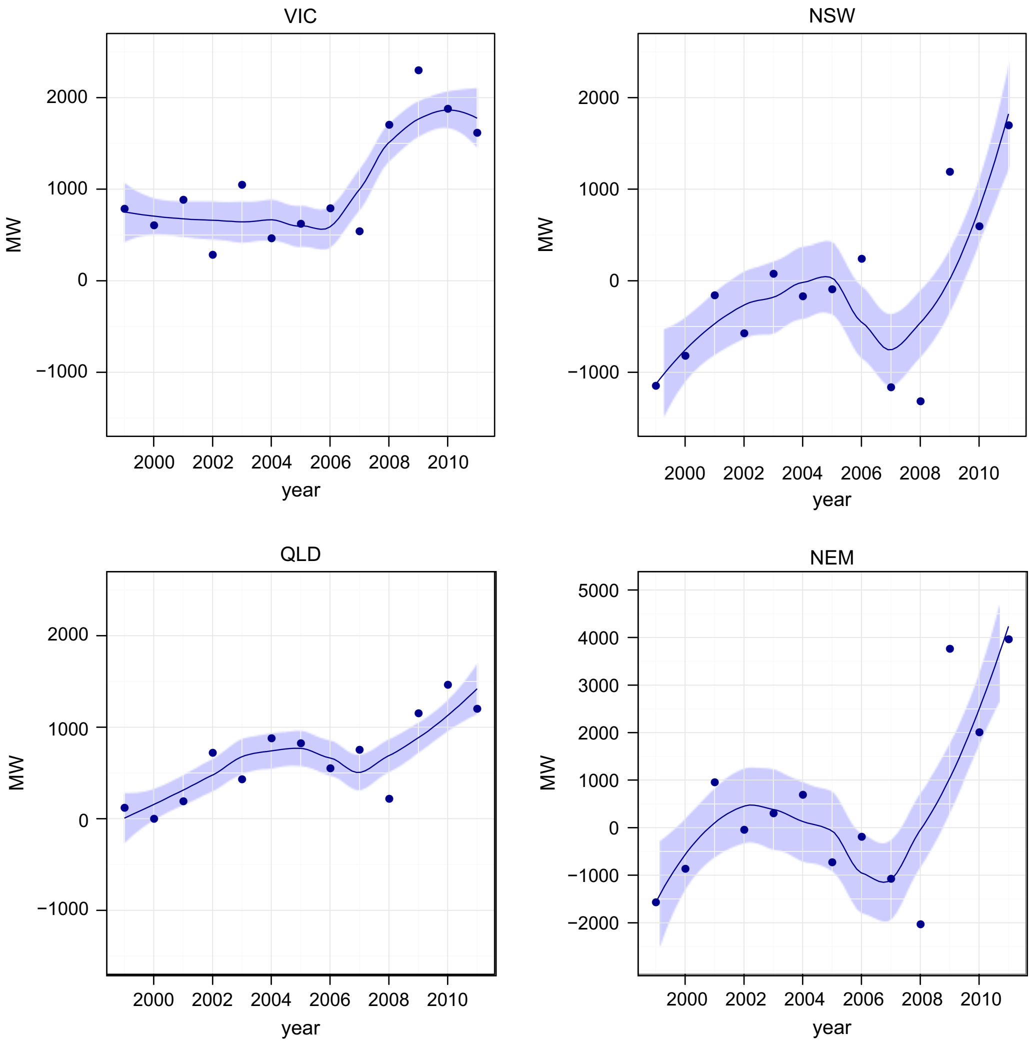

Fig. 2. Difference in Annual summer peak and annual winter peak consumption in each of the three main NEM regional jurisdictions (VIC—Victoria, NSW—new South Wales, QLD—Queensland) and the entire NEM, for years 1999–2011 (up to and including August 2011). Positive values imply summer peak demand exceeds winter peak demand while negative values imply the reverse. Data from AEMO.

Photovoltaic conversion efficiency is strongly affected by the magnitude of received radiation, and by cell temperature. We use the technical specifications of a supplier solar panel (Silex SL270 solar panel) to calculate the power output and capacity factor at each time-step, accounting for efficiency losses due to temperature and received radiation.

Constant conversion loss factors including inverter losses (2.8%), ohmic wiring losses (2%), array mismatch losses (2.2%) and module quality losses (1.6%) are taken from the University of Geneva's "PVSyst" model (PVSYST, 2011).

We use the standard approach from Duffie and Beckman (1991) to calculate the clear-sky radiation on a solar PV panel for any orientation for any geographic location. The Extraterrestrial Horizontal Radiation (instantaneous) is calculated as a function of latitude, longitude and time, correcting for solar time and the Equation of Time. The angle of incidence is calculated based on assumed panel orientation.

We calculate the clearness index (the ratio of measured Global Horizontal Irradiation to Extraterrestrial Horizontal Irradiation) using the Erbs et al. (1982) correlation, to calculate diffuse and beam components of the incident radiation. The 'HDKR model' of solar radiation, which assumes anisotropic sky conditions and takes into account horizon brightening effects, is used to calculate total global horizontal radiation on the panel surface as per equation 2.16.4 from Duffie and Beckman (1991).

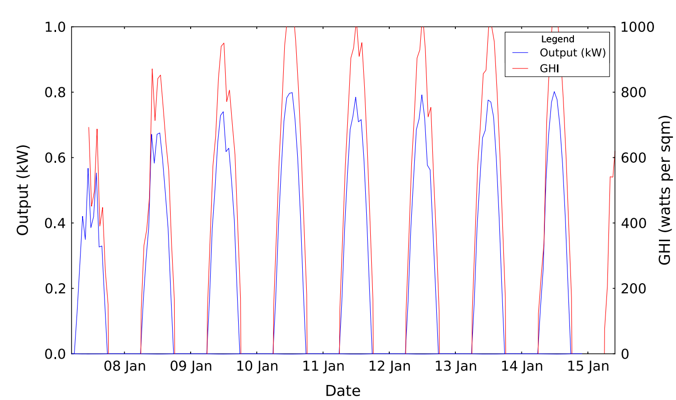

Fig. 3. Solar PV model results for a 1 kW north-facing PV installation at 30° slope in Brisbane, January 2010.

From the calculations of incident radiation and PV panel output described above, the hourly capacity factor (the ratio of instantaneous power output to rated peak power output) is determined, and then used to calculate the output of larger

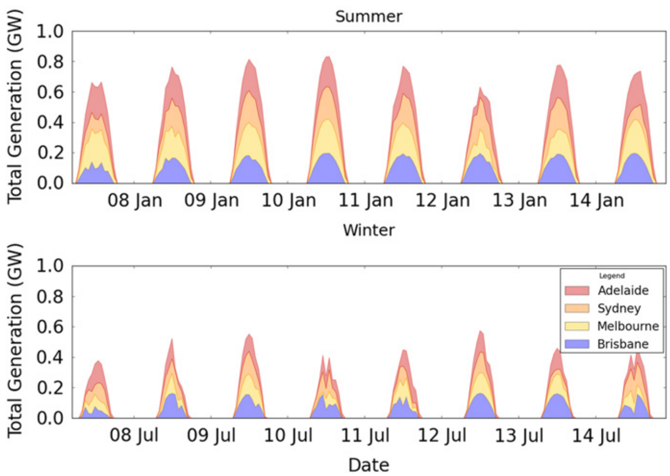

Fig. 4. Cumulative output for 1 GW of PV, distributed throughout eastern seaboard in summer and winter 2010.

Table 2
Annual capacity factors generated from the solar PV model.

City	Calculated annual capacity factor (2009) (%)	Calculated annual capacity factor (2010) (%)
Brisbane	19.0	18.1
Sydney	17.1	18.1
Melbourne	17.6	17.7
Adelaide	18.7	19.5

installations. The calculated solar output for a 1 kW PV system for a week in January 2010 for Brisbane is shown in Fig. 3. Fig. 4 illustrates the cumulative output over all regions for a 1 GW distribution, in summer and winter. Table 2 shows the annual capacity factors (the ratio of actual output to potential output if operated at full capacity) for 2009 and 2010 for the major cities based on the solar model.

It should be noted that no solar dataset is available for November 11 or the period November 15–26, 2009. No attempt was made to estimate placeholder values in this period, which effectively means that no solar output was modeled over this period. As this period contains a number of relatively high wholesale spot price events, the consequence is for the model to underestimate the total market impact of PV by an estimated 3–5% in 2009.

4. Price–demand model

There are thousands of constraints and constraint equations that govern the NEM dispatch process. These constraints include (but are not limited to) interconnector capacities and generating constraints. These are required in order to ensure reliable and safe provision of electricity, but also impact wholesale spot pricing. To simplify the evaluation of the approximate value of the merit order effect of a given PV installation, all other factors being equal, we have made use of the following assumptions in modeling the NEM dispatch process:

- We consider the NEM as a single region. This is equivalent to assuming the Marginal Loss Factor's (MLF) between the NEM regions to be 1, and that there are no capacity constraints between the 5 different regions.
- We ignore other generation constraints, such as generation constrained on or off.
- We assume that PV generation cannot produce negative spot prices in the model.
- We assume bidding behavior of existing generation is static and does not respond to increased PV generation.

The impact of each of these assumptions is discussed below.

Considering the NEM as a single region significantly simplifies the process of estimation of wholesale spot prices, as only one total demand is considered and one price needs to be resolved. A consequence is that throughout the entire NEM, the cheapest electricity (at a given Regional Reference Price, RRP) is available to satisfy all demand on the NEM; i.e., the cheapest electricity anywhere in the NEM is preferentially dispatched. This assumption yields a lower value for electricity prices, relative to the actual operation of the NEM where transmission capacity constraints and MLF's do apply. Our calculated 'NEM wide' price is typically lower than, and sometimes much lower than, the actual volume weighted average price for high price events within a particular region when interconnectors are constrained (AEMO, 2010), as typically happens in peak demand summer heat wave events in south-eastern Australia (see Table 4 in Section 5).

Due to technical realities of operating the power system, other constraints arise to ensure security of supply, including constraining generation off or on. Generation that has been 'constrained off' is dispatching at a level below what would otherwise be expected from the merit order, or the market determined schedule. In order to balance supply, generation which is higher in the merit order (and would otherwise not be dispatching) must be 'constrained on'. Constrained on generation is, by definition, higher in the merit curve. Whilst under normal operation this generator would receive at least the price it is bid into the market, when constrained on, the compensation or price received is the prevailing regional reference price in the market at the time. Thus 'constrained on' generation has no price impact, and ignoring this constraint does not impact the determination of the price.

It is feasible that significant penetration of PV could induce negative prices events, analogous to the negative price high wind events in SA (Boerema et al., 2010; Cutler et al. 2009). However, unlike large-scale wind which is contracted or hedged, PV generators could be considered fully merchant traders with no start up and shutdown costs. As such, PV generators could be expected to curtail production instead of paying to export to the grid. That is, we assume that production (and hence bidding behavior) is not price independent. It is unlikely that PV owners would pay to feed electricity into the grid.

As outlined earlier bidding behavior in the market would eventually be affected and change as a result of the addition of significant installations of PV. However, as our motivation is to estimate the near-term price impact of large-scale renewable penetration a partial equilibrium (ceteris paribus) approach is sufficient. The manner in which bidding behavior would change is unknown. It could be argued that, for example, price would be more volatile as generators (especially 'peakers') would have less opportunity to make their expected income, thus affecting pipeline capacity and gas contracts. However, it could equally be argued that in a fully competitive market, generators would have limited ability to raise (and may even lower) bids, to ensure they are dispatched at all and that their asset is utilized.

In combination, these assumptions allow for the development of a simplified model of the NEM dispatch process, which tends to underestimate the wholesale spot price. We compare the modeled wholesale spot price with PV installations against the modeled wholesale spot price without PV when determining the merit order effect.

Historic bid data is publicly available from the Australian Energy Market Operator (AEMO), and details information about the dispatch offers including the amount of energy a generator will sell at a certain price. For the purposes of this analysis, third party software NemSight (Creative Analytics, 2011) was used to extract the bidding data and dispatch data for all generators in the NEM for each 5 min period since 2009. This data included the generator identification, the region, the dispatch quantity offer, the dispatch price offer and the actual electricity dispatched in the 5 min period. Each dispatch price offer is tied to a quantity offer for a particular generator, and the price has been adjusted to include Transmission Loss Factors (TLF's). The actual dispatch captures the fact that during a particular trading period, the generation may be constrained (on or off) due to the many different constraint equations to ensure reliable supply of electricity. Table 3 shows a sample bid stack from a 5 min period in August 2011.

The PV generation is assumed to occur on a residential scale, and acts to reduce demand. That is, the PV generated electricity is not bid into the market itself. In reality, not all electricity will be used onsite, and at different times of the day a proportion of the energy will be exported to the grid. We assume any electricity returned to the grid is used locally and thus acts to reduce demand for the large-scale generators participating in the wholesale electricity market.

In order to calculate a wholesale spot price that incorporated the impact of PV using the model described above, a new demand profile input (that also incorporates the impact of PV) is required. PV generating capacity from 0 to 5 GW was used with the solar model in conjunction with the historical demand profile to produce this modified demand profile. The historical 5 min demand was calculated by summing the actual dispatched electricity in a 5 min period. The modified demand (including the impact of PV generation) was calculated by subtracting solar output (MW) from this historical underlying demand. As the instantaneous GHI solar data was available in one hour increments, we have used a linear interpolation to obtain relevant 5 min solar output. The new demand profile was then used in conjunction with the historical bid stacks from a 5 min period to determine a new dispatch price for that 5 min period, using the static bid model described above. The calculated price (at the end of each 5 min period) was averaged over the half hour trading interval to yield the spot price for the interval.

Table 3
Sample bidstacks for 10 August 2011 at 2 pm. Data from NemSight.

Rank	Unit name	Region	Price (AU$/MWh)	Quantity (MW)	Dispatched (MW)
1	BDL01	VIC	−1052.79	20	20
2	REDBANK1	NSW	−1001.2	76	76
3	CPP_4	QLD	−1000	200	200
4	STAN-3	QLD	−1000	220	220
…	…	…	…	…	…
178	TARONG#1	QLD	24.53	20	20
179	TARONG#4	QLD	24.53	20	20
180	TARONG#3	QLD	24.53	20	20
181	LD04	NSW	24.93	140	140
182	LD02	NSW	24.93	140	140
183	LD01	NSW	24.93	170	170
184	ER03	NSW	25.05	140	140
…	…	…	…	…	…
353	CG1	NSW	12,500	175	0
354	STAN-1	QLD	12,500	130	0
355	STAN-3	QLD	12,500	85	0
356	BDL02	VIC	13159.86	44	0

5. Results

Our price demand dispatch model has been validated by running a simulation with a 0 GW installation of PV. Figs. 5 and 6 directly compare the model output with the actual regional prices (volume weighted to a national price) in a winter and summer week. The model results generally approximate historical wholesale spot prices well, but underestimate the historical prices during short duration price spikes, as suggested in Section 4.

The model output can be further compared with the real price data by contrasting and analyzing cumulative value plots; plots that illustrate the cumulative value traded through the NEM over a period of time. The accumulation of the traded value ($) allows the model result and performance to be compared over an extended time period, without losing granularity. Comparing monthly or even weekly values would mask finer detail. Comparing hourly or even daily values over extended time periods (e.g. a year) would convolute the analysis, also obscuring detail.

The cumulative value plot illustrates detail that may occur on very fine timescales (e.g. extreme price events), whilst also showing the value aggregated over longer time periods.

For example, extreme price events can be identified (as near vertical sections in the plot), a detail that would be lost with aggregation over a large time scale. Similarly, by accumulating the value, longer term revenue trends can also be identified (with, for example, the gradient in non-extreme price events representing a more typical value traded per time period). This detail would be obscured if comparing only the value on short timescale, with daily values fluctuating by more than an order of

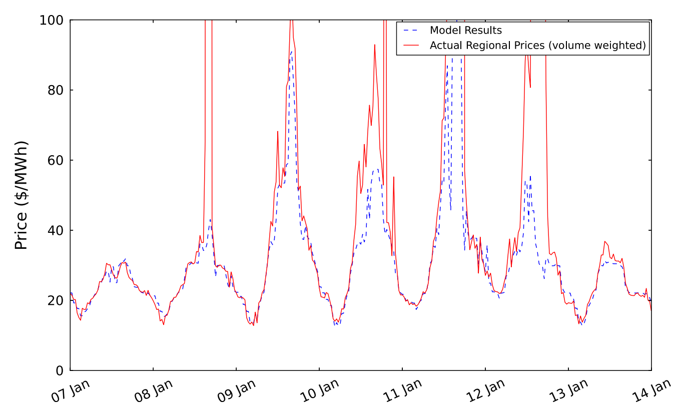

Fig. 5. Comparison of model results (blue, dashed) and actual prices (red, solid) in summer 2010.

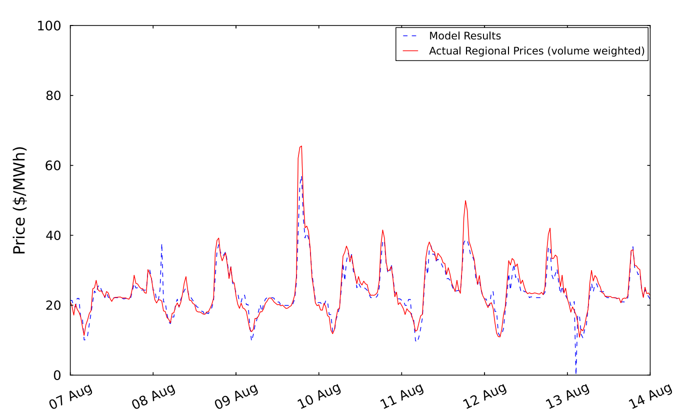

Fig. 6. Comparison of model results (blue, dashed) and actual prices (red, solid) in winter 2009.

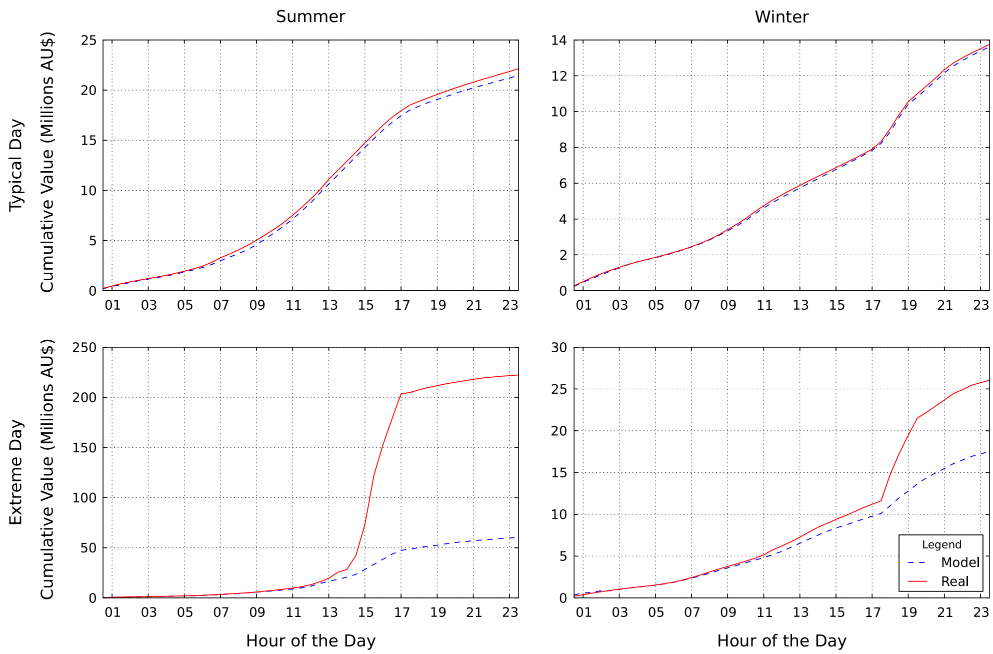

Fig. 7. Performance of dispatch model (blue, dashed) compared to market (red, solid) in cumulative value on typical days (top panel) and extreme days (bottom panel) in summer and winter.

magnitude (and hourly price values fluctuation by up to four orders of magnitude).

Fig. 7 illustrates the performance of the model and shows a representative daily volume weighted spot price revenue for typical summer and winter days, compared to actual revenue. Fig. 7 also shows extreme days, including January 29, 2009, when spot prices yielded one of the largest 'revenues' on the NEM.

Fig. 7 shows that our dispatch model does not capture extreme price events, which occur as a consequence of high demand and severe constraints. For example, the January 29, 2009, high price event in Victoria (with a spot-market value of ~$550 million) resulted from a combination of near record demand and failure of the Basslink interconnector linking Victoria and Tasmania, as well as other transmission failures (NEMMCO, 2009). In treating the NEM as a single market in our model, interconnect failure constraints are not captured.

Fig. 8 illustrates the cumulative value plots of modeled results and the real price data for 2010, and Fig. 9 shows the plot for 2009.

As can be seen in Fig. 8, the modeled traded value over 2010 was $4.8 billion AUD, compared to actual traded value of $7.2 billion AUD. For 2009, the modeled traded value was over $6 billion compared to the actual value of almost $10 billion (Fig. 9). The near vertical line segments in the real data plot represent peak periods of extreme high prices and value. The absence of these price extremes from the modeled results reflects the fact that the model significantly underestimates the peak price periods and their corresponding value. Table 4 compares the annual volume weighted prices and the peak prices for the modeled and actual regional wholesale electricity prices (volume weighted to a national average). Individual regional prices could (and did) go as high as $10000/MW h (the market cap price) in 2009 and 2010.

Comparing the mean absolute error (MAE) and mean signed difference (MSD) also confirms the underestimation of the model, particularly during extreme price events. Table 5 shows the MAE and MSD for the modeled spot prices, and the modeled spot price excluding the top 1% of actual extreme events. This analysis indicates that the model generally underestimates spot prices, and in particular, significantly underestimates spot prices in high price events.

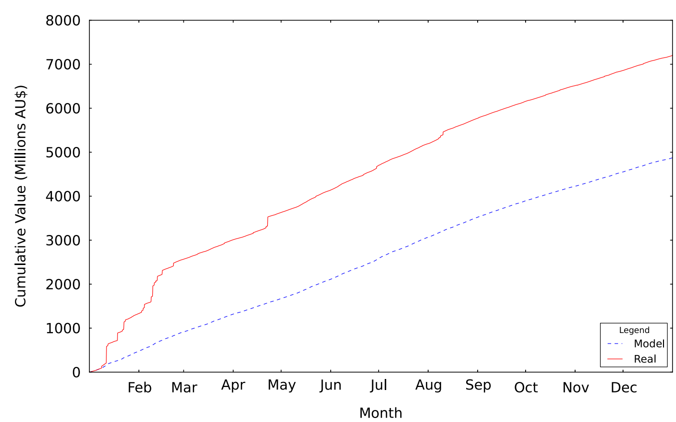

Fig. 8. Dispatch model (blue, dashed) and real market (red, solid) performance for year 2010.

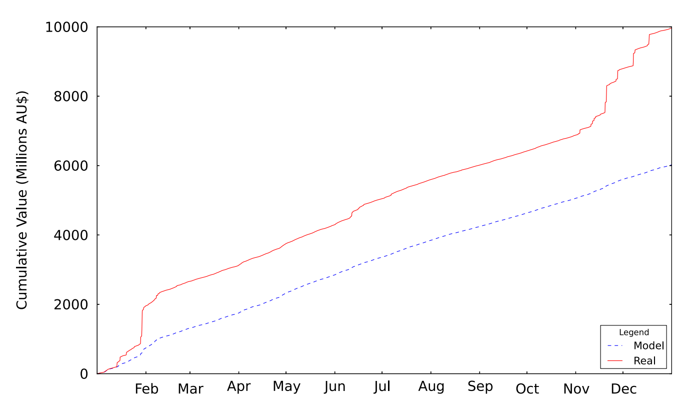

Fig. 9. Dispatch model (blue, dashed) and real market (red, solid) performance for year 2009.

The wholesale spot price savings indicated in this paper are calculated compared to the model scenario with 0 GW of

Table 4
Model and actual annual volume weighted prices (VWP) and peak prices for 2009 and 2010.

	2009		2010	
Price	Modeled	Actual regional price (volume weighted)	Modeled	Actual regional price (volume weighted)
Annual VWP	29.52	48.6	23.91	35.2
Peak	521.25	5800.5	118.94	3598.15

Table 5
Mean absolute error and mean signed difference for the modeled wholesale spot prices.

	Mean absolute error ($/MW h)	Mean signed difference ($/MW h)
Modeled spot prices	10.05	−8.9
Modeled spot prices, excluding top 1% of extreme price events	1.86	−1.07

additional PV capacity installed. As our baseline model underestimates prices during peak period, the estimated value of the merit order effect presented in this paper is also likely to be underestimated.

Simulations were run from 0 to 5 GW installations of PV capacity in 1 GW increments, with 5 GW representing an equivalent installation capacity to Germany on a per capita basis, of around 250 W per capita. As of September 2011, Germany had an installed capacity of 20.6 GW (BNetzA, 2011) and population of around 81 million. Figs. 10 and 11 illustrate the impact of varying installation capacities on both prices and demand. The three shaded areas in the demand graphs indicate the cumulative decrease in demand due to local power generation by hypothetical PV installations. Similarly, the three shaded areas in the price graphs indicate the cumulative wholesale electricity price savings with 1–5 GW of PV installed, compared to the modeled prices with no additional PV capacity.

It can be seen from our analysis that for only minor productions of solar electricity, a significant depression in the spot price can occur, representing significant value. This is particularly evident in summer, with the summer peak demand and high price events better correlated with the solar production as shown in Fig. 10.

The total value of the merit order effect was evaluated for solar installations from 1 to 5 GW. This was evaluated by taking the difference between the total cumulative value modeled for a given solar installation and the modeled value for no installation. In 2010 the value of a 5 GW installation due to the merit order effect could have been $628 million. The value, realized through the depression of the wholesale spot price (and the volume weighted price), represents 8.6% of the total value traded value in 2010. In 2009 the value of 5 GW due to the merit order effect could have been $1.2 billion, representing over 12% of the total value traded value in that year. Table 6 shows the potential value of the merit order effect in 2009 and 2010, as a function of installation capacity. The lower merit order effect in 2010 is reflective of the lower price volatility and the general lower amount traded through the pool in that year.

The total value of the merit order effect will increase with increasing installations of PV (Table 6). However, as can be seen in Fig. 12, the marginal merit order value of each additional unit of capacity decreases due to the remaining peak price events becoming smaller in magnitude. As solar capacity increases, peak

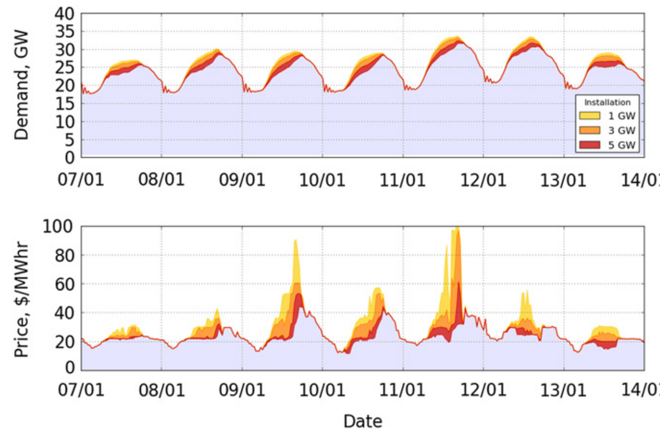

Fig. 10. Modeled impact of PV on demand and price in summer 2010.

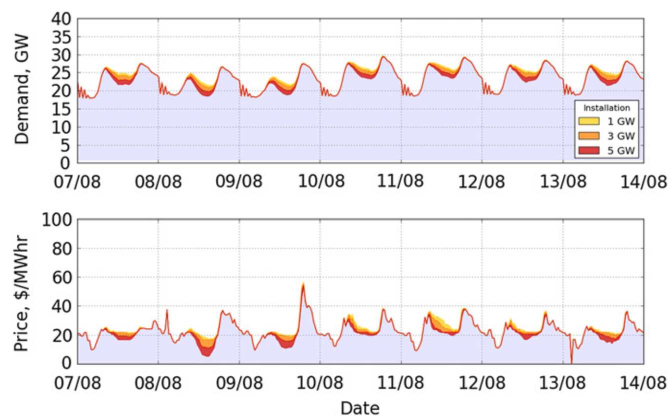

Fig. 11. Modeled impact of PV on demand and price in winter 2009.

Table 6
Potential value of the merit order effect as a function of installed capacity for 2009 and 2010.

PV installed capacity, GW	Merit order effect (million AU$)	
	2009	2010
1	390	169
2	670	302
3	893	412
4	1073	520
5	1229	628

demand periods reduce in magnitude and frequency, and solar begins displacing cheaper baseload generation, rather than higher cost peak generation.

It should be noted that exported PV electricity also has a primary value: the wholesale value of the energy. Previous studies (Gerardi and Stevens, 2011) have estimated this value by assessing the time and volume weighted wholesale value of the electricity produced by solar. This approach allows the value to be captured based on the time of generation (i.e. during the day, at typically higher than average prices) and the volume produced. Specifically, Gerardi and Stevens (2011) concluded that in NSW, the electricity produced by solar had a weighted wholesale value of 7.8 c/kW h.

A similar approach was used to determine this value in our analysis. However, the impact of the merit order effect (the

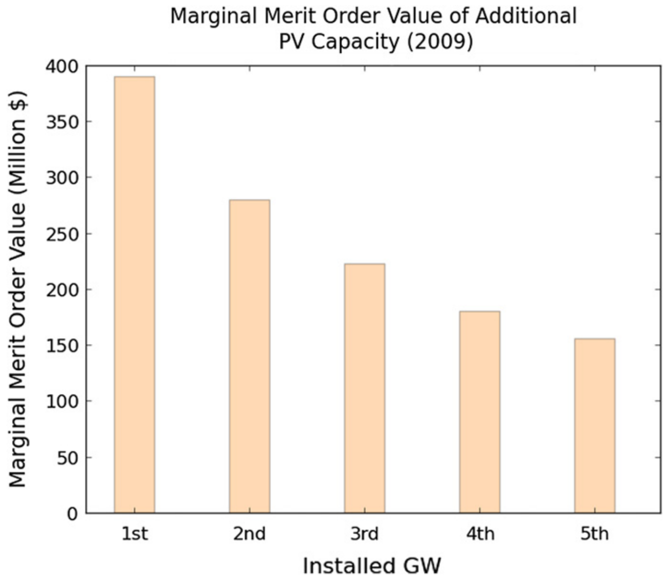

Fig. 12. Marginal merit order value of additional PV capacity for 2009.

Table 7
Impact of PV generation on the wholesale weighted price, in solar production times.

PV installation (GW)	Average wholesale value (c/kW h)
1	5.3
2	4.9
3	4.7
4	4.6
5	4.4

depression of electricity prices during times of solar production) was included. As solar penetration and production increases, this depression in spot price becomes more prominent and the value of the wholesale electricity decreases. Table 7 above illustrates the average wholesale value of electricity as a function of PV installation.

6. Policy implications

Currently in Australia there are two financial incentives for PV system installation: state-based feed-in-tariffs; and revenue from the sale of Small-scale Technology Certificates (STCs), as part of the Federal Small-scale Renewable Energy Scheme (SRES). Feed-in tariff schemes provide revenue over and above the market price of electricity and the STC's provide an upfront subsidy, nominally to recognize the value of electricity generated with zero emissions, and to allow industry development (and cost reductions through learning effects and economies of scale).

These schemes invariably impart a cost on the consumer (typically passed through to consumers through electricity bills), which is often criticized and has been described as an "unjustifiable burden on electricity consumers" (DRET, 2011) or a "regressive form of taxation" (Nelson et al., 2011). However, considering these costs in isolation misrepresents the overall cost of the scheme. These costs are counter-acted by offsets such as that created by the merit order effect. In an efficient market one would expect lower electricity spot prices, with the resulting downward pressure on contract prices, to flow through to customers by reduction in the wholesale component of electricity bills. In effect this should result in a wealth transfer from generators to consumers. By not considering this value, the cost of both feed-in tariffs and STC's to consumers is somewhat exaggerated. The German Federal Ministry for the Environment (BMU) does consider the merit order effect in its evaluation of the overall cost of the various German renewable energy policy schemes (BMU, 2011).

The following analysis considers the impact of the merit order analysis on a hypothetical feed-in tariff scheme that operates independently to other support mechanisms (e.g. the SRES scheme). Consideration of the merit order effect allows determination of the 'overall' cost of feed-in tariff schemes, and the determination of a 'breakeven point'. Since the PV output is considered as demand reduction, and to avoid double counting, no value (e.g. sport market value) is given to the in electricity fed into the grid from PV installations. The 'breakeven point' can be considered as the feed-in tariff rate at which the cost of the feed-in tariff scheme is equal to the value of the merit order effect or the value saved in the wholesale spot market, assuming an efficient market in which such reductions are passed through to consumers. Tariffs above the 'breakeven point' will impose a net cost on consumers, while tariffs below this point will create a net saving to consumers. The overall cost of the schemes will depend on the type of scheme and export rates.

Currently in Australia the majority of feed-in-tariffs offered by the state governments are net feed-in tariffs. These tariff schemes pay PV electricity generators only for the energy that is exported to the electricity grid or in other words, the energy that is not used locally at the PV generation site. The amount of energy exported from a system is quantified by the export rate, a percentage of the total energy generated that is exported into the electricity grid. Based on the export rates recently tabled from systems in NSW (Balding and Kua, 2010), export rates range from as low as 17% for 1.5 kW systems in predominantly metropolitan NSW, to as high as 84% for 10 kW systems in regional NSW. The average size of new connections between January and June 2010 was found to be 2.1 kW, with 1.8 kW being the total average system size. The export rate for 2 kW systems ranged from around 30% (predominantly metropolitan NSW) to 40% (regional NSW), with a trend towards larger systems and thus larger export rates.

In this study export rates of 40%, 50% and 60% were used to estimate the breakeven point at which the cost of a net scheme would be offset by the merit order effect. Fig. 12 illustrates this breakeven point, as a function of total installation capacity and export rate.

For example if the average export rate was 60%, then for an installed capacity of 2 GW, a net tariff of 35 cents would not impose any additional cost or burden on the electricity consumer base, assuming grid augmentations and associated costs are not required. A tariff less than 35 cents would deliver a net saving to the wider consumer base (providing sufficient PV was actually installed). Moreover, if the merit order effect delivered a saving greater than the cost of the scheme, a tariff below the breakeven value, could be considered a progressive measure, with those that install capacity creating a benefit for those that cannot (i.e. a wealth transfer from generators to consumers, as opposed to from consumers to PV system owners).

It is also of interest to note that the tariff required for the breakeven point in Fig. 13 decreases as the installed capacity increases. This is commensurate with the decrease in marginal merit order value shown in Fig. 12 as additional PV capacity is added to the grid. Similar 'breakeven' analysis could be undertaken for different mechanisms. For example, a level of upfront support from the SRES (which is passed through to consumers in electricity bills) that 'breaks even' when included merit order effects could also be determined.

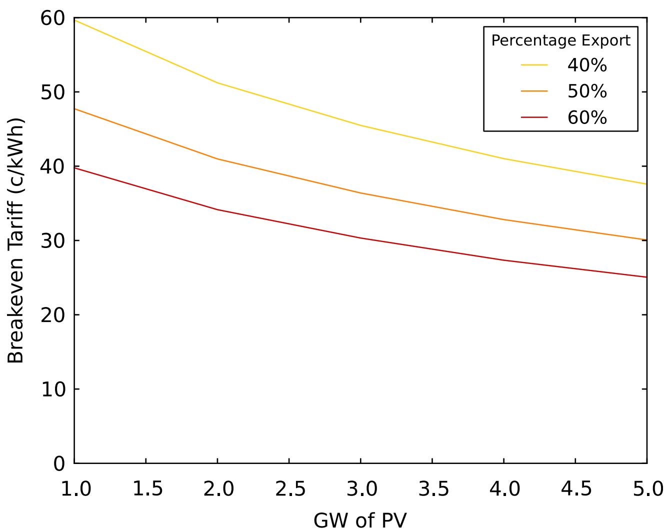

Fig. 13. Breakeven tariff as function of installed capacity and percentage exports.

7. Discussion and avenues for future work

At the market level our price demand model is limited by ignoring several key constraints within the system. In particular, not including the constraints placed on the inter-regional interconnectors means our model misses several of the key high price events that impact significantly on annual spot market revenue, resulting in the value of the merit order effect being underestimated. Including these constraints would allow regional analysis to be conducted and allow the analysis to capture more of the high price events (some of which occur because of interregional connector constraints), and determine if PV has the potential to relax or alleviate these constraints. Further work would be needed to incorporate the marginal loss factors and capacity constraints and provisions for the generation constraints.

To further improve the analysis the impact of PV installations on the grid investment needs could be quantified. As mentioned, network costs may be deferred due to PV helping mitigate peak loads. A highly distributed generation system may also reduce loss factors throughout the network. Alternatively, network costs may be increased due to the need for improved transmission and distribution infrastructure, to accommodate stability issues. There may be a need to curtail PV generation to ensure a stable grid, or a requirement for more ancillary services.

It is recognized that in reality not all rooftop panels installed would be at a 30° angle. Remodeling and analysis could be performed to find the most appropriate average angle. This could also involve changing orientations, for example to north-west or directly west to generate more power during afternoon electricity peaks. More geographically diverse PV installations could also be considered and would likely reduce the variation in the solar output model. Variations in the distribution of PV throughout the NEM (based on population and solar resource) should also be investigated. Higher PV penetrations could also be considered, especially taking into account the likelihood of solar PV reaching retail grid parity. Germany's 2030 target of 66 GW would be equivalent to over 17 GW in Australia on a per capita basis, if emulated here.

The manner in which the merit order effect would impact the long term functioning of the National Electricity Market could also be investigated. The long term effects on the system will have implications for the operation and development of the grid, generation mix and overall system reliability. For the market to create the right signals to encourage construction of new capacity and deliver new investment in large scale energy projects, market dynamics may have to adapt to the impact of the a large penetration of renewable generation and the merit order effect. Consideration of the likely change in bidding behavior could also be investigated.

8. Conclusion

As demonstrated in our analysis and other studies, significant photovoltaic energy generation has real and substantial economic value, as demonstrated by the reduction of wholesale electricity prices through the merit order effect. Our modeling shows that in 2010 the value of a 5 GW installation due to the merit order effect could have been $628 million, or 8.6% of the total value traded through the electricity pool in 2010. In 2009 the value of 5 GW due to the merit order effect could have been $1.2 billion, representing over 12% of the total value traded in that year. The smaller saving in 2010 is due to less volatile prices in that year.

These results indicate that policy incentives such as feed-in tariffs actually produce an economic benefit—savings in wholesale electricity prices via the merit order effect. The cost of such policy schemes should not be considered in isolation from their benefits. Incentives can be set slightly below the breakeven point, such that a net transfer of wealth to consumers occurs.

As the overall reported cost of the scheme does not reflect the merit order value it remains an externalized benefit of PV generation; a benefit not recognized by the wider public.

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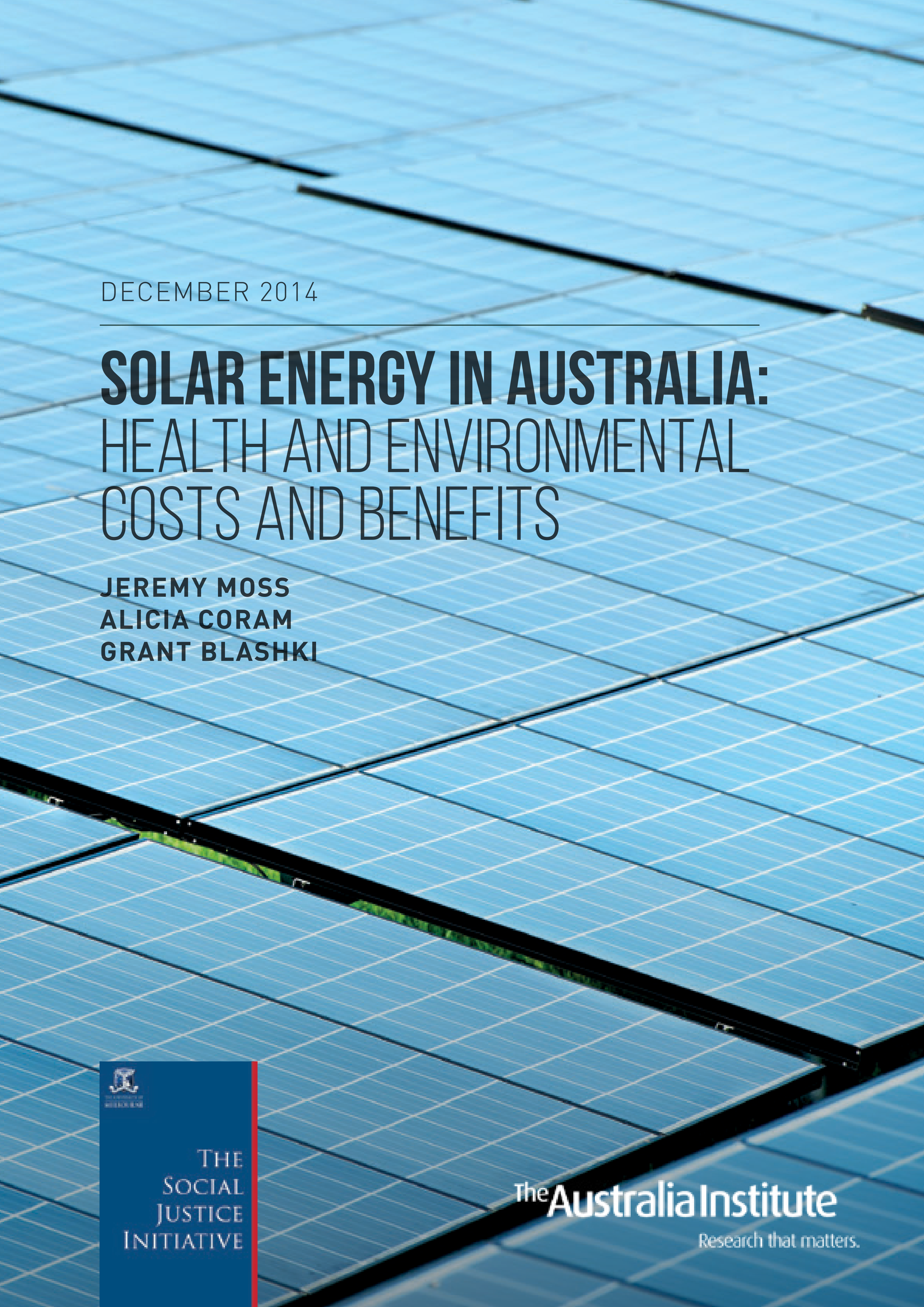
Attachment 5



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SOLAR ENERGY IN AUSTRALIA: HEALTH AND ENVIRONMENTAL COSTS AND BENEFITS

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The Social Justice Initiative

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Research that matters.

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Solar energy in Australia:

Health and environmental costs and benefits

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TAI

Technical Brief

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Summary

Australia has some of the best conditions in the world for producing solar energy, and new research suggests it is also the nation's preferred future energy option.

This paper considers various advantages and disadvantages of harnessing energy from the sun. It finds the health and environmental impacts of solar to be minimal in comparison to fossil fuels, and argues that, as the cost of gas begins to rise, solar will become an increasingly competitive and valuable energy source.

It is estimated that solar thermal energy could produce up to 60 per cent of Australia's on-grid electricity, which would dramatically reduce our greenhouse gas emissions and reliance on fossil fuels.

Public polling by The Australia Institute[1] shows solar is the most popular energy choice of the future, with 63 per cent of people ranking it as their number one preferred energy choice, and 90 per cent of people ranking it within their top three preferences.

This stands in strong contrast to coal and coal seam gas (CSG), which were listed among the top three energy sources by a mere 35 and 38 per cent of Australians respectively.

Fossil fuel derived energy sources such as coal and CSG have been widely criticised for their environmental and health impacts. Six out of 10 Australians consider coal and CSG to have a detrimental effect on the landscape, while only a fraction of that – 13 per cent – share the same concern in relation to solar energy.

Despite the favourable conditions and strong public support, solar's share of electricity output in Australia is half the OECD average. With the high potential for solar expansion in Australia, it is important to determine the costs and benefits of this energy source.

Overall, the health risks for workers in the solar sector are considerably less than for those in the fossil fuel industries. While the paper discusses some health risks associated with the manufacturing of solar photovoltaic material, these are likely to lessen over time as further improvements are made in the technology used.

There are only minimal environmental impacts in harnessing solar energy. Despite the need for large land surface areas, there is little evidence that solar resources conflict with other land uses such as farming. Additionally, community benefits can accrue from both large and small scale solar projects, such as jobs in remote areas.

Overall, solar energy is found to have minimal health and environmental impacts, particularly when compared with fossil fuels. The public desire for harnessing Australia's solar resources is strong, with 90 per cent of people wanting more solar energy, and it is predicted to become an increasingly cost-effective energy source as the technology improves.

[1] Results are drawn from an online poll taken by the Australia Institute in August 2014 (n=1410).

Contents

Executive summary

High levels of solar radiation and suitable land make Australia one of the best countries in the world for solar energy. However, solar's share of electricity output in Australia is half the OECD average.[11]

Apart from issues of cost and infrastructure, there are health and environmental considerations that need to be taken into account. The impact profile of solar depends on the kind of system—photovoltaic (PV) or concentrated solar thermal (CST); large or small scale—along with factors affecting the production of materials. The most serious health implications are borne by countries that produce materials for PV systems that use toxic materials, which are similar to those in the microelectronic industry more generally.[2,3] As an importer of these materials, Australia has a greater moral responsibility for the mitigation of such risks than is currently acknowledged.

The environmental impact of solar is minimal in many ways, but there are some concerns about the long-term impact of disposal in the case of PVs and of water-use in CST systems.[4] In general, the overall GHG intensity of solar is higher than other forms of renewable energy, but significantly less than fossil fuels.[5] Solar generally enjoys high levels of community support and there are employment opportunities with the expansion of the sector.[6] In particular, small-scale, community based systems—such as the 'Bushlight' initiative in remote Indigenous communities—can provide a range of benefits for local communities.[7]

Although there are some serious health risks associated with the manufacture of PV materials, these risks are considerably lower with CST techologies, and the overall risk profile of all types of solar energy is far lower than that of fossil fuels.[8,9] Other impacts of concern include the relatively high cost of solar compared to other energy sources and water-use in large-scale CST systems. However the steady improvement in solar technologies will likely reduce these impacts considerably, and the rising costs of gas that will attend Australia's expanding export industry will likely mean that solar becomes relatively competitive.[10]

Key findings

- The health and environmental profile of solar energy depends heavily on the type of system used.
- The manufacturing of solar photovoltaic materials (PVs) has the greatest associated health risks, similar to those found in the microelectronic industry. These risks mostly affect workers that manufacture PVs, however long-term environmental pollution from PV disposal is also of concern.
- As Australia imports all of its raw silicon wafer/cell material, the majority of these health risks are outsourced to countries such as China, Japan and the USA.
- Concentrated solar thermal (CST) systems have a lower health risk profile and are also more efficient, however many CST technologies use considerable quantities of water.
- Although requiring large quantities of land, there is little evidence of resource conflict from large-scale solar projects in Australia and there are benefits that can accrue to communities from both large and small scale solar including jobs in remote areas.
- GHG emissions from solar are higher than other renewables but substantially less than fossil fuels, and becoming lower with new technologies.
- Overall, solar represents a low-impact option, especially compared to fossil fuels, and advances in technology are likely to reduce these impacts further. While the health impacts of PVs and environmental impacts of some CST systems are non-negligible, improvements in technology and correct decommissioning and recycling of materials can substantially reduce these impacts.

1. Introduction

Australia's solar energy resources are among the best in the world, with high levels of solar radiation and considerable land-mass suitable for large-scale solar developments. Despite this comparative advantage, solar's share of electricity output in Australia is half the OECD average.[11] The cost of materials and installation, the difficulties in storing solar energy, and the need for substantial additional infrastructure are impediments to the expansion of the industry, however advances in solar technology and reductions in cost are likely to see the percentage of solar energy increase over coming decades.[1]

Although the health and environmental profile of solar is much less damaging than fossil fuels, it currently has greater impacts than many other renewables. Given the nature of the health risks and the fact that Australia currently imports materials for PV module assembly, the health impacts are most likely to be experienced by workers in the countries responsible for the production of photovoltaic (PV) cells, which involves many toxic materials that are also used in the microelectronic industry more generally.[3] The exposure pathways are mostly limited to workers inhaling fumes or coming into direct contact with materials such as silicon tetrachloride, lead and cadmium, however there are several reports of toxic material being released into the wider community.[12,13] The actual health impacts that result from these processes is then dictated by the extent to which industry bodies adhere to health and safety protocols, and the improvement of materials and production techniques.

Solar energy is not responsible for any direct GHG emissions from energy generation, however the production of materials—especially for solar PVs—is currently quite energy intensive, making its GHG emissions profile high compared to other renewable energy. However, this is still substantially less than the GHG intensity of fossil fuels and much lower for technologies such as large-scale CST systems.[5]

The running of solar facilities has very low impact on human an environmental health. Despite large-scale solar developments requiring considerable areas of land, there appears to be little land-conflict in Australia. However, some forms of large-scale solar use considerable amounts of water—more than coal and gas in some instances—which is of particular concern in Australia.[4]

While current solar technologies have greater health and environmental costs than other sources of renewable energy, it is still a relatively young technology with advances in the field seeing these costs rapidly decline. Even using current technologies, its impacts are still substantially less than fossil fuels. However, careful attention needs to be paid to the distribution of benefits and burdens that attends different solar technologies and scales of implementation. The current risk associated with the production of PV materials for workers in other countries in particular, suggests that Australia needs to accept moral responsibility for this aspect of the industry.

2. Overview

2.1 Solar energy

The amount of solar energy which strikes the Earth is far greater than the world's energy demand.[11] However, only a small amount of the world's solar energy is converted to electricity due to the established energy infrastructure, as well as technical obstacles concerning variability, storage and transport that mean that solar energy is currently a more expensive energy option than fossil fuels.[1] However, technical advances and other drivers are likely to see overall use of solar energy increase, and it has been estimated that it would be possible (given certain policy and technological changes) for solar to provide up to a third of the world's energy by 2060.[14]

There are two main types of solar energy—photovoltaic (PV), which converts photons directly into electricity, and solar thermal (ST), which converts solar radiation into thermal energy. There are several different systems that capture solar energy, all of which have different health and environmental profiles.

2.1.1 PV systems

Rooftop PV –comprise of panels of PV cells mounted to rooftops (see Figure 1).

Large-scale PV –PV systems can be scaled up, however currently the cost of transport and the fact that energy from PVs cannot be stored long does not make these the most cost-effective system.

Concentrating Photovoltaic Solar (CPV) – uses concentrating mirrors or lenses to create large-scale centralized power using PV cells (see Figure 2). While more efficient than other large-scale PV, these are not as flexible as concentrating solar thermal[1] (CST—also known as concentrating solar power or CSP – see below).

Figure 1: Photovoltaic roof panels

Figure 2: Concentrating Photovoltaic Solar Field

PVs require substantial resources in their creation. Materials must be mined, processed and purified. This process is responsible for some GHG emissions (considered in section 4) and also other health risks associated with their manufacture (see section 3).

2.1.2 Solar thermal systems

Small-scale temperature converters – at present, the majority of Australia's solar energy comes in the form of solar hot water heaters that use plates to heat water directly using the sun's energy.[11]

Concentrating Solar Thermal/Power systems (CSP or CST) - concentrate energy from sunlight to a focal point, which is used to create steam to drive a turbine or power chemical processes. Heat that is excess to requirement is stored in a material (‘working fluid’) such as salt, water or oil, which is then used to generate more steam. The ability to store and release energy makes them more flexible and potentially more efficient than CPV systems.[1]

There are four major designs of CST: heliostat fields with central receivers (see Figure 3), paraboloidal dish systems (see Figure 4), parabolic troughs (see Figure 5) and linear Fresnel reflectors (see Figure 6). Parabolic troughs and linear Fresnel reflectors only track the sun east-west, while the others also track its elevation. A recent report from Beyond Zero Emissions (BZE) recommended a CST system using molten salt storage to meet most of Australia’s solar energy needs for its “low losses, low cost, material stability, raw material availability and material safety”.[1]

Figure 3: Gemasolar Heliostat Field (Fuentes de Andalucia, Spain)

Figure 4: Parabolic Trough

Figure 5: Fresnel reflectors

Figure 6: Paraboloidal dishes, Spain

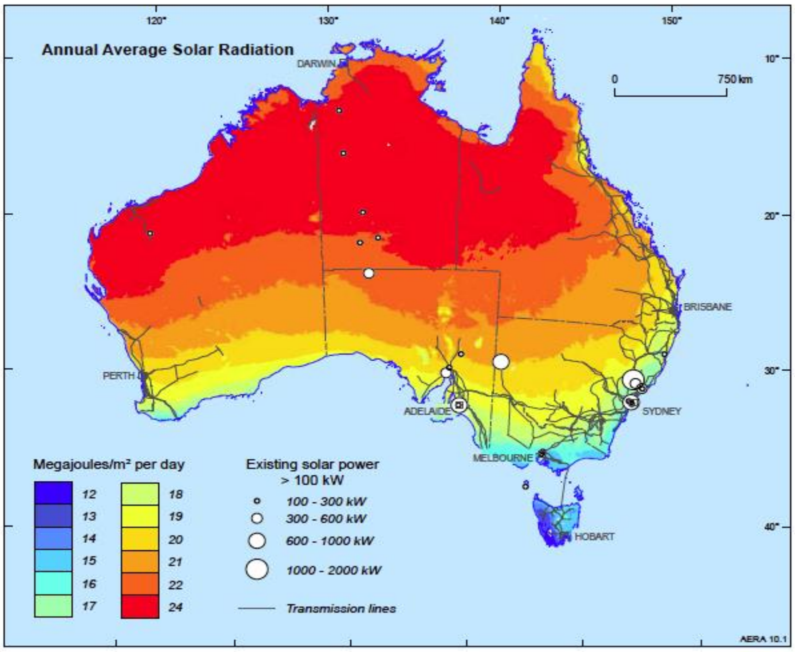
2.2 Solar in Australia

Australia has excellent solar resources in terms of both land mass and solar exposure, with the highest solar radiation per square meter of any continent (see Figure 7).[11] However, solar energy currently accounts for only about 0.2 per cent of current primary energy consumption.[55]

Solar energy use was previously projected to increase from 7 PJ (in 2008) to 24 PJ by 2030.[11] However, incentives for solar have been cast in doubt by the current government’s stance on climate change mitigation, reduction of funding to renewable energy schemes such as the Australian Renewable Energy Agency (ARENA), and lack of support for renewable policies such as the Renewable Energy Target (RET).[15]

The current commercial-scale solar projects have a small capacity, with four out of five commissioned projects less than or equal to 1 MW (apart from one NSW project with a capacity of 2MW). However there are plans to construct much larger scale projects of up to 1000MW.[11]

Figure 7: Average solar radiation and currently installed solar power stations with a capacity of more than 10 kW. Source: Bureau of Meterology 2009; Geoscience Australia



It has been estimated that the majority of Australia's energy needs (up to 60 per cent of projected future energy requirements) could be met be CST with molten salt storage.[1] Cost and the fact that solar energy cannot be stored for long periods of time or traded are the main obstacles to its further development in Australia. At present, solar energy relies on subsidies to be economically viable, although it is predicted that the cost of solar energy will drop considerably with technological improvements.

2.3 Impacts of solar energy

As with any energy source, the generation of energy using solar PVs or CST systems has some consequences for human and environmental health. Below, these are considered in relation to the direct and indirect consequences for human health, impacts on the environment through land use and the potential bioaccumulation of hazardous materials, and impacts on GHG emissions.

2.3.1 Health

The health concerns accompanying solar systems arise from their manufacture, and in particular the manufacture of solar PV. Potential health impacts are most likely to affect workers who are exposed to toxic materials and gases during production, with some risk that such exposures might also affect the wider population.[2,3] These can be mitigated by adherence to health and safety protocols, however as production of materials for PV cells takes place off-shore, this is not under the control of the Australian government. The increasing interest in new nanotechnologies potentially introduces further hazards, although the nature of these is at present uncertain.[16]

Although beyond the scope of this report to give full consideration, there are also some concerns raised over the potential cost of solar energy and its effect on vulnerable groups.

2.3.2 Environment

Australia has a large amount of space suitable for the installation of large-scale solar systems that would not directly compete with other interests, however when the establishment of infrastructure and the environmental consequences of manufacturing, disposal and decommission—especially of PVs—is also taken into consideration the environmental impact becomes more substantial. Some varieties of CST technology also require considerable water use, with some systems estimated to use more than fossil fuels.[4]

2.3.3 Greenhouse Gas Emissions

Energy produced from solar power is not directly responsible for any GHG emissions, however the construction of solar systems can be energy intensive, depending on the nature of the system. The level of emissions differs considerably depending on the technology used, and comes from the energy sources (such as coal, oil and nuclear) that are used in the production and transport of material. These emissions remain significantly less than fossil fuels, which means that switching to solar from coal or gas would see a sizeable overall decrease in greenhouse gases.[5]

2.3.4 Benefits

Increasing the amount of solar energy used in Australia would confer substantial benefits, especially concerning the reduction of GHG emissions. There are other benefits that accompany particular types of solar systems—for example, distributed systems, where solar energy is created by households or communities and used on site would see a reduction in power being transported, and hence reduced electromagnetic radiation.[17] PV panels integrated onto building surfaces would see a reduction of land use[17], and the establishment of community-based solar systems can also have social benefits, especially in remote communities.[7]

However there are some health impacts that need to be taken into account, particularly concerning the manufacture of PV components that takes place off-shore. This provides some reason for favouring large-scale CST systems, and also suggests that there is a moral responsibility for Australia to help mitigate these risks.

Even taking into consideration these impacts, the benefits from replacing currently employed coal and gas technologies with large scale solar would be substantial, as discussed in Section 5.

3. Health

Most of the health concerns with solar energy relate to the production of the semiconductors used in PVs, which involves several potentially hazardous materials. Nearly all of these health risks affect overseas workers rather than the general population, except in cases where materials are incorrectly disposed of.

The materials used and the hazards faced are often the same as those found in the microelectronics industry more generally. This means that there is considerable information regarding the health implications of PV manufacture. However, the interest in new materials and processes—particularly nanoparticles and technologies—has introduced some uncertainties.[16]

Despite remaining concerns, technological advances have been steadily improving the health impacts of solar. This is demonstrated in the difference between an earlier study estimating that producing solar power had "30 per cent higher health impacts than natural gas", while follow-on studies showed health impacts reduced to "about 0.1-0.2 cents per kWh [$1 - $2 per MWh], primarily caused by GHG, lead, and particulate matter emissions".[18] Solar in Australia has elsewhere been estimated to have health impacts of approximately $5 per MWh, compared to gas at $19 per MWh.[19]

3.1 Photovoltaics

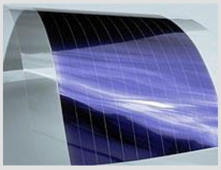
There are several different materials used to create PV systems, and the technology in this area is constantly evolving. The first major category is *thin PV film,* which is made from thin layers of semiconductor materials—in particular, amorphous silicon (a-Si), cadmium telluride (CdTe), copper indium selenise (CIS) and copper indium gallium selenide (CIGS)—that can then be applied to cheap materials such as glass or metal. Cadmium telluride is currently more commonly used for PV film as it is cheap and efficient, but it is a rare material and so not a long-term prospect.

The second major type of PV is *silicon wafers* that are used in rigid panels. These are made from materials such as mono-crystalline silicon, multi-crystalline silicon, or ribbon-silicon, all of which have an unstable intermediate form of silicon tetrachloride (SiCl4). These are still the most common form of PVs, although the incorporation of new nanotechnologies may see thin-film PVs become more popular.[3]

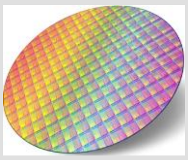
While the risks differ depending on the materials, all PVs carry potential risks for workers in their production, and there are some risks in their installation and disposal that can affect the wider community. Currently, there are no manufacturers of PV wafers or thin-films in Australia, and no data readily available that breaks down Australia's imports of these materials on a country-by-country basis.[20] However, this breakdown can be assumed to mirror general levels of production: the largest producers of polysilicon are China (40 per cent), USA (24 per cent) and Germany (15 per cent); and of solar wafers China (76 per cent), Japan (7 per cent), the USA and Germany (3 per cent each).[21]

BOX 1:
Types of PV

Thin film PV including amorphous silicon, cadmium telluride, copper indium selenise and copper indium gallium selenide (a-Si, CdTe, CIS, CIGS)



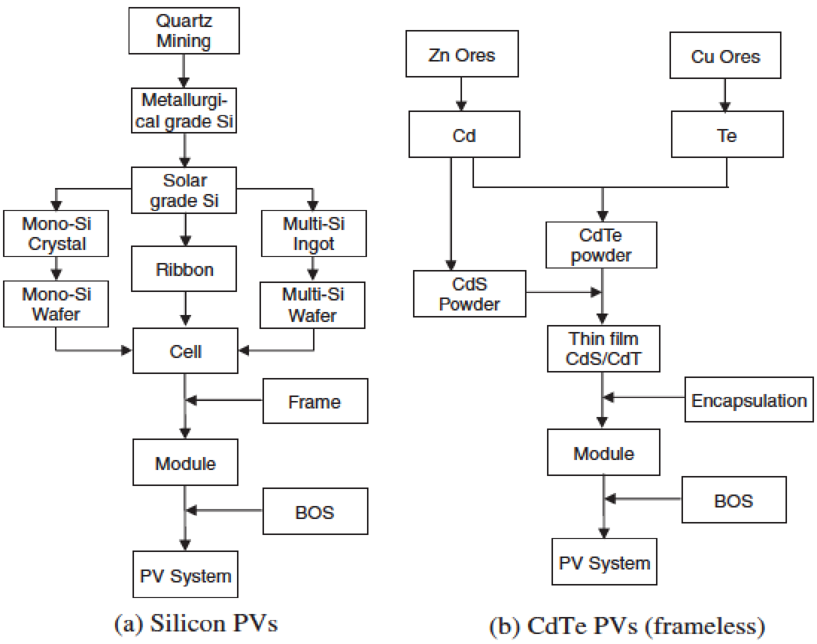
Silicon wafers including mono-crystalline silica, multi-crystalline silicon and ribbon-silicon.



The production of PV cells can be broken down into the stages of 1) mining raw materials, 2) processing and purifying them into electronic-grade materials, 3) manufacturing solar modules and solar systems, and 4) decommission and disposal.[22]

Figure 8 below gives an indication of the stages associated with silicon and cadmium telluride PV cells.

Figure 8: Flow diagram of the raw material acquisition to manufacturing stage of PVs. Source: Fthenakis et al, 2008



The biggest potential risks with current manufacturing are found at the stages of processing and purifying raw materials, because of the presence of toxic and flammable materials.[22]

3.1.1 Mining

Silicon PVs require the mining of crystalline silica from sand or quartz. The mining process produces silica dust, which can cause silicosis.[3]

The risks associated with silica dust exposure are well-known, and it is subject to many regulations which should mitigate the risk of silicosis. However, as with many of the risks associated with PVs, the greatest concern is manufacturers in large silicon producing countries who may not comply with such regulations to protect their workers.

3.1.2 Processing and purification

It is the processing and purification stage, together with manufacturing the solar cells from this material, that carries some of the greatest health risks overall.

Once extracted, the silica needs to be processed and purified for use in silicon wafers. This involves combining the silica with carbon (such as charcoal or coal), and then further refining the resultant silicon. The 'Siemen's process' is commonly employed, using silane (SiH4) or trichlorosilane (HSiCL3) gas to produce silicon for use in the production of silicon wafers. These and other chemicals that can be used to produce different types of silicon, along with their potential health effects, are listed in Table 1 below.

The production of SiH4 and HSiCL3 results in waste silicon tetrachloride (SiCL4). This is highly toxic, producing hydrochloric acid in contact with the air, and can cause skin burns, irritate eyes, skin and the respiratory system.[3,12] In addition, sulfur hexafluoride (SF6)—which has a GWP 25,000 greater than CO_2—is used in the process.

The dangers inherent in processing and purification and the need for enforcing proper regulation were highlighted in a 2008 incident in China. Waste SiCl4 was dumped into fields near the production facility, resulting in nearby villagers experiencing eye and nose irritations, and crops wilting.[13] Such incidents raise concerns where the manufacture of PV materials is largely outsourced to countries that may not enforce strict environmental, health and safety regulations.

However, although there are distinct risks if proper health and environmental measures are not taken, other production facilities use a 'closed loop' process, capturing byproducts for reuse, and waste gases that are not recycled are treated before release. In these facilities, environmental releases of damaging materials are very low.[12]

The creation of *thin-film a-Si* PVs involves the steps noted above up until the use of the Siemen's process. Overall, thin-film PV manufacture has lower energy requirements than silicon wafers, requiring less silicon and producing lower emissions overall. However, the gases used are considered extremely hazardous, highly toxic, or pyrophoric (ignite spontaneously in air), posing occupational dangers.[23] Potentially hazardous chemicals used in the production of a-Si are summarized in Table 1.

Cadmium telluride (CdTe) cells use different processes. Cadmium—a by-product of zinc mining—is a known carcinogen, with the "potential to cause kidney, liver, bone, and blood damage from ingestion and lung cancer from inhalation", and workers are potentially exposed to cadmium compounds.[12] Because of health concerns, most products containing cadmium have been banned from sale by the European Economic Community (EEC), although CdTe is of lower toxicity than pure cadmium.[24] The creation of CdTe cells can also use potentially harmful materials such as molybdenum, nickel, sulfur, tellurium, and tin.[12]

Other PV technologies are being developed. While there is currently not much information about the health hazards associated with these alternatives, they involve toxic materials such as hydrogen selenide, which is dangerous at very low concentrations, and sometimes cadmium sulfide (CdS). However, the rest of the materials are generally non-toxic or only mildly toxic.[12]

There is increased interest in the use of nanoparticles to create 'quantum dots' to increase the efficiency of PVs. Such materials are likely to have greater health hazards because their scale may increase toxicity, mobility and bioaccumulation.[12,16] Though there were no studies identified looking specifically at the risks from nanoparticles in PVs, there is some evidence that nanoparticles can enter the body through lungs and ingestion, with the possibility they may penetrate through the skin.[25]

The health risks accompanying the use of these materials are for the most part borne by workers, with potential hazard pathways including the inhalation of materials in the form of dust and fumes, and contact after spills. Some of the risk pathways associated with the materials that have been considered here are also a risk for surrounding communities, who may be exposed to hazardous gases. There are a number of occupational and environmental regulations as well as best practice that is adhered to by many facilities, with "no known catastrophic releases of toxic gases from photovoltaic manufacturing facilities in the United States"[3], however this is not necessarily the case for other countries that Australia imports material from.

3.1.3 Manufacture of silicon wafers

Silicon wafers are produced by sawing ingots of monocrystalline or multicrystalline silicon into thin wafers. This process produces silicon dust known as 'kerf dust' and can generate silicon particulate matter (PM). An anti-reflexive coating is applied, and electrical conductors are printed onto them.[3]

This manufacturing process involves several potentially hazardous chemicals. Aside from exposure to kerf dust, workers can also be exposed to solvents such as nitric acid, sodium hydroxide and hydrofluoric acid through inhalation or through accidental spills, with many of these solvents posing a risk of chemical burns.[3] The silane gas used in depositing the coating to the wafers is extremely flammable, with the "semiconductor industry report[ing] several silane incidents every year".[12]

The next stage in the assembly of a silicon wafer PV system is joining together individual cells to form a module. Some module production takes place in Australia, although many modules are imported already assembled. These are usually wired together (usually without toxic materials, although some manufacturers have been known to use solders containing lead or other hazardous materials) and enclosed in a protective material before being mounted, covered and put in a frame.[3] Module assembly is not considered to be a particularly risky pathway for human exposure as much of the assembly is automated.

Table 1: Health impacts from materials used in production of solar PVs. Source: Mulvaney 2009 and Oregon Govt. 2013

Material	Use	Health hazards
Acetone	Released in fugitive air emissions; manufacturing a-Si	
Ammonia (NH3)	Released in fugitive air emissions	Skin, eye, throat, and lung irritant; lung damage, blindness and death can result from exposure to very high concentrations.
Argon (Ar)		Non-toxic; asphyxiant in confined spaces.
Arsenic (As)		Poison; can affect throat, lungs, blood cells, heart and blood vessels; high levels increase cancer risk; skin problems.
Arsine (AsH3)	Doping semiconductor materials	Highly toxic gas; damages red blood cells, and can affect kidneys; carcinogenic.
Boron trifluoride (BF3)	Doping silicon semiconductors	Exposure to large amounts over short periods can affect the stomach, intestines, liver, kidney and brain and eventually lead to death
Brominated Flame Retardants (BFRs)		
Cadmium (Cd) (also (CdCl2); (CdSO4); (CdS))	Manufacturing CdTe cells	Carcinogenic; potential to cause kidney, liver, bone and blood damage from ingestion; lung cancer from inhalation.
Cadmium telluride (CdTe)	Manufacturing CdTe cells	Less toxic than other cadmium compounds. CdTe quantum dots could trigger cell damage.
Carbon nanotubes (CNTs)		Inhalation hazards similar to asbestos.

Carbon tetrachloride (CCl4)	Manufacturing c-Si cells	Exposure to very high amounts can damage the liver, kidneys, and nervous system; potential carcinogen.
Copper (Cu)		Can be poisonous or fatal at high exposures, damaging liver and kidneys. Inhalation can cause nasal and throat irritation. Ingestion of high levels can cause nausea, vomiting, and diarrhea.
Diborane (B2H6)	Manufacturing a-Si cells	Highly flammable; skin irritant
Ethyl vinyl acetate (EVA)	Encapsulating PV cells.	May release volatile organic compounds
Gallium (Ga)	Soft metal used in GaAs PV	Not considered toxic, but may cause skin irritation.
Germane (GeHH4)	Manufacturing a-Si cells	Extremely toxic; can kill red blood cells; cause anemia and kidney failure.
Helium (He)	Manufacturing thin film PVs	Inhalation causes dizziness, dullness, headache, and possible suffocation. Contact with liquid He can burn skin.
Hexafluoroethane (C2F6)	Etching semiconductors	Asphyxiant; in high concentrations may cause dizziness, nausea, vomiting, disorientation, confusion, loss of coordination, and narcosis. Can cause skin burns. Potent GHG.
Hydrochloric acid (HCl)	Remove impurities from semiconductor materials; etch wafers	Corrosive; inhalation can lead to pulmonary edema; ingestion can cause severe injury to the mouth, throat, esophagus, and stomach.
Hydrofluoric acid (HF)	Remove impurities from semiconductor materials; etch wafers	Corrosive; low levels can irritate the eyes, nose, and respiratory tract; high level exposure can cause death; ingestion of Seven a small amount affects internal organs and may be fatal.
Hydrogen (H2)	Manufacturing a-Si cells	Highly flammable
Hydrogen sulfide (H2S)	Manufacturing a-Si cells	Irritant; highly flammable
Indium (In)	Used as the semiconductor for CIS/CIGS, indium gallium phosphide, or indium gallium nitride solar PV and lead-free solders.	Made from highly reactive trimethylindium, which can spontaneously combust.
Indium gallium nitride (InGaN)	PV semiconductor	Toxicology unknown; irritant
Indium phosphide (InP)	Cleaning c-Si wafers; multijunction solar PV	Carcinogen
Lead (Pb)	Wiring, solder coating	Toxic to the nervous system; can cause anemia; high exposure levels severely damage the brain and kidneys and may ultimately cause death.

		Probable carcinogen.
Molybdenum Hexaflouride		Toxic and corrosive gas
Nitric acid (HNO_3)	Cleaning wafers, removing dopants, and cleaning reactors	Occupational chemical burn hazard.
Nitrogen (N_2)	Used to manufacture c-Si cells; used to dope semiconductors	Workplace asphyxiation hazard
Nitrogen trifluoride (NF_3)	Cleaning reactors and etching polysilicon semiconductors	Can cause asphyxiation. Potent GHG.
Phosphine (PH_3)	Doping semiconductor materials; manufacturing a-Si cells	Highly toxic; explosive risk
Polybrominated diphenyl ethers (PBDEs)	Added to plastics and foam products	Little known about human health effects. Toxicity to the liver, thyroid, and neurodevelopment reported in animals.
Selenium (Se)	found in CIS/CIGS	Poison; respiratory tract irritation, bronchitis, difficulty breathing, and stomach pains; short-term exposure to high concentrations may cause nausea, vomiting, and diarrhea. Chronic exposure can cause selenosis (including hair loss and neurological abnormalities)
Selenium dioxide (SeO_2); Selenium hydride (H_2Se)	CIS/CIGS manufacturing	Highly toxic when inhaled; may cause skin burns and eye irritation. Chronic exposure may cause selenium-related diseases. H_2Se is extremely flammable.
Silane (SiH_4)	Applying silicon thin films and make silicon crystal semiconductors	Explosive risk; respiratory tract, skin, and eye irritation. Silane gas is extremely explosive. At room temperature, is pyrophoric (spontaneously combusts in air without external ignition).
Silicon (Si)	The most widely used solar PV semiconductor	Crystalline silica (silicon dioxide, SiO_2) is a potent respiratory hazard. Lung cancer is associated with occupational exposures to crystalline silica
Silicon tetrachloride ($SiCl_4$)	Waste from production of silane and trichlorosilane; by-product and intermediary in silicon-based PV cell production	Extremely toxic; reacts with water; causes skin burns; respiratory, eye and skin irritant
Silicon tetraflouride	Manufacturing a-Si cells	Can emit toxic fumes
Silver (Ag)	Making electrical contacts	Exposure to high levels over long time periods may cause discoloration of the skin and other body tissues. Exposure to high levels can result in breathing problems, lung and throat irritation, and stomach pains.
Sodium hydroxide (NaOH)	Cleaning and etching semiconductors	Harmful to eyes, lungs and skin at even low levels. High-level exposure can cause severe burns to the eyes, skin, and gastrointestinal

		tract, which may cause death.
Sulfur hexafluoride (SF6)	Cleaning reactors used in silicon production	Asphyxiant; the most potent GHG
Tetrobromo bisphenol A (TBBPA)	Used in printed wiring boards and inverters	Endocrine disruptor.
Thiourea (CH4N2S)	Manufacturing CdTe and CdS PV semiconductors	Blood toxin; carcinogen
Trichlorosilane (HSiCl3)	main source of electrical grade silicon	Flammable; inhalation causes burns, difficulty breathing, headache, dizziness, bluish skin color, and lung congestion. Blurred vision results from eye contact, and ingestion can cause burns, vomiting, and diarrhea.

A full appraisal of the health implications of PV solar energy then needs to consider the kind of PV manufacturing processes that are used and where this takes place.

3.1.4 Balance of system components

Apart from the solar panels themselves, PV systems also need balance of system (BOS) components to convert the electricity generated from direct current (DC) to alternative current (AC), and to otherwise support the supply of useable electricity and enable rooftop or ground mounting. These components can include aluminium framing, inverters, mounting structures, grid connecters, concrete and office facilities.[22] The manufacture of BOS components introduces further health and environmental impact pathways, however there are few studies that take these into consideration, and none found that were directly relevant to Australia.

3.1.5 Installation

The installation phase is generally a very low risk in PV systems, although there is a small risk of PV materials becoming dangerous in the case of a fire.[3] This is of particular concern in the case of cadmium, although even this a low risk.[12] The risk that toxins would be emitted may be slightly higher in larger scale facilities (such as commercial and industrial buildings) as fires can reach higher temperatures.

Another concern that is sometimes raised in relation to many electricity sources is the health effect of electromagnetic fields (EMF). However, the level of EMF produced by PV systems "do not approach levels considered harmful to human health".[3]

3.1.6 Disposal

PVs are expected to last in the vicinity of 25 years.[12] Disposing of them is accompanied by potential health issues similar to the disposal of electronics components. In particular, there is the potential for hazardous materials to leach when they are deposited in landfills. Thin-film PVs tend to have less of an impact through this pathway than silicon wafers.

Many of these potential problems can be avoided by proper decommission and recycling of material, which also reduces the requirement of new materials in manufacture. The industry as a whole has several take-back and recycling programs to this end, and the EU has restricted sale of products containing some of the materials posing the greatest risk through this pathway.[12] However, while the industry as a whole seems committed to maintaining the environmentally-friendly profile of solar and there are many feasible recycling options that would substantially reduce waste[26], current levels of regulation, especially in non-EU countries, is not enough to mitigate the environmental issues accompanying disposal.

Some studies performed life-cycle analysis of different systems, including one that considered four scenarios for large-scale, ground mounted PV systems. This calculated impacts on human health of between 3.24 – 4.65E-08 disability adjusted life year/kilowatt (DALY/kWh). As noted above, it was manufacturing that generated the biggest health burden.[27] Reports containing direct comparisons with other energy sources reveal the significantly lower externalities compared to fossil fuels.[19] Furthermore, although emissions of heavy metals such as arsenic, cadmium and lead are of concern in PV manufacturing, one study found that such emissions still remain below those emitted in relation to fossil fuels.[26] The comparative impact of solar in relation to coal and gas is considered in further detail in Section 5.

3.2 Solar thermal

There were no identified studies that looked specifically at the health implications of CST, however these are generally predicted to be less than those accompanying PVs as there is less need for intensive manufacturing processes and they do not involve components containing requiring the use of toxic materials. Overall, these considerations suggest that the health impacts of CST will be much less than PV systems. However, some kinds of CST systems have significant water-use impacts, discussed in section 4.

4. Social and environmental impacts

4.1 Social impacts

Unlike many other energy sources, there is little opposition to solar projects in Australia. Social impacts tend to be related to economic benefits from jobs and benefits that may accrue to remote communities, and are mostly positive. While it is beyond the scope of this report to give a detailed analysis of the economic costs and benefits of solar energy, some comparisons that have been made to other energy sources will be considered.

4.1.1 Jobs

There are many jobs related to the production of solar materials, although currently many of these exist in countries that supply the raw materials for Australia's PV industry.

However, there are also jobs in operations and maintenance, with one Californian study finding that each 100MW of capacity from a CST system was responsible for "94 permanent operations and maintenance jobs, compared with 56 for combined cycle gas and 13 for simple cycle gas turbine plants"[29], with a similar figure of 120 jobs per 100MW given by Greenpeace.[30] Another benefit arising from these jobs in Australia is that many would be located in remote communities. This could potentially be a source of employment in remote Aboriginal communities that did not involve leaving the community, with some initiatives such as 'Bushlight' demonstrating this potential.[7]

4.2 Environmental impacts

4.2.1 Land use

The land-use required for small-scale solar systems is negligible, although the potential environmental hazards of PV manufacture need to be taken into account when calculating overall environmental impact.

Land requirements for large-scale PVs and CST systems are far more substantial; however they seldom result in resource conflict in Australia. Land use for large-scale PVs and CST systems varies considerably depending on the layout of the solar array, the types of structures they are mounted on and other variables. While one study estimated that approximately 200km^2—about 0.5 per cent of the area of the continent—would be able to provide all of Australia's 'gross energy use' from solar power 'at the conservative figure of 4.5 W/m^2'[31] , this is much lower than several other estimates that take into account the intermittent nature of solar energy. A report from the Australian Academy of Technological Sciences and Engineering based on a range of estimates estimating that "with current technology a large scale solar thermal farm takes up at least 0.05 km^2 for each MW of generating capacity".[19]

4.2.2 Water use

Depending on the type of system, large-scale solar can use considerable amounts of water. These requirements can be similar or even higher than conventional fossil fuel plants for some CSP systems[32], with some needing to withdraw "as much as 3,500 liters per Megawatt hour (MWh) generated [compared to] 2,000 liters/MWh for new coal-fired power plants and 1,000 liters/MWh for more efficient natural gas combined cycle power plants".[4] However, it has also been suggested that new technologies may cut water use by up to 90 per cent.[4]

No dedicated reports on the impact this would have on water resources in Australia were identified.

4.3 Greenhouse gas emissions

Although energy generated from solar power does not produce GHG emissions, the production of PV cells and solar thermal facilities does produce emissions, mainly from electricity and fuel use. These will vary according to the energy technologies that are used (such as coal, gas, oil or nuclear), and levels will depend on where materials are produced as well as the degree to which they are recycled. However, there are some studies that provide a useful estimation of the total emissions from production.

One comprehensive study calculated figures for different types of rooftop mounted PV cells in the US and Europe (Figure 9). These are likely to decrease with improvements in the recycling of materials, and reduction in material and energy use.

Figure 9: Life-cycle emissions from different types of PV cell

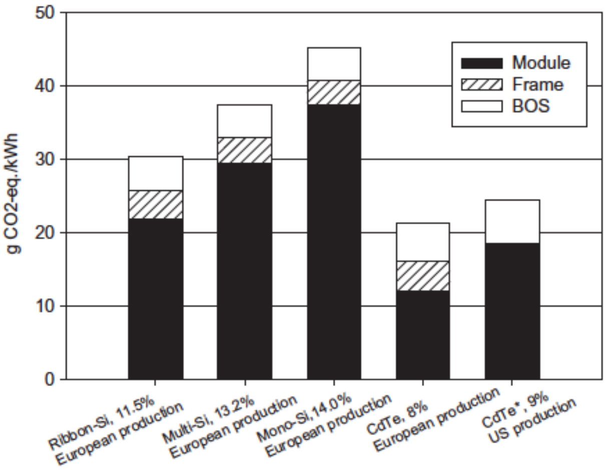


Fig. 3. Life-cycle GHG emissions from silicon and CdTe PV modules, wherein BOS is the balance of system, that is the module's supports, cabling and power conditioning (Alsema et al., 2005; Fthenakis et al., 2004; Wild-Scholten et al., 2005; Fthenakis et al., 2005; Raugei et al., 2007). Unless otherwise noticed, the estimates are based on rooftop-mount installation, Southern European insolation, 1700 kWh/m^2/year, a performance ratio of 0.75, a lifetime of 30 years. *Based on ground-mount installation, average US insolation of 1800 kWh/m^2/year, and a performance ratio of 0.8.

Although these emissions are not negligible, they are minor compared with the emissions generated by other forms of energy that Australia currently relies on (see section 5), and other analyses give even lower figures—a life-cycle analysis of different technologies performed in 2006 estimated GHG impacts of 25–32g/kWh, with a prediction that these would be reduced to approximately 15g/kWh in the future.[28]

No recent studies were identified that considered life-cycle emissions from solar thermal systems, however these would be expected to be significantly lower than solar PV because they do not require the same energy intensive manufacturing for their components. An earlier study estimated GHG emissions from solar thermal to be roughly one-third to one-eighth that of solar PV (see Table 2 below).[33] Although the estimates were based on 1998 data, and so are out of date, the relative emissions of PV and thermal are likely to be roughly correct.

Table 2: Estimated life-cycle emissions from various energy sources. Source: Akella et al 2008

Energy Sources	Green-house gas emission		
	CO_2	SO_2	NO_x
	g/kWh	g/kWh	g/kWh
Coal (best practice)	955	11.8	4.3
Coal (NO_x) and FGD	987	1.5	2.9
Oil (best practice)	818	14.2	4.0
Natural gas (CCGT)	430	–	0.5
Diesel	772	1.6	12.3
Small hydro	9	0.03	0.07
Large hydro	3.6–11.6	0.009–0.024	0.003–0.006
Wind	7–9	0.02–0.09	0.02–0.06
Solar photovoltaic	98–167	0.2–0.34	0.18–0.30
Solar thermal electric	26–38	0.13–0.27	0.06–0.13
Energy crops – current practice	17–27	0.07–0.16	1.1–2.5
(likely to improve to)	(15–18)	(0.06–0.08)	(0.35–0.51)
Geothermal	7–9	0.02	0.28

5. Comparisons with coal and gas

A discussion of the health and environmental impacts of solar and wind technology is only meaningful in a framework that considers the impacts of the energy generation technologies currently employed in Australia. At present, coal provides approximately 35 per cent of Australia's energy needs while gas is responsible for 23 per cent [34], with an expansion in the unconventional gas industry likely to see coal seam and shale gas occupy a greater role in the future. Given the wealth of evidence concerning the damaging impacts of coal, and to a lesser extent gas, it is clear that considerable health benefits will arise from replacing these technologies that need to be factored into the health profile of solar and wind.

This discussion is not intended to be an exhaustive survey of the literature on the impacts of coal and gas. In what follows, their direct and indirect impacts will be briefly considered in order to give a general context in which the health benefits of adopting large scale solar and wind technologies can be understood.

There are no primary studies that have been carried out on the heath impacts of coal in Australia[35], however the international evidence demonstrates the substantial impacts that the mining and burning of coal has on workers and the wider community. Each stage of coal processing produces pollutants, and there are significant occupational hazards attending its production.[36] The high level of GHG emissions from coal fired energy production adds a substantial health burden.

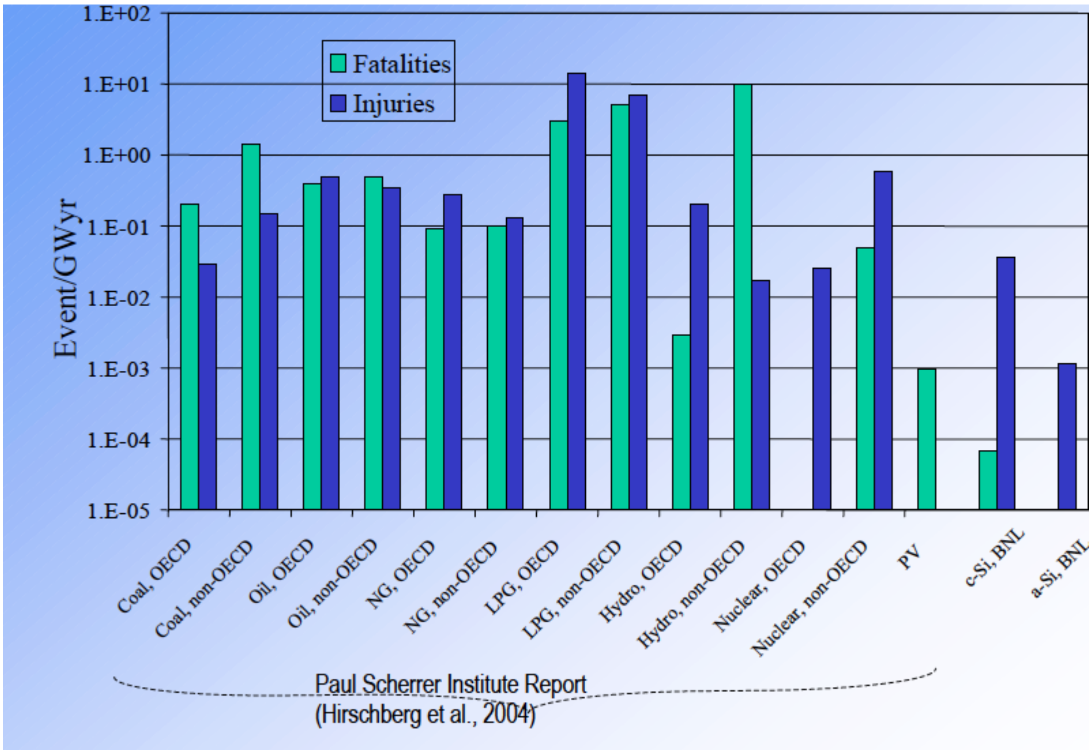
Conventional gas, while less damaging than coal in several respects, has far more direct and indirect health implications than renewable technologies. While there is a high degree of uncertainty regarding the impacts of unconventional gas, the available evidence suggests that there are potentially serious impacts through air, water, land and social pathways.[37]

5.1 Direct health impacts

Coal remains one of the most dangerous forms of energy generation from the perspective of workers[38], with up to 12 per cent of coal miners developing a potentially fatal disease such as pneumoconiosis, progressive massive fibrosis, emphysema, chronic bronchitis, or compromised lung function.[39] Although Australian operations are less dangerous than many, mine collapse, asphyxiation, explosion and diseases from coal dust still represent risks for workers.[36]

While the manufacture of solar systems has risks accompanying both normal operations and potential accidents, there has to date not been any accidents of the severity that have occurred in other forms of energy production, as illustrated in Figure 10 below.[22]

Figure 10: Comparison of risk estimates. Source: Fthenakis et al 2006



For the wider population, air pollution from coal combustion is the most serious threat to health. Coal combustion is responsible for the creation of damaging particulate matter (PM_{10} and $PM_{2.5}$), which is known to be associated with a wide range of negative health effects including respiratory problems (such as aggravation of asthma and decreased lung function), heart arrhythmia, higher rates of mortality from heart and lung disease, and allergic reactions among others.[19,35,40] Sulphur dioxide (SO_2) and nitrous oxide (NOx) emissions are also of concern, mainly for their contribution to the creation of PM.[39] A recent literature review also listed other toxic elements with serious health implications released with coal combustion, including arsenic, mercury, fluorine, cadmium, lead, selenium and zinc. These can accumulate in the environment, with the authors noting in particular that "[o]ver a third of all mercury emissions attributable to human activity come from coal-fired power stations".[36]

Gas produces substantially less PM than coal and Australian operations have relatively low air pollution impacts, however they are still responsible for non-negligible levels of pollutants such as NOx, which contributes to photochemical smog.[41] Information about the impact of unconventional gas operations on air quality in Australia is scarce and they are likely to be lower than their US counterparts, however there are potential impacts from fugitive emissions; emissions from equipment; evaporation from wastewater ponds, spills, well blowouts, venting and flaring.[37] Furthermore, it has been suggested that *any* level of such pollutants can have an impact at the population level.[42]

Wastewater is a potential hazard in both coal and unconventional gas operations. Coal mine discharge has been found to have severely compromised freshwater streams in NSW.[43] Both fracturing chemicals and naturally occurring contaminants represent real risks for water quality in unconventional gas operations[37], as illustrated by the recent contamination of an aquifer by naturally occurring uranium.[44]

The cumulative effect of pollutants from coal fired power generation is notable, with increases in mortality from lung cancer, heart, respiratory and kidney diseases in affected communities. One review of evidence found "[t]he risk of premature death for people living within 30 miles of coal-burning power plants…[has been] quoted to be three to four times that of people living at a distance".[36] In addition, adults living in coal mining communities have been found to be at greater risk of cardiopulmonary disease, chronic obstructive pulmonary disease, hypertension, and lower self-rated health and reduced quality of life generally.[35] There are also higher rates of birth defects and low birth weight in children and infants in coal mining communities.[35] Considering the combined costs to health from pollutants such as PM, SO_2 and NOx, a report on the externalities of energy generation in Australia found the total health damage costs of three of Australia's coal-fired power stations to be "equivalent to an aggregated national health burden of around $A2.6 billion per annum."[19]

The cumulative health effects of unconventional gas extraction are uncertain, however data from several sources demonstrates that such gas developments are responsible for emissions of a complex mixture of pollutants, surpassing those from vehicle traffic in some US regions.[45] One measurement of the health risks directly associated with air pollution due to unconventional gas developments in the US estimated cumulative cancer risks at "6 in a million for residents >1/2 from wells and 10 in a million for residents ≤1/2 mile from wells"[46], while another indicated adverse effects on infant health, identifying several potential health pathways.[47]

In addition to health effects from air and water pollution, coal operations are also connected to increased road traffic accidents and have been associated with increases in criminal and other anti-social behaviours.[35] Evidence indicates similar issues arising in gas operations, and in particular there are concerns over the use of fly-in/fly-out workers.[48]

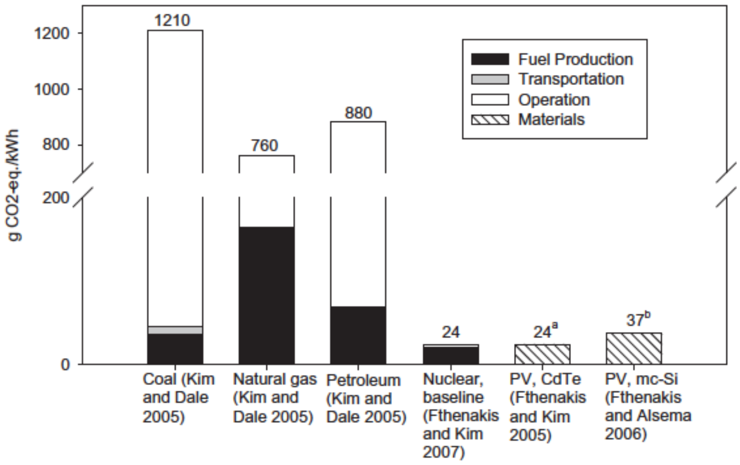
5.2 Indirect health impacts

One of the most serious health impacts from fossil fuels is the release of greenhouse gases. Coal fired power plants produce around 1000 kg of CO2e per megawatt hour[39,41,49]—the highest level of GHG emissions per unit energy of any form of energy generation. A WHO study estimated that "global warming that has occurred since the 1970s caused over 140 000 excess deaths annually by the year 2004" [50], primarily through the impact of malnutrition, diarrhoea, malaria, floods, and cardiovascular disease in developing countries. While it is impossible to precisely calculate the causal effect of coal power on health through its influence on climate change, it is clear that Australia's reliance on coal for use domestically and for export burdens us with a considerable moral responsibility.

While conventional gas fares somewhat better in respect to GHG release, with many reports estimating its combustion is responsible for approximately half (or less) the CO2e emissions of coal[51], this remains a substantial amount in absolute terms. Furthermore, debate over the GHG impact of fugitive methane emissions renders such figures uncertain at best for unconventional gas, with some estimates suggesting it offers no GHG advantages over coal.[52,53] The GHG emissions from solar and wind technologies are by comparison negligible, and mostly arise from the non-renewable energy technologies used in their production.[19]

Figure 11 below compares the emissions from materials, transportation, fuel production and operation with coal, gas, nuclear and petroleum. The upper estimate of emissions from the production of materials for PV (which is higher than CST) is approximately 37g CO2e/kWh, compared to 1210g CO2e/kWh for coal and 760g CO2e/kWh for gas—that is, at the highest levels the emissions from solar energy are over 32 times less than coal.[22]

Figure 11: Comparison of emissions from PV and conventional power plants



Coal and gas production is also responsible for considerable environmental damage through water, air and land pathways. For coal, this includes damage through acidification affecting land and water (especially from sulphurous black coal), eutrophication (responses by the water system to additional substances, such as algal blooms or reduced oxygen content) and waste such as ash.[41] The production of coal fired energy also requires substantial water use, with the five coal plants in the Latrobe Valley using 125 billion litres annually—approximately 13-17GL a year per 1000 MW plant, or the equivalent of about one third of Melbourne's water supply.[54] This creates resource competition that is likely to be further exacerbated by climate change.

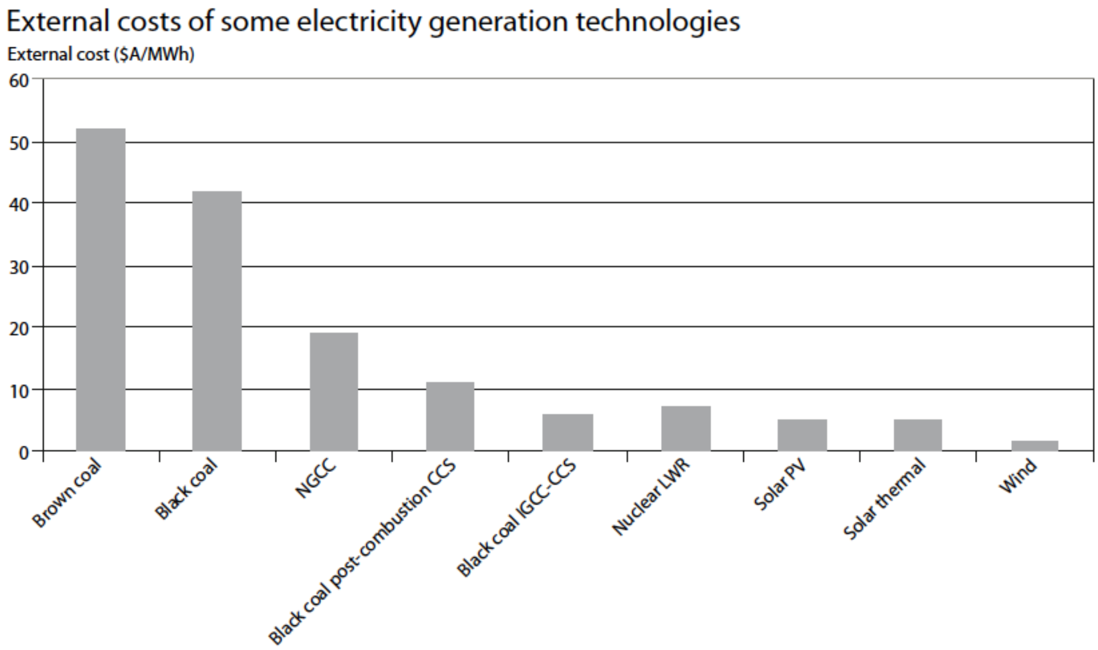
The environmental impact of unconventional gas in Australia is uncertain, however some degradation of land and water is likely, and a potential for serious negative impacts on biodiversity and ecosystem health.[37]

5.3 Comparative profile

It is obvious that the technologies currently providing the majority of Australia's energy needs place a considerable burden on human health. A review of the international evidence for coal's effects found that there "are clear indications …that there are serious health and social harms associated with coal mining and coal-fired power stations for people living in surrounding communities".[35] While conventional gas is somewhat less impactful, the negative effects are also substantially higher than any renewable energy alternative. The impacts of extracting coal seam and shale gas using fracturing is beset with uncertainty, however there are several serious concerns.

Comparing the externalities generated by coal, gas and renewable energy, the Australian Academy of Technological Sciences and Engineering estimated costs of "$A19/MWh for natural gas, $A42/MWh for black coal and $A52/MWh for brown coal" compared to "$A5/MWh for solar photovoltaic electricity and $A1.50/MWh for wind power" (Figure 12 below).[19] These figures are likely to underestimate the health impacts of solar that occur in the manufacturing stage, and do not include a consideration of the potential impacts of land and water use. However, even if a true reflection of the externalities of solar requires a substantial increase in these figures, it is highly unlikely they would approach externalities of fossil fuels, which are estimated at four to ten times as high. These figures are indicative of the substantial health benefits that would attend the replacement of coal and gas with the adoption of large-scale solar and wind technologies.

Figure 12: External costs associated with energy generation technologies in Australia. Source: ATSE



6. Conclusion

Unlike other forms of energy generation, solar energy enjoys high levels of public support, with little sign of conflict over resources or adverse health implications from power generation. However, expansion of the industry may see some of the impacts considered here become more salient—especially the potential health risks to workers in countries that Australia sources raw materials from, and the significant amounts of water required for many large-scale CST systems.

The level of risk associated with toxic materials used in the production of materials for solar PV cells is largely determined by the degree to which best practice and environmental health and safety guidelines are adhered to. As an importer of PV materials, Australia has a moral obligation to support efforts to improve conditions, and ensure its imports come from manufacturers that hold to such guidelines.

Large-scale CST systems may be preferable in Australia because of their relatively low health impacts and efficiency. Although some such systems can use comparable, or even greater, amounts of water than fossil fuel, there are signs that improvements in technology may substantially reduce demand for water. However, there are also benefits that stem from smaller-scale distributed systems. While the social impacts of solar energy in Australia have not been studied in depth, there are opportunities for the expansion of jobs directly generated by the industry and further community benefits from distributed systems in particular.

The likely rise in gas prices as Australia increases its exports, the shrinking coal export market, and the impacts of climate change may all serve to increase the comparative advantage of solar over existing fossil fuel technologies. The industry is currently somewhat underdeveloped, and there are issues of efficiency, along with health and environmental impacts that will most likely change considerably with improvements to current technology.

While solar energy is not without its health and environmental impacts, these are significantly less than those accompanying fossil fuels. Large-scale CST solar systems in particular are an attractive option for contributing to Australia's future energy needs with minimal impacts.

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