Australia's Energy Options:
Renewables and efficiency

May 2012

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About this publication
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Page 21: Robert Murphy, one of the installers of the solar panels on the Queen Victoria market roof, Fairfax Syndication/Julian Kingma.

Page 45: Genetic picture of electrical pylons near Melbourne, Fairfax Syndication/ Jessica Shapiro.

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We achieve this through a rigorous and evidence-based research agenda, and forums and events that deliver lively debate and critical perspectives.

CEDA's expanding membership includes more than 900 of Australia's leading businesses and organisations, and leaders from a wide cross-section of industries and academia. It allows us to reach major decision makers across the private and public sectors.

CEDA is an independent not-for-profit organisation, founded in 1960 by leading Australian economist Sir Douglas Copland. Our funding comes from membership fees, events, research grants and sponsorship.

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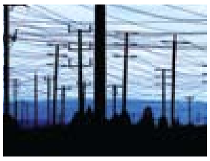


Foreword

It is with pleasure that I present the second of three policy perspectives in CEDA's *Australia's Energy Options* series – Renewables and efficiency.

CEDA has chosen to examine renewables and efficiency because both are vital if Australia is to transition to a low-carbon emissions energy future at the potential cost of billions of dollars. If we don't get this right it will have significant economic, social and environmental costs for Australians.

However, significant uncertainty surrounds what are the best energy policies to pursue, with debate often marred by vested interests.

This policy perspective draws together experts to examine:

- The key considerations that need to underpin good energy policy decisions, including environmental, social and economic factors;
- Policy options to mitigate market barriers and failures;
- A methodology to model options to better predict the viability of emerging technologies, providing a means to quantify the value of different policy interventions; and
- The importance of, and options for, improving energy efficiency, including changes to the structure of our energy market.

Globally, attention on addressing climate change has seen a significant focus on developing renewable energy options. In this context Australia really is the lucky country. With the exception of hydro, we have a plethora of options, including solar, wind, wave and geothermal, meaning we can pick the best technologies without being limited by source.

However, most renewable technology is still in its infancy in terms of commercial deployment and there remain question marks as to which technologies will become the best options for long-term sustainable energy supply.

And, unfortunately, support for the development and deployment of emerging renewable technologies has been ad hoc with a scatter gun approach to policy at both a State and Federal level. This is despite the fact that over the next few years it is anticipated there will be significant technological and cost breakthroughs for renewable technologies.

Equally, the focus on improving efficiency has been limited, despite it having the potential to mitigate climate change and reduce the impact of raising energy costs in the next decade.

However, as highlighted in John Dashwood's chapter, these gains can be significant – projected global energy use by 2040 would be four times greater if not for expected energy efficiency gains. Improving energy efficiency has the potential to buy time before choices need to be made about which renewable technologies are deployed for the long-term.

Andrew Pickford's chapter discusses one option for improving energy efficiency based on changing Australia's energy market, from one based on energy as a commodity to an energy services model, similar to how the mobile phone industry operates. Under this model consumers are able to buy an energy service depending on usage, rather than predominantly fixed service charges.

While energy efficiency gains would buy time, it is critical that government and industry embrace a proactive approach to these matters.

Market failures and barriers such as transmission connection hurdles, subsidies to existing commercial technologies and policy instability must be addressed if renewables are to reach their full potential in Australia.

As highlighted by Tony Wood, as a starting point, an ETS is needed with predictable rules and mechanisms to allow industry the certainty it needs to make investment decisions and in the short-to-medium term, Governments must support research, development and deployment of demonstration plants.

What is required is public policy that is robust enough to adjust to changing economic conditions and to technological improvements. To guide public policy intervention government must continually model and reassess technology options due to the significant cost and risk involved in investing in renewable energy.

In this respect, Professor John Burgess provides an alternative methodology to model scenarios that take into account what technological breakthroughs are required for individual technologies and also the probability of that occurring.

This model allows the value of different technologies to be measured under different scenarios such as a changing carbon price. It has the potential to provide trigger points as risk decreases for technologies, as to when government or industry should invest in research and development, pilot plants, infrastructure or land.

Finally, Professor Paul Hardisty objectively discusses the environmental, social and economic factors that must be considered in assessing energy generation including environmental costs of developing and building renewable technologies.

I would like to thank the sponsors of this policy perspective, Rio Tinto and ElectraNet, along with the authors, for their contributions which ensure CEDA can undertake important projects such as this.

I hope this policy perspective provides insight and a valuable resource to the energy debate.

Professor the Hon. Stephen Martin
Chief Executive
CEDA

Introduction

In the following policy perspective CEDA examines the challenge of establishing socially sustainable renewable energy policies, puts forward a methodology for determining effective renewable energy interventions, and recommends the creation of a market in energy efficiency.

The world is wrestling with the challenge of ensuring an ongoing supply of energy that does not damage the environment while enabling billions of people to appreciate the benefits of modern life. Global interest in renewable technologies is accelerating the maturity of many of these energy sources. These efforts are vital if the quality of human life is to be improved across the planet without causing its further degradation.

Energy underpins all aspects of modern life and generates many externalities that affect both the environment and society more broadly, such as the environmental consequences of extracting the raw materials used in all energy generation. All forms of energy generation create externalities, although not all have an influence on the climate.

Numerous policies have been established to adjust for climatic externalities in the energy generation and to incentivise low carbon emission sources of energy. There is a complex interplay between technological and economic factors influencing the deployment of renewable technologies, the relative cost of generating energy from different sources, and the broader political and economic cycles. Given how fundamental reliable energy is for modern life the costs involved in mitigating climate change are substantial. The scale of change requires examining public policy outcomes throughout the world to ensure that interventions are producing effective results in Australia.

While there is considerable public goodwill to effectively deal with the challenges of climate change, there is no clear means of determining what actions are most effective for resolving the problem. Many policy decisions on renewable energy appear to be made on an ad hoc basis, with little quantification of the desired benefits or accurate estimates of the costs involved, resulting in frequent and substantive changes. Public policy needs to be based on the robust and objective quantification of uncertainties involved if it is to receive sufficient community acceptance to be maintained across the economic and political cycles.

Improvements in energy efficiency are set to make the most significant contribution to climate change mitigation without any explicit policy support. However, there is an opportunity to incentivise energy efficiency improvements while potentially delaying the need to deploy energy generation capacity.

This policy perspective examines the challenges of accounting for social and environmental consequences of energy generation and the outcomes of various policy interventions both in Australia and internationally. It also contains a potential methodology to replace ad hoc political decision making with an objective analysis of the options. Finally, it explores the role of energy efficiency improvements to meet energy demand and proposes a model to incentivise further improvements that could effectively forestall the need for immediate deployment of energy generation capacity.

A measured debate

This policy perspective includes discussions on the following issues:

- *Making renewable energy sustainable.* Professor Paul Hardisty, Global Director of Sustainability & EcoNomics™ for WorleyParsons, discusses the externalities of energy and the range of factors that need to be considered for optimal energy generation deployment;
- *Policy – the drug of choice for renewable energy.* Tony Wood, Program Director, Energy, Grattan Institute, describes the rationale for government support of renewable energy, reviews the policies applied to date and recommends options to move forward;
- *Financial uncertainty of technological change.* Professor John Burgess, Australian Academy of Technological Sciences and Engineering Fellow and Principal Niche Tasks, outlines the risks involved in investing in energy generation and a methodology for evaluating what actions by investments or government are rational;
- *The outlook for energy: A view to 2040.* John Dashwood, Chairman of ExxonMobil Australia, details a forecast of the global energy supply mix over the next 30 years and explains the role of energy efficiency in mitigating energy demand; and
- *Dealing with peak demand: The potential of an energy services model.* Andrew Pickford, Managing Director, ISSA Indo-Pacific, describes the problem of fast growing peak demand, outlines one approach to address it, and introduces the broader concept of the energy services model which could incentivise greater levels of energy efficiency improvements in the future.

A sustainable basis for renewable energy

Renewable energies are forecast to grow at a rapid pace, with some technologies, such as wind, forecast to rise by more than 900 per cent from 2010 to 2040.[1] Policy support for renewable energy needs to ensure a match between the marginal social cost and benefit of removing additional carbon emissions from the economy if it is to avoid the boom and bust cycles that have plagued the renewable energy sector.[2] While the social cost of carbon is set to increase substantially over time,[3] it will continue to be an externality requiring government intervention to quantify.

Government policy on renewable energy should have climate change mitigation as its primary objective. Any government initiative should have clear objectives that define what magnitude of carbon emissions are being mitigated both now and in the future, with explicit examination of underlying assumptions about technological progress and the future cost of carbon.

How to make the right decisions

To move beyond ad hoc decision making requires a robust quantification of the probabilistic outcomes of a full suite of energy technologies. Such an approach would model the net present value (NPV) of an investment in an energy generation technology under a range of scenarios. These scenarios should include different levels of technological development, various carbon prices, and the relative cost of different energy sources.

Understanding the contours of investment risk around the deployment of low carbon emission technologies also allows the merit of various policy initiatives to be quantified. For instance, while the net present value (NPV) of solar thermal towers may not be positive at this point, analysis may suggest a range of policy options that can be undertaken now to facilitate future deployment should technological advances occur. These may include funding research and development, supporting early-stage deployment and providing assistance with transmission connection hurdles and so forth. By analysing the risk contours of an investment decision, the effectiveness of various policy alternatives can also be objectively quantified and compared.

Developing the capacity to deploy low carbon emission technologies in the future can be considered as equivalent to the nation buying a call option, which is a right but not an obligation to purchase the underlying asset in the future, on this form of energy. Initial estimates would suggest that Australia has a portfolio of renewable energy call options worth approximately $12 billion. The anticipated social benefit of individual policy interventions can also be quantified. All government programs should be assessed to ensure they are returning an efficient amount of mitigation.

Buying time

Australia could delay the need to deploy more energy generation capacity by more effectively managing the peak period of energy demand. Since energy investments are long lived assets, and are undergoing considerable technological innovation, such an action would represent a valuable extension of the nation’s call option on low carbon emission technology.

The need to deploy more energy generation capacity is being driven by growth in peak energy demand. During 2008–09 in Victoria, approximately 25 per cent of the network capacity was used for only 10 days. While residential consumers, who drive peak demand, only constitute 27 per cent of electricity use, there are no incentives for them to avoid using the peak and are major sources of its growth.[4]

One way to address peak load growth would be to establish long-term predictions for energy supply requirements for network distribution and transmission networks, and then inviting energy service providers and demand side participation companies to engage in competitive bidding to address them.[5] This approach effectively uses the social benefit of not deploying energy generation capacity as an incentive for a number of participants to deliver energy efficiency options.

Even without such a market, energy efficiency improvements are set to make the largest contribution to global carbon emissions mitigation. Adopting an energy services model, whereby customers pay for the service energy makes available rather than paying for the commodity of energy itself, could create substantive incentives for a wide range of participants to find innovative ways to achieve improved levels of energy efficiency.

Renewables and efficiency in the long-term

In order to achieve long term socially sustainable renewables policy:

- Quantify the value of renewable energy sources for mitigating carbon emissions over the long term so that monies expended on them match their social value; and
- Replace ad hoc decision making with a rigorous methodology that accounts for the risks, and assumptions, influencing policy intervention.

To maximise the nation's social benefit from low carbon emissions technology development:

- Introduce a market incentivising energy efficiency and, potentially, buy a considerable period of time without further energy generation capacity needing to be deployed, allowing more time for renewable technological innovation to occur prior to deployment.

Nathan Taylor
Chief Economist, CEDA

Endnotes

1 Dashwood, J., 2012, *The Outlook for Energy: A view to 2040*, CEDA.

2 Wood, T., 2012, *Policy – the drug of choice for renewable energy*, CEDA.

3 Hardisty, P.E., 2012, *Making renewable energy sustainable*, CEDA.

4 Australian Government, 2011, *Draft Energy White Paper 2011: Strengthening the foundations for Australia's energy future*, Department of Resources, Energy and Tourism, page 173.

5 Pickford, A., 2012, *Dealing with peak demand: The potential of an energy services model*, CEDA, page 3.

1. Making renewable energy sustainable

Paul E Hardisty

Paul Hardisty, Global Director of Sustainability & EcoNomics™ for WorleyParsons, discusses the importance of making objective energy policy decisions that take into consideration environmental, social and economic factors.

Paul Hardisty is Global Director of Sustainability & EcoNomics™ for WorleyParsons, one of the world's leading engineering and project delivery firms with offices in over 40 countries. EcoNomics™ is a service that embeds sustainability into all stages of the project life-cycle.

Paul is a Visiting Professor in Environmental Engineering at Imperial College of Science and Technology in London, UK, and an Adjunct Professor at the University of Western Australia School of Business. His new book, *Environmental and Economic Sustainability* is available through amazon.com and other on line booksellers.

Are renewables sustainable?

At first, this may seem an odd question. To some, renewable energy and sustainability are synonymous: renewable energy is by definition sustainable. To others, sustainability as a concept is symbolised by renewables: visions of elegant white turbine blades revolving above green fields, glinting solar mirrors silently tracking the sun across a clear desert sky. These are potent images. It might seem redundant to suggest that if renewable energy, be it wind, solar, wave, tidal or geothermal, is to become a significant part of Australia's energy future, it must be sustainable. However, a number of key questions arise when this issue is examined more closely:

- What does true sustainability entail, in the context of energy supply?
- Are low carbon emissions alone sufficient to make renewable energy sustainable?
- Are there other factors that might have bearing on our determination? and
- Might renewable energy, in some forms and in certain applications, be unsustainable?

Objective answers to these questions are not possible without a clear definition of sustainability, a much used and often abused word.

Defining sustainability

Sustainability as a concept has been around for a long time – at least a generation in common western parlance and for centuries in many traditional societies. In the last few decades, formal definitions, such as the classic Bruntlandian construct ("meeting the needs of the present without compromising the ability of future generations to meet their needs") have become mainstream.[1] Organisations large and small have launched efforts to become more sustainable, publishing sustainability reports and joining indices such as the Dow Jones Sustainability Index and FTSE4Good. However, simple, quantitative explanations of what sustainability actually means in practice, and how to achieve it, remain rare.

History suggests that the *idea* of sustainability alone has not been enough to drive real change. [2] Globally, we continue to degrade our environment at an ever increasing rate, with significant effects on society, despite widespread support for the idea of sustainability.[3,4] This divergence between what we *want* and what we actually *do* is in part a function of an economic system that currently places no value on "externalities" - environmental and social assets which are not valued in conventional markets - and a short-term focus driven by discounting and rate of return expectations that devalue the future.[5,6]

Achieving real sustainability requires balancing the often competing needs of society, the environment and the economy, objectively and rationally, over the life-cycle of the proposition. Trade-offs must be examined explicitly and quantitatively. Access to affordable electricity brings huge benefits to society, including increases in life expectancy, access to information and education, and development of industries providing needed goods and services. But there are hidden costs to power generation across the life-cycle, which are not reflected in the market price of electricity. Providing power to remote communities in WA results in improved health for its Aboriginal citizens, but generates carbon emissions in a largely fossil-fuel powered grid. Native forests are cleared to mine the compounds that find their way into sophisticated photovoltaic systems. Large amounts of precious fresh water is used for cooling to enhance the efficiency of power generation.

> "History suggests that the *idea* of sustainability alone has not been enough to drive real change. Globally, we continue to degrade our environment at an ever increasing rate, with significant effects on society, despite widespread support for the idea of sustainability."

Everything has an opportunity cost, everything we do costs money and everything affects everything else. If we are not including external costs and benefits when making decisions about energy, we are working with an incomplete picture, and true environmental, social and economic optima will elude us. True sustainability requires that the actions we undertake actually deliver real and long-lasting net gains to society. The total costs of undertaking a project must include capital and operational costs, but also the costs of consequential damage to society and the environment. These must be balanced against the benefits produced, not just to the proponent in the form of profits, but to society and the environment as a whole. Put more quantitatively, to be sustainable, the full environmental, social and economic benefits of a proposition must exceed its environmental, social and economic costs, over its life-cycle.

Adopting this definition of sustainability and using a common unit of measure for all stakeholders' concerns (money), allows trade-offs to be compared objectively, quantitatively and rationally, and all components of the decision to be assessed on an equal footing.[7] It allows us to see the value of what we are giving up or damaging, in the context of what we are gaining, over the long term. It enables us to appreciate, in a language we all understand (money) the full implications of our choices.

Renewable energy and climate

One of the main advantages of renewable energy is its relatively low greenhouse gas (GHG, which includes carbon dioxide) footprint. Until now, in most of the world, carbon emissions have been treated as an uncosted externality. A recent life-cycle study of various Australian energy sources for export showed that concentrated solar and wind power were significantly less GHG-intensive than coal, liquefied natural gas (LNG), and coal seam gas (CSG) for the production of electricity.[8] Other studies have shown similar results for a variety of renewables. [9]

Meeting global targets for GHG emission reductions will almost certainly require major deployment of renewable energy. According to the International Energy Agency, if we are to have a 50 per cent chance of reaching a 450 parts per million (ppm) atmospheric CO_2 target, and therefore have an even chance of escaping the worst effects of climate change, renewables including hydro and biomass will need to make up at least 27 per cent of the global energy mix by 2035. [10] More aggressive targets will require even more intensive deployment of renewables.

The new Australian carbon tax will provide a price signal for fixed electricity generation, and will accelerate the development and introduction of new technologies and operational techniques within the Australian power sector. [11] But the imposed carbon pricing scheme is unlikely to result in a price high enough to mirror the social cost of carbon (SCC), which reflects the full value of the carbon externality – the damage to the world's economy and ecosystems caused by each additional tonne of GHG put into the atmosphere. Estimates of the SCC vary (as shown in Figure 1)[12], depending on the breadth of damage included and assumptions about emissions trajectories over time.[13] Because the damage from climate change is a function of the concentrations of GHG in the atmosphere, the higher our emissions, the higher the SCC will be. The longer we wait to take action, the higher the SCC becomes (Figure 2).[14] Conversely, if action is taken to stabilise emissions, the damage will be lower and the SCC will be lower. [15] Thus, the SCC is directly related to the total amount of GHG in the atmosphere – which under business-as-usual (BAU) policies, is rising rapidly.[16]

Under Stern's BAU emissions scenario (now eclipsed, such is the rate of growth of emissions worldwide), the SCC was estimated at about US\$85/tCO_2-e. However, assuming that world action is successful in stabilising atmospheric GHG concentrations to the 450-550 ppm level (now considered a long shot), Stern estimated an SCC of about US\$ 35/tCO_2-e.[17] Older studies underestimated short-term growth in emissions and looked at fewer elements of damage. More recent studies conducted at reasonable social discount rates[18], including the US Government's recent review of the SCC for regulatory impact analysis[19], and the UK Government's shadow cost of carbon[20], reveal the trend of increasing SCC with time. Figure 1 reflects these differences.

The implications are clear: Long-term investment decisions in the energy sector need to consider not just short- or medium-term carbon costs under an emissions trading scheme, but the longer term prospect of the SCC becoming the eventual

FIGURE 1
CURRENT ESTIMATES OF THE SOCIAL COST OF CARBON (US$/t$CO_2$-e)

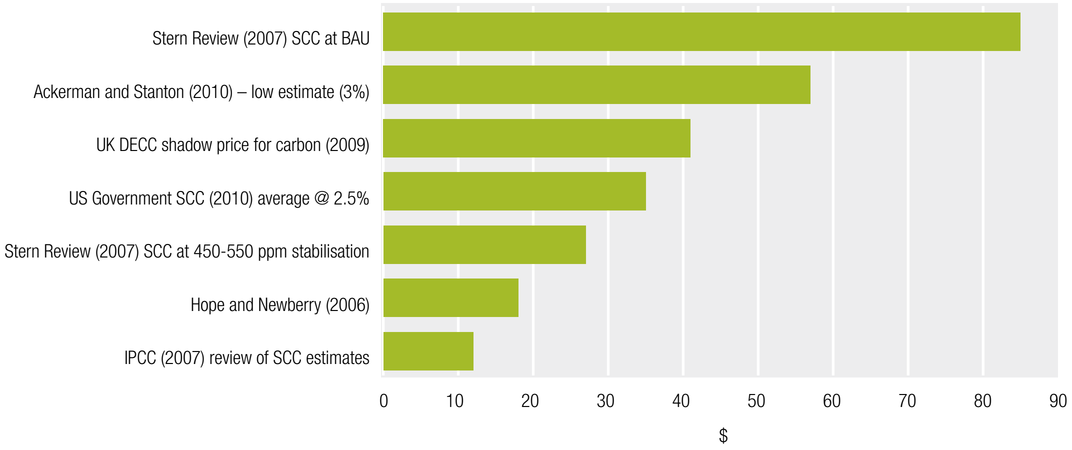
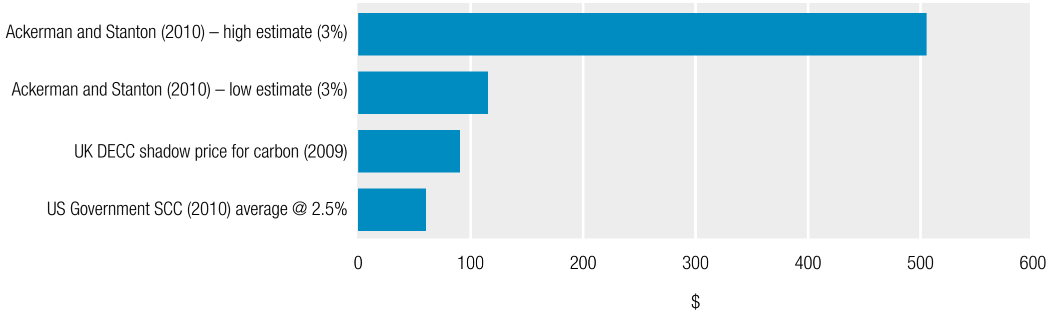


FIGURE 2
2050 ESTIMATES OF SCC (US$/t$CO_2$-e)



benchmark for carbon prices[21]. Looking out to 2050, SCC estimates are more variable (see Figure 2), but the trend is clear: The longer we wait to take action, the more it will cost us.

Applying the SCC to renewable energy's GHG advantage over fossil fuels demonstrates the scale of the potential benefit. Using life-cycle estimates, wind power's carbon benefit over sub-critical coal fired power is about US$80/MWh when using Stern's BAU SCC estimate. Using Ackerman and Stanton's 2010 low estimate, it is about US$50/MWh. When compared to domestic natural gas, these values are approximately halved. In context, typical OECD levelised costs without a carbon price are about US$70/MWh for supercritical coal-fired power and US$90/MWh for offshore wind.[22] The effect that the SCC has on overall real costs of fossil energy is significant, and all other things being equal, makes low emission energy sources (including renewables, nuclear, and carbon capture and sequestration) more attractive.

However, making energy more expensive works against another key social goal: poverty alleviation. Access to cheap electricity drives a host of positive social outcomes. A recent study into provision of power to small remote aboriginal communities in WA found significant benefits to life expectancy, health, employment opportunities, education, and even fire safety.[23] Indeed, Andrew Charlton, in his recent essay, argues that if we are to solve the climate issue, we must also eliminate poverty. For this, we need energy that is not only clean, it must also be plentiful and cheap.[24]

Other benefits of renewable energy

Significant reduction in the carbon externality is a major benefit of renewable energy. However, there are other benefits that come from the adoption of renewables. Conventional power generation using coal and other fossil fuels carries other air pollution externalities: the health, environmental and infrastructure damage associated with non-GHG emissions such as NOx (nitrogen), SOx (sulphur), particulate matter and heavy metals emissions. The European Union estimated total air emissions externalities (including GHG) for coal-fired power at between US$2 and US$23/MWh[25]. In comparison, wind and solar were estimated to contribute between US$0.02 and US$1/MWh in external emissions costs. Recent studies in the US have estimated the scale of human health damage from coal-fired power stations emissions alone at over US$60 billion a year.[26]

We can add the social and environmental damage created during the exploitation of fossil fuels – coal mining deaths in China, for example, and the environmental footprint associated with open pit mining, to name a few. Similarly, the damage associated with mining and producing the materials that go into renewable energy generation also cannot be ignored. However, compared to the various social and environmental externalities embedded in coal over its life-cycle, renewable energy is a clear winner.

Water can also be examined from the perspective of unaccounted for external costs and benefits. The total economic value of water explicitly recognises the full value (TEV) that each unit of water provides to society, including direct use values, and indirect use values such as ecosystem support and recreation.[27] Where renewable energy systems do not require water for cooling (such as wind and PV solar), application of TEV allows monetisation of an additional benefit when compared to fossil fuel power systems which do require freshwater cooling.

Renewable energy costs

Australian 2015 estimated levelised costs of electricity and associated GHG emissions (as CO_2 equivalent emissions) are provided in Table 1[28]. This data reflects the significant variability in cost between different electricity generating systems, when externalities such as carbon are not included. It also shows that if the SCC is applied, overall costs of fossil fuel power generation increase significantly to the point where they are equivalent to or greater than selected renewables such as wind power. While the capital costs of some renewable energy systems have been falling over the last decade, there are also wider system integration costs that cannot be ignored. [29] As discussed above, the longer we wait to take action to reduce global emissions, the higher and the more quickly the SCC will rise, further favouring renewables of all types. Recent estimates for total system integration of renewables, including adequacy costs (meeting peak demand), balancing costs (variable supply inherent in many renewables places greater flexibility demands on the rest of the system), and grid integration costs (expanding and upgrading transmission and distribution systems) range from US$5 to US$25/MWh[30], potentially defraying some of the air emissions externality benefits.

TABLE 1

2015 LEVELISED AUSTRALIAN ELECTRICITY COSTS

Generation Technology	Levelised cost (AUD$/MWh)	GHG emissions (tCO_2-e/Mwh)	External GHG cost (Stern's BAU SCC @ AUD$ 85/tCO_2-e)
Black coal super-critical	60–90	0.75	$63.75
CCGT (Combined cycle gas turbine)	75–120	0.38	$32.30
Wind	120–150	0	$0
Fixed PV	300–375	0	$0
Concentrated solar thermal with storage	320–700	0	$0

Source: EPRI 2010

All renewables are not created equal

As shown above, arguing for or against renewable energy *per se* is an empty exercise. Blanket statements advocating renewable energy are gross over-simplifications, as are assertions that gas is good, or coal is bad. The variability between technologies, systems, capital and operational costs, environmental and social externalities, and local conditions will all have a bearing on overall performance, and therefore sustainability as defined here.[31]

There is a wide variety of renewable energy technologies available, some well-developed and widely used (like wind power and biomass), others still in various stages of development. Different renewable technologies produce power in different ways, using different media, require vastly different capital expenditure, and produce power under varying circumstances. Each type of renewable energy has its own life-cycle, internal and external costs, which must be explicitly examined if a full appreciation of the relative merits of various systems can be determined.

> "…arguing for or against renewable energy *per se* is an empty exercise. Blanket statements advocating renewable energy are gross over-simplifications, as are assertions that gas is good, or coal is bad. The variability between technologies, systems, capital and operational costs, environmental and social externalities, and local conditions will all have a bearing on overall performance…"

A recent study in Australia examined a range of renewable energy alternatives which could be used to meet expectations of broadening MRETs (mandatory renewable energy targets). An evaluation of the full life-cycle of environmental, social and economic sustainability of a range of relatively small renewable power opportunities for deployment in a rural area was completed.[32] This particular region of the country has been badly affected by soil salinisation which has been caused by extensive clearing of native vegetation.

Removal of up to 95 per cent of the deep-rooted native trees over vast areas has caused water tables to rise, introducing salt into the shallow soils. This phenomenon has rendered large areas of land unable to support agriculture.[33] To arrest the impacts, farmers and the government have started to plant oil Mallee Eucalyptus trees, which are driving down the water table, and reversing the effects of soil salinisation. A number of the renewable energy options evaluated in this example involve planting and copsing Mallee trees to use as feedstock for energy production, either in purpose-built biomass plants, or for co-firing in existing coal-fired facilities. Wind and various solar possibilities were also examined. Along with the traditional financial parameters, a number of key externalities were valued and included in the analysis, including the total economic value of water, the community, biodiversity, and agricultural benefits of salinity reduction, GHG, NOx, SOx and particulate emissions.

The results showed that some of the renewable energy options (including small scale biomass, co-firing and 100MW wind) were strongly NPV positive, over the 20-year planning horizon, at discount rates ranging from three to 10 per cent, delivering on balance more environmental, social and economic benefits than costs. These advantages were maintained over a range of valuations for a range of externalities. They were sustainable. However, under the particular conditions modelled, other renewable options, including the 20MW solar PV option, were not sustainable, using the definition offered earlier in this paper. Sensitivity analysis revealed that, as expected, all renewable energy options performed better as energy and carbon prices rose. However, the relative differences between the renewable alternatives and their overall ranking did not change over a wide range of future valuation conditions.

> "Not all renewable energy is sustainable. But perhaps more importantly, given the scale of the carbon emission reduction challenge facing the country and the world, just being sustainable is not enough. No energy system can be assessed in isolation."

The study discussed above revealed that there are conditions under which the life-cycle costs (including SCC) of deploying certain kinds of renewable energy systems, at particular scales and at specific locales, can outstrip the benefits they bring, compared to other alternatives. Not all renewable energy is sustainable. But perhaps more importantly, given the scale of the carbon emission reduction challenge facing the country and the world, just being sustainable is not enough. No energy system can be assessed in isolation. It must be considered with reference to other alternatives, over a wide range of possible future conditions that reflect the inherent uncertainty in the future values of externalities and market commodities, under site-specific conditions. Optimality is required. We need to deploy the most environmentally, socially and economically beneficial energy systems. Simply being good is not good enough; we have neither time nor money to waste.

An energy mix for the future

Providing reliable and reasonably priced power, while reaching our GHG reduction targets, is one of the biggest challenges facing Australia and the world today. Given our current energy mix, the challenge is significant. However, in many ways, Australia is also uniquely positioned not only to make the transition smoothly, but to export the resulting knowledge and expertise around the world. That renewables can and will play a major role in this transition is certain. However, the ultimate degree to which renewable energy deployment is truly sustainable, the timing of that deployment, which technologies are used, and the extent to which other carbon management approaches in power generation and the rest of the economy will play a role, should depend on sound policy guided by clear, rational analysis free of hyperbole and over-simplification. Shouting more loudly does not make something so.

> "It is clear that a more sustainable and economic energy future for Australia depends on a mix of energy solutions, including reducing demand by increasing efficiency, reducing waste and simply using less. In determining that mix, all options, including nuclear energy, should be considered and compared on a full life-cycle basis."

The type of analysis touched on here reveals that when it comes to an issue as important as Australia's energy future, there is no substitute for objective, all-inclusive analysis based on the latest information. As our energy policy develops, the need to include all of the environmental, social and economic factors in decision-making will become ever more important if we are to avoid locking in sub-optimal choices. Decisions based on pre-conceived qualitative notions of what is "bad, good and better" can be misleading. Business-as-usual solutions are not always optimal, precisely because business-as-usual decision-making typically ignores wider environmental and social costs and benefits, or treats them only qualitatively. Equally, much of what we do in the name of sustainability is actually not sustainable at all when examined objectively, quantitatively and rationally. However, real optima always exist – they simply must be found.

The enormous challenges of the 21st century require a robust and quantitative way to reveal the real overall costs and benefits of our actions. Perhaps if we knew the real value of what we are gaining and giving up, we would be more likely to change our ways, and move onto the path of a more sustainable future.

It is clear that a more sustainable and economic energy future for Australia depends on a mix of energy solutions, including reducing demand by increasing efficiency, reducing waste and simply using less. In determining that mix, all options, including nuclear energy, should be considered and compared on a full life-cycle basis. Renewable energy can play a much more extensive role in our future energy mix than conventional wisdom suggests, but it must be sustainable, and its place in the overall mix should be an optimal one. By pricing in externalities of all kinds, including carbon, more sustainable and inherently more profitable and robust energy strategies can emerge.

The economist John Kenneth Galbraith wrote:

> *"Few problems are difficult of solution. The difficulty, all but invariably, is in confronting them. We know what needs to be done; for reasons of inertia, pecuniary interest, passion or ignorance, we do not wish to say so."*

Sustainable energy and a more sustainable world require that we conquer inertia, tame our passions, inform ourselves and ensure that the wider social and environmental impacts of our choices become part of our pecuniary interest.

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2. Policy – the drug of choice for renewable energy

Tony Wood

Tony Wood, Program Director, Energy, at the Grattan Institute, reviews current government policies to support renewables and explores policy options for sustainably integrating renewables into the Australian energy mix.

Tony Wood has more than 30 years' experience in the fertiliser, chemical, transport and energy industries.

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Tony is the Program Director, Energy at the Grattan Institute, and also works with the Clinton Foundation in the role of Director of the Clean Energy Program, where he leads their activities on accelerating the deployment of low emission energy technologies in the Asia-Pacific region and coordinates their international partnership with the Global CCS Institute.

Tony is on the Executive Board of the Committee for Melbourne and he was seconded to the Garnaut Climate Change Review in 2008.

He is a member of the Northern Territory Chief Minister's Green Energy Taskforce and in late 2010 chaired a medium-scale solar working group for the Victorian Government.

Introduction

Renewable energy has been gaining an increasing foothold in the global energy mix, to the extent that non-hydro renewable energy as a share of global power generation is forecast[1] to rise from three per cent in 2009 to 15 per cent by 2035, with much of the increase coming with explicit government support.

Proponents will use a range of data to justify support for their preferred options including anticipated rapid cost reductions, cleanliness and job creation.

Detractors will equally point out the ongoing cost gap, intermittency, job exports and the dependency on government subsidies.

It seems that each time a particular renewable energy achieves a material share in any market, the government or consumers react to the cost imposed on energy bills or government budgets. This results in the support that created the gains being just as rapidly withdrawn or greatly reduced, with both sides lamenting the outcome.

This paper explores the role of renewable energy in the global energy mix with a particular focus on Australia. It identifies the rationale for government support, reviews the policies applied to date and assesses the results of these policies. Finally it addresses the question of how a sustainable role for renewable energy could be achieved in Australia.

Why bother?

Climate change mitigation demands electricity decarbonisation inside 40 years

Renewable energy could logically be defined as energy with a fuel source that never runs out, and that is an obvious advantage against any form of energy that, in its production, consumes a finite resource. The long-term benefit that this implies, and the fact that some forms of renewable energy supply already have a significant role in some countries, however, pale by comparison with the characteristic that drives today's global focus on renewable energy sources: they produce zero, or near-zero greenhouse gas emissions (GHG).

International agreement to contain average global temperature increases to less than two degrees Celsius has resulted in commitments such as that by the Australian Government to reduce GHG emissions by 80 per cent of 2000 levels by 2050. A large part of achieving this goal is likely to come from reductions in Australia's physical emissions, and from changes in the mix of electricity technologies, since it is the major source of these emissions.[2] Based on modelling for the Australian Treasury, it is estimated that Australia must achieve a carbon intensity of 0.2 tonnes of CO_2 per megawatt-hour or lower to meet its target.[3] The sustainability of these political commitments will be determined by the social acceptance of the policy responses adopted.

A shift of this magnitude will require large-scale changes in Australia's electricity generation sector. Gas could play an important bridging role, but in the long-term, there will need to be a shift to coal and gas plants with carbon capture and storage or replacement of fossil fuel plants with low- or near-zero emission technologies.[4]

The modelling for Treasury referenced above[5] foresees a major ramp-up of renewable energy from under 10 per cent market share to becoming the largest source of electricity by 2050. It is challenging and possibly stretching credibility to be confident that the current momentum will cause this transformation to be achieved. The time span available, compared with other historical energy sector transitions, provides part of this challenge. A second major factor is the need for renewable energy generation capacity to be integrated into a system designed around an existing structure that might be very different from one with a high renewable energy market share.[6]

Why should government intervene?

With some exceptions, it is generally accepted that pricing the environmental damage of GHG emissions is likely to be the first most effective step towards a lowest cost approach to mitigation. This is reflected in the adoption of emissions trading systems (ETS) in the EU, New Zealand, Australia and several other countries. In addition, China is trialling an ETS approach with a view to implementing a national system by 2015.

However, government intervention beyond pricing carbon is required for a number of reasons. These include[7] early mover technology development spill-over risks, market barriers associated with regulatory structures and existing subsidies for fossil fuels, finance barriers and carbon price discounting. These market failures are also the basis for the OECD to conclude that there are economic efficiency arguments for policy instruments on top of a cap-and-trade system.[8]

This is not a policy-free space into which a carefully crafted set of complementary policies could be introduced to address market failures and barriers and lead to a necessary and sufficient policy framework to meet the objective of lowest cost mitigation over the long term. A number of policy instruments have been introduced to support renewable energy, or low-emission technologies. Some of these are technology-neutral and some are very technology-specific. Their nature and performance is worthy of assessment.

"…government intervention beyond pricing carbon is required for a number of reasons. These include[7] early mover technology development spill-over risks, market barriers associated with regulatory structures and existing subsidies for fossil fuels, finance barriers and carbon price discounting."

A history of boom and bust

In its assessment of the role that renewable energy could play in contributing to climate change mitigation, the International Energy Association (IEA) has observed[9] that its projections for market share growth for non-hydro renewable energy in power generation is underpinned by annual subsidies that rise almost five times to $180 billion. China and the European Union drive this expansion, providing nearly half of the growth. The IEA states:

> *"Even though the subsidy cost per unit of output is expected to decline, most renewable energy sources need continued support throughout the projection period in order to compete in electricity markets. While this will be costly, it is expected to bring lasting benefits in terms of energy security and environmental protection."*

Well-intended initiatives deliver results best viewed through favourable eyes

A Grattan Institute analysis of a wide range of Australian policies with emissions reduction as one of the objectives[10] concluded that: "Market mechanisms, such as a carbon trading scheme, have delivered the greatest emissions reduction and have met targets ahead of time." While some of the policies in the area of grant-tendering and rebate programs have other objectives, including building industry capacity, it is difficult to conclude that these have been successful. Generally, the design of such programs has led to short-term cycles of boom and bust, rather than sustainable activity. The following sections assess the three generic policies adopted to date, namely tradable green certificate (TGC) schemes, feed-in tariffs (FiTs) and grant/rebate programs.

Tradable green certificates

TGC schemes have the common characteristic that they impose an obligation on energy suppliers to purchase a defined quantum of renewable energy. This liability is generally acquitted via certificates or credits that can be created and sold/ bought across the industry. The price is determined by demand and supply in the certificate market. The intent, and usually the result, is to generate that nominated quantum of renewable energy at the lowest cost. The well-known versions of such schemes include the Renewable Obligation (RO) in the UK, Renewable Portfolio Standards (RPS) in a number of states in the USA and the Renewable Energy Target (RET) in Australia.

The UK's RO has undergone a number of reforms and improvements since it was introduced in 2002 with an original target for a renewable energy market share of 15 per cent by 2015. This was the UK's principal mechanism to meet its obligation under the Renewable Energy Directive which established renewable energy targets across the EU for 2020.

The most significant change to the UK's RO was to introduce banding in April 2009, which arose from concerns that the RO was not delivering the optimal mix of renewable energy technologies, specifically not enough offshore wind. With this change, the RO moved from being technology-neutral to becoming technology-specific. This moved the RO from a mechanism which offered a single level of support for all renewable technologies, to one where support levels vary by technology, according to a number of factors including their costs, relative maturity and potential for future deployment. As described by Wood and Emmett[11], through this change, the RO became closer to a quasi-feed-in tariff (FiT). In mid-2011, the UK Government released a White Paper on Electricity Market Reform, one element of which was a proposal to replace the RO with FiTs. Part of the reason for this change is a view that the impact on consumer electricity prices will be lower through lower investor risk exposure and lower potential for further political intervention. It remains to be seen whether this prospect can be realised.

RPS policies in the USA cover more than 20 states and around half of nationwide retail electricity sales.[12] The design of these policies varies widely and they have often been coupled with investment tax credits and/or government loan guarantees to achieve their desired outcomes.

Australia's RET has delivered emissions reductions in line with the scheme's design (almost nine million tonnes in 2010) and is projected to continue to do so at a cost of \$30–\$70 per tonne CO_2-e[13]. This policy has been a success in terms of delivering a targeted level of renewable energy at a relatively modest cost. As with the RO in the UK, there has been criticism that such schemes deliver the lowest cost technology deployable today and may not facilitate investment in a mix of technologies that might have lower costs in the long term. Further, the RET's limited life and the adverse effect of other concurrent Federal and State renewable policies have meant that the price of certificates has recently been very low and there is much debate about whether the 2020 target can be achieved without a cost blowout.

In addition to the criticism that TGC schemes support the cheapest near-market technologies (usually onshore wind)[14], the other major criticism is that they expose investors to market price risk (both electricity price and certificate value), thereby increasing costs.[15]

Feed-in tariffs and power purchase agreements (PPAs)

FiTs and PPAs with governments have the common characteristic that the price is set by government and the market determines the volume, although most schemes also have some form of cap to limit total budget exposure and/or consumer price increases. This means that market price risk is effectively borne by government, and the success of the policy, perceived or real, is determined by the setting of the tariff level. There are many variations in the design of FiTs and by 2010 more than 45 countries had FiTs, including most of Europe.[16]

The challenge in getting the FiT parameters right is reflected in the problems encountered in Australian states, notably NSW, and the current German and Spanish claw-back. The German Federal Environment Minister commented:

> *"Our proposal on assistance for photovoltaics aims to effectively limit the quantity of new capacity and the costs. With regard to the sharp rise in new capacity seen in the last two years, the renewed adjustment of assistance primarily aims to keep the renewable energies surcharge stable for the electricity consumer and to maintain public acceptance of photovoltaics and renewable energy in general. The aim is for photovoltaics to achieve market maturity in a few years so that the technology can be used without any subsidies at all."*

Recent countries to adopt FiTs have sought to avoid past mistakes and implemented systems with the following characteristics:

- Tariffs differentiated by technology type and project size; and
- Tariff step-down scenarios with clear criteria for triggering such steps.

An innovative approach to introducing a level of market competition to reduce prices is to run a reverse auction in which project proponents bid a contract price for access to a capped total capacity.

Grants and rebates

Grant tendering schemes involve government directly funding projects that produce low-emission energy. The history of such schemes has been poor. Grants are generally slow to deliver results, have failed to build substantial domestic industry capacity (few projects have proceeded to completion[17]) and are limited in their ability to contribute materially to significant reductions in greenhouse gas emissions.[18] Despite $7.1 billion being allocated to grant tendering schemes over the past decade in Australia, only a small fraction of this amount has ever been allocated to viable projects. The most recent example of such schemes and their challenges is the Solar Flagship Program where the selected projects have failed to achieve key milestones and the process has been revisited. This and other grant tendering schemes struggle due to a mixture of ill-defined success criteria and the complexities of new technologies or projects.

Australian State and Federal Governments have allocated more than $5 billion over recent years to support rebates for a range of products that have claims of energy efficiency and/or renewable energy.

Rebates have suffered from two inherent problems: the challenge of setting the rebate at the right level to deliver a sustainable outcome and the almost inevitable disruption when the budget is exhausted, even if the scheme's end is communicated well in advance. The experience has commonly been characterised by cycles of boom and bust (the solar photovoltaic rebate program) or just bust (the recently terminated solar hot water rebate program) as schemes become victims of their own success.[19]

> "Rebates have suffered from two inherent problems: the challenge of setting the rebate at the right level to deliver a sustainable outcome and the almost inevitable disruption when the budget is exhausted, even if the scheme's end is communicated well in advance."

The above criticisms are based on the practical experience of these schemes in Australia and have little to do with the potential value or cost of the renewable energy being supported.

Loans, loan guarantees, tax credits and other financial instruments

In various countries, notably the USA, additional financial instruments have been adopted to support the primary policy such as the TGC. For example, loan guarantees have been effective in lowering financial risk premia for projects already underpinned with power purchase agreements triggered by an RPS. In a similar vein, the UK is establishing the Green Investment Bank and the Australian Government has announced a Clean Energy Finance Corporation. Both institutions intend to target financial market failures and barriers to the deployment of clean or renewable energy technologies.

The results to date have been at best mixed – it depends on the perspective

Most comparisons of the above policies to support renewable energy deployment concentrate on TGCs and FiTs and compare them on the basis of effectiveness and efficiency.[20] As described above, both approaches can demonstrate a capacity to deliver on policy objectives, including meeting some form of quantity target. However, there is some evidence that FiTs generate greater investor support through the transfer of market risk to the public sector. This may also lead to lower costs. A more pragmatic conclusion might be that either approach, if well designed, can produce both effective and efficient outcomes.

The detailed policy design is important because different policies and different detailed elements within a policy produce quite different risk mitigation outcomes, even when the level of financial support is identical.[21] Compared with a TGC, FiTs transfer an element of risk from investors to consumers, rather than reduce risk. If the objective is lowest cost achievement of carbon abatement targets over decades, and when technology risks are also significant, the relevant question might more appropriately be when might such a risk transfer be socially justified?

What's wrong with what we've got?

The core proposition of this paper is that the primary objective in supporting renewable energy is to facilitate a transformation of the energy sector to near-zero emissions over 40 years.

A carbon price, introduced via an ETS is the necessary first step. If the emissions cap is binding, additional policy instruments will not lead to any extra reduction in emissions.[22] However, like TGCs, an ETS will facilitate near-term low cost emissions abatement, not necessarily long-term, lower cost technologies. Early movers face higher costs in areas of finance, regulatory frameworks and resource mapping. They can also face higher barriers to transmission connection and may not share the implicit subsidies provided to existing energy sources through existing distribution and transmission infrastructure. The rewards to early movers are low. Innovators will struggle to defend intellectual property in an undifferentiated product market, and because government policy on climate change is inherently unreliable, they cannot bank the full value of projected higher long-term revenues for low emission electricity. The end result is that markets will under-price carbon and therefore will under-invest in low emission technologies, including renewable energy.[23]

> "The rewards to early movers are low. Innovators will struggle to defend intellectual property in an undifferentiated product market, and because government policy on climate change is inherently unreliable, they cannot bank the full value of projected higher long-term revenues for low emission electricity. The end result is that markets will under-price carbon and therefore will under-invest in low emission technologies, including renewable energy."

A way forward

As implied above, the first and fundamental issue is to define the objective. The premise of this paper is that the right approach to support renewable energy is for it to achieve a market share consistent with an optimal inter-temporal allocation of emissions reduction. This approach begins with implementation of the proposed ETS as the central plank in the policy platform. To ensure investor confidence in the government's policy, the forward emissions caps must be structured to build credibility, and there must be predictability in the way that the ETS rules and mechanisms respond to future developments. Over time, this could allow the private sector to rely increasingly on the ETS framework to form a view of the future carbon price and investment opportunities, in the way of other industrial markets.

In the short-to-medium term, additional policy instruments must then address market failures and barriers to deployment of renewable energy, such as transmission connection hurdles and subsidies to incumbent technologies. Finally, financing and early mover barriers mean that governments should support research and development in areas of national interest[24] and early-stage deployment of a suite of low emission technology options[25]. Technology development at the demonstration and early deployment stages involves more local issues and requires more overall funds than at the R&D stage, although risks may be lower. Criteria to target this support should be based on addressing the relevant early mover risks. Uncertainty about future costs of all technologies means that government should also support a variety of options.

> "In the short-to-medium term, additional policy instruments must then address market failures and barriers to deployment of renewable energy, such as transmission connection hurdles and subsidies to incumbent technologies."

Conclusion

Renewable energy will make its optimal contribution to the global and Australian energy mix only when it is deployed via a credible, flexible and predictable policy framework that creates an emissions-constrained energy market and addresses the political risks. This is unlikely to be achieved via policies based on narrowly focused self-interest, including most of the approaches used to date. It will categorically fail if governments do not resist the temptation to make continued and unexpected changes to the policy framework.

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3. Financial uncertainty of technological change

John Burgess

John Burgess, Principal, Niche Tasks, discusses an alternative model to evaluate the viability of emerging technologies.

John Burgess BE, ME, PhD, HonDEng, FIEAust, FIChemE, FTSE

Principal, Niche Tasks and Fellow, Australian Academy of Technological Sciences and Engineering

Professor John Burgess is a chemical engineer with extensive experience in process technology, especially associated with high temperature metallurgical process engineering and mining technology.

After a period as a chemical engineering academic at the University of Queensland, John became a Senior Research Engineer at BHP in 1987, working on iron-making technology. He became the Group General Manager Research for BHP in 1993 and then Vice President in the Safety and Environment areas for BHP from 1996 until 2001. During this period he attended Harvard Business School, where he acquired skills in the financial valuation of enterprises. Since that time John has worked as a consultant in chemical engineering and more recently has been studying the financial analysis of future low-carbon power generating technologies through the Australian Academy of Technological Sciences and Engineering (ATSE). He also serves as an independent member or Director of several research institute boards and contributes widely to the analysis of low carbon technologies. John is also an Honorary Professor at the Universities of Melbourne and NSW.

Introduction

Investing in energy generation is a risky proposition. Major changes in energy generation costs for renewables are anticipated, due to technological breakthroughs and improvements, but are not certain. Adding to this uncertainty is climate change policy.

Understanding the nature of the risks involved with deploying sustainable technologies is vital for investors and also government, to ensure implementation of effective climate change policies.

This chapter explores a new methodology for analysing the financial risk of an investment, using probabilistic assessments of various outcomes and then modelling an anticipated Net Present Value (NPV).

This approach gives policy makers and investors greater insight into the span of risk involved with different technologies. It can also make explicit the impact of underlying assumptions around the impact of climate change policies, anticipated technological progress and costs of alternative energy sources.

For example, having a probabilistic assessment of the NPV for different technologies may help in assessing if the risk for a new technology has diminished enough to warrant deployment or that enabling actions, such as land reservation or further research and development, should be undertaken now to allow deployment in the future if risks decrease further.

Sources of uncertainty in the future costs of electrical power generation

Australia requires considerable investment in energy generation capacity in the years ahead. To mitigate carbon emissions, considerable amounts of this investment must be in renewable and sustainable fossil fuel technologies. The uncertainties involved in this investment are legion. Understanding the risks involved with deploying sustainable technologies is a necessary stage in developing climate change policies. Innovative analysis utilising financial modelling of uncertainty can provide critical insights for policy setting.

The changing global treatment of carbon emissions is creating uncertainty for all investors in energy. New technologies for electrical power generation have a number of additional uncertainties, principally driven by the relatively fast pace of technological innovation. To illustrate this for the case where investment in the new generator is made using private capital, it is useful to disaggregate the sources of uncertainty in the cash flow generated by the investment. Thus, the monetary value of a new technology today to an investor, or NPV, is a function of:

- The revenue the investor will receive after the generating plant is operational;
- The capital expenditure and operating costs of the facility over its life; and
- The cost of capital (including both debt and equity) as the discount rate for the free cash flows generated by the operation of the facility.

The first two items, namely the revenue stream and the capital and operating costs, are the main sources of uncertainty to the financial viability of a technology.

Revenue stream

The revenue from an electricity generator is, on average, the wholesale price of electricity received, times the amount of electricity generated over time, plus income from any grants or incentives.

Different technologies have different revenue profiles in terms of electricity generation. For example, a new gas fired combined cycle gas turbine is essentially a base-load facility with a high capacity factor and therefore has constant revenue stream with variation of price during the daily and seasonal cycles.[1,2] On the other hand, some renewable technologies have a low capacity factor, owing to their intermittency, such as solar technologies and wind. The revenue streams from electricity generation for these intermittent technologies depend on the time of day that the energy is generated and vagaries of the weather. Intermittency makes the revenue streams more uncertain. Renewable technologies also receive incentives, such as those provided by the Renewable Energy Certificates (REC) scheme, where the price is market-based and hence uncertain.[3]

For all energy generation investments, the future trajectory of wholesale electricity price, which is linked to the future CO_2 price, is important. Therefore, some of the factors affecting **revenue uncertainty** are:

- The future price trajectory of wholesale electricity price, both on average and as a function of time of day and season, over the life of the facility;
- The future price trajectory of CO_2 and its impact on the wholesale electricity price over the life of the facility. The CO_2 price will influence the wholesale electricity price through its effect on the costs of different new and old technologies over time and the rate at which these are introduced;
- The future price of RECs applicable to renewable technologies; and
- The technological improvements in the efficiency of the technologies, that will change their capacity factor and hence revenue raising ability from the sale of electricity.

The Australian Treasury provides forecasts of the expected CO_2 price trajectory to 2050 based on global equilibrium CO_2 permit trading models. Treasury also provides estimates of the future wholesale electricity price trajectory based on the forecast costs of new technologies and their subsequent penetration of new generating technologies into the generation fleet portfolio mix under the influence of different CO_2 price scenarios.[4,5] Under the most recent 'medium global action' scenario, Treasury has CO_2 prices climbing to $100/t$CO_2$ by 2050 in real terms, while wholesale power prices climb to around $65/MWh, from $40/MWh now. Treasury have also provided a second scenario ('ambitious global action'), which sees CO_2 prices reaching $200/t$CO_2$ by 2050 and wholesale electricity prices climb to over $80/MWh.

There is still great uncertainty in these projections and scenarios, and great uncertainty in the financial analysis of the new power generating technologies from this influence. The greater the level of uncertainty about future revenue flows, the less an investor can rely on it in making investment decisions.

Capital expenditure and operating costs

The required **capital expenditure** for new technologies depends on many uncertain factors. Key risk factors include:

- The value of associated construction costs and the Australian dollar;
- The technological learning curve; and
- The construction profile.

The technological learning curve represents the forecast change in the capital costs of plant and equipment in the future. Since the innovation that drives down the technological learning curve is related to the progressive amount of capital invested in the technology, the technological learning curve is generally expressed as a rate of change and as a function of the installed capacity of the technology (for example a five per cent reduction in capital required, per doubling of installed global capacity).

In order to undertake financial analysis of particular investments in a particular year, the technological learning curve needs to be expressed as the change in capital cost per year (for example five per cent change in capital cost every year). To convert from one to the other, the fleet generation mix and technology penetration needs to be forecast, which then feeds back to the technology learning curve. The interrelated nature of these forecasts creates multiple layers of uncertainty surrounding the future capital costs of a whole range of new technologies for power generation.

The other substantial risk that investors face relates to the construction profile and life of the new technology. Cash flow calculations discounted to present value begin in the first year of the construction through to when the new generation capacity is finalised, which can be several years. Once the facility is operating, and begins generating revenue through to the end of the facilities life, the cash flows become positive. The initial period of construction, referred to as the construction profile, is very important in determining whether a project adds or detracts value from the net worth of an investor.

> "Because the risks associated with the total costs of commercialising new technology can be high, another layer of uncertainty is added to the capital costs of new technologies. These contingencies can be substantial, depending on the level of development of the technology, sometimes doubling the capital cost relative to the bare erection costs."

In situations where the costs of construction are uncertain, as they are for new technologies, it is advisable to ensure that appropriate risk contingencies are applied to the overall construction cost. The "bare construction costs", which are often quoted for new centralised power generating technologies to illustrate their competitive cost, may in fact be only a small proportion of the final capital cost when the risk contingencies and other owner's costs are added in. One method to properly estimate these total costs has been provided by the USA National Energy Technology Laboratories (NETL) of the US Department of Energy.[6] Because the risks associated with the total costs of commercialising new technology can be high, another layer of uncertainty is added to the capital costs of new technologies. These contingencies can be substantial, depending on the level of development of the technology, sometimes doubling the capital cost relative to the bare erection costs. Total capital costs into the future are therefore inherently uncertain, and this is especially true for untested new technologies.

The value of the Australian dollar over time and the proportion of capital components that are imported, are also both significant sources of uncertainty.

The profile of operating costs that will apply in the future for a new power generating technology also have sources of uncertainty. These are:

- For technologies that burn fuel to provide thermal energy, the future cost of fuel can be uncertain. This is particularly the case for natural gas in Australia, where current LNG developments on the East Coast could cause the natural gas price to reach export parity at some time in the future, a real increase in price for the power generators. The burgeoning coal seam gas industry in NSW and Queensland, and its contribution to the supply of natural gas for power generation, also adds a level of uncertainty to future gas prices. As a result, the future price trajectory of fuel over the life of the generating facility will add uncertainty to its financial viability.

- For technologies that emit CO_2, the future price of CO_2 is a source of great uncertainty. This is especially true of technologies that are expected to improve efficiency on one hand, but will suffer a CO_2 cost penalty on the other (for example new supercritical coal-fired plant[7]). The cost of carbon capture and geological storage (CCS)[8] applied to either coal-fired or gas-fired technologies is in itself inherently uncertain at this point in time and the efficiency of CO_2 removal will also be another key source of technical and financial uncertainty.

As can be seen, the future financial viability of new electricity generating technologies is highly uncertain. This is because most of the components that go to make up the NPV for a future investment are uncertain and have cost or revenue streams that vary in wide ranges when viewed from today's standpoint. This means that indicators of financial viability, such as the "levelised cost of electricity"[9] for a new technology should ideally be expressed as ranges that depend on the uncertainty level of the input parameters.

Quantifying the impact of risk on investment value

There is another approach to understanding these future investments, and that is to determine the probability of when an investor will make a profit, calculated by the future probabilistic distributions of an investment NPV. This approach attempts to quantify the multiple uncertainties an investor is confronting. In this way, the value of the investment "at risk" can be determined and an option valuation approach can be applied.

In considering what amount of money to invest in energy generation, an investor will be influenced by the amount of money being generated over and above operating expenses. The free cash flow (FCF) for each year of an investment in a new power generating technology is given by[10]:

1. FCF = EBIT (1–tax) + depreciation – capital expenses

where: EBIT = earnings before interest and taxes, after depreciation

= revenues – costs – depreciation

tax = tax rate = 30 per cent in Australia

The appropriate rate of discount for the yearly FCF is the weighted average cost of capital (WACC):

2. $WACC = \{(1-tax)K_D D + K_E E\}/(D+E)$

where: K_D = cost of debt

K_E = cost of equity

D = amount of debt

E = amount of equity

For any given year, the FCF is discounted according to:

3. $FCF_{n,disc} = FCF_n/(1+WACC)^n$

where: n = number of years since the start of investment, over the life of the investment

The NPV is then given by (assuming no residual value):

4. $NPV = \Sigma(FCF_{n,disc})$

Uncertainty in the range of values for the input parameters to a financial calculation can be handled by allowing the cost and revenue parameters in the above equations to be governed by probability distributions. The distribution of NPV can be built up probabilistically using a Monte Carlo method, which takes samples from the input distributions for each financial parameter in the calculation and then repeats the iteration many times and distributes the resulting NPVs. The final outcome of the calculation is a probability distribution of NPV for an investment at some time into the future. Judgement calls on the shapes of the input distributions and their variance can be made on the basis of published data, cost calculations or experience. This approach attempts to quantify the risks and makes the underlying assumptions about the various uncertainties in the investment explicit.

The probabilistic NPV is a useful distribution to consider. At an NPV of zero, the investor is just earning the cost of capital. For NPV>0, the firm is creating shareholder wealth, whereas for NPV<0, the firm is destroying shareholder wealth.

The distribution of NPV may be used to determine the “value at risk” to the investor. The position on the curve where the NPV is zero is important. If, for example, 10 per cent of values in the cumulative distribution of NPV lie below NPV=0, then there is a 10 per cent probability that the firm will earn less than the cost of capital and a 90 per cent probability that the firm will earn more than the cost of capital. In other words, there is a 90 per cent probability that the firm will increase shareholder wealth. On the other hand, if the probability above NPV=0 is only 10 per cent, then there is a high likelihood that the firm will destroy value for the investor. In this way, the probability distribution can be used to determine the “value at risk” to the investor, given the uncertainty in the input cost and revenue parameters.

Real option analysis – an alternative approach to uncertain financial analysis

If part of the NPV distribution is NPV positive, it means that there is some possibility that the investment will be wealth creating when commercialisation occurs in the future. The portion of the forecast NPV distribution above NPV=0 represents possible upside for the investor due to the variance or “volatility” in the distribution. Given the possibility that this NPV positive result can feasibly occur, even if the mean NPV is predicted to be negative now, means that an investor can undertake decisions that enable them to capture the positive outcomes if they eventuate. Since these actions, such as reserving land for CCSG, are much less expensive than the final investment decision, they do not put as much capital at risk and are NPV positive today. This is referred to as a real options approach, as described by Luehrman.[11,12]

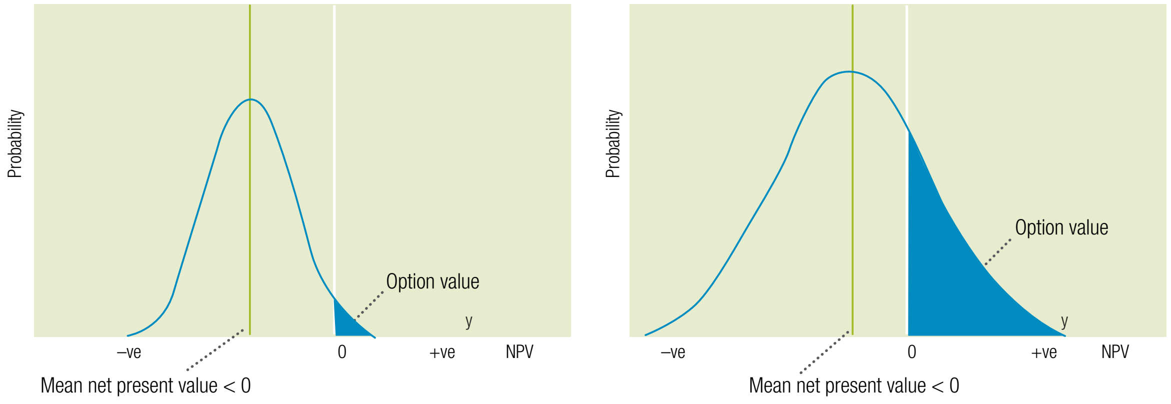
Figure 1 shows four hypothetical NPV distributions, ranging from a negative NPV and small volatility, to a positive NPV and large volatility. The option value is shown as the dark blue shaded area. Clearly, the higher the variance of the NPV distribution, the more likely the potential upside. Also, the higher the mean value of NPV, the more likely the potential upside and the higher the option value. This is analogous to a call option for share purchase on the stock market, where variance, or volatility, is provided by uncertainty in future share price. The more volatility, the

FIGURE 1

FOUR HYPOTHETICAL NPV PROBABILITY DISTRIBUTIONS WITH DIFFERENT MEAN AND VARIANCE OF THE DISTRIBUTIONS

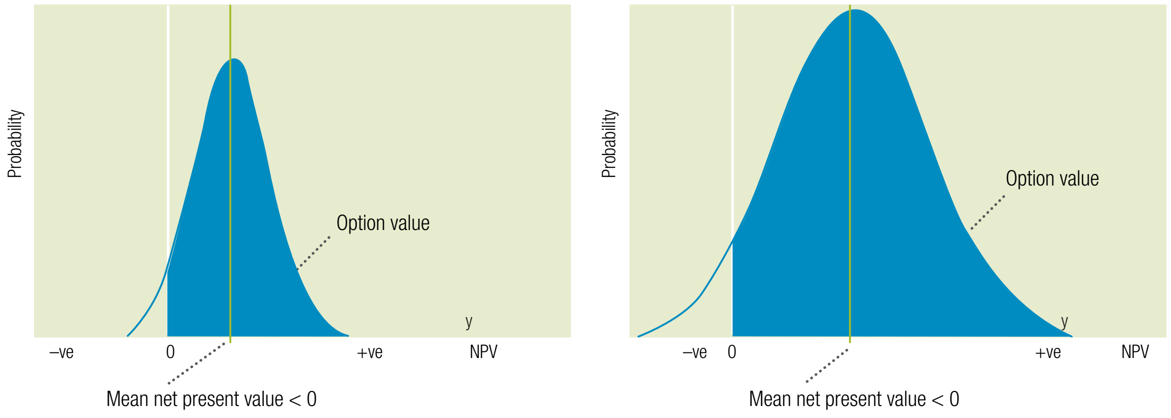
Option value is shown for NPV>0 by the dark blue shaded area.

(With permission, Australian Academy of Technological Sciences and Engineering (ATSE), Low Carbon Energy: Evaluation of New Energy Technology Choices for Electrical Power Generation in Australia, December 2010, pp. 59).



a) Negative NPV and small volatility

b) Negative NPV and large volatility



c) Positive NPV and small volatility

d) Positive NPV and large volatility

higher the option price, and the higher the expected mean of the share value distribution, the higher the option price. By analysing the future NPV distribution of a new technology investment a type of option price (or option value) for the technology can be calculated, where the option value is the NPV in that part of the distribution where NPV>0. This is under the assumption that the investor will go ahead with the future investment as long as the cost of capital of the firm is being earned.

> "Since these actions, such as reserving land for CCSG, are much less expensive than the final investment decision, they do not put as much capital at risk and are NPV positive today. This is referred to as a real options approach."

There are many methods for calculating option value. Perhaps the most common is the Black-Scholes method applied to the stock market.[13] In this method the call exercise price (called "X") is discounted to today at the risk free rate and the stream of cash flows generated by "X" (called "S") is discounted at the cost of capital of the firm. An analytical equation, which includes a term for "volatility", uses "X" and "S" in the form of S/X to compute the option value. In real options, "X" is the capital investment (exercise price) needed to secure the cash flows from the future revenue and cost streams "S". Luehrman describes how investment opportunities can be mapped to a stock market call option and how option value may be calculated using the Black-Scholes equation or option value tables.[14]

The option value or price is the monetary value that an investor pays now to have the right to exercise the option in the future. By analogy, the real option value now is the monetary value that the investor should spend now to ensure that a capital investment can be made in the future when and if the investment is value-creating. This option purchase could be for a variety of enabling expenditures now, for example R&D, pilot technology studies, infrastructure provision, purchase of land, having a "capture-ready" plant for CCS, or purchase of CO_2 sequestration rights and exploration. Clearly, judgement is required in deciding whether to purchase such an option now, just as it is in the purchase of stock market options on shares. Similarly, financial judgement is required in the future when it comes time to exercise (or not) the option through the investment of capital.

The Australian Academy of Technological Sciences and Engineering (ATSE) has undertaken a study that includes an option value analysis of new power generating technologies based on their NPV probability distributions at several different investment years in the future.[15] In this study both the capital costs ("X") and the aggregated future after-tax free cash flows ("S") were discounted at the weighted average cost of capital to calculate the NPV distributions of the new technologies at a future investment date using a Monte Carlo method.

The option value in this analysis was referred to as the Net Present Option Value (NPOV) to distinguish it from stock market option value calculation methods such as Black-Scholes. The volatility in the input distributions for revenue and costs streams, including capital costs, operating costs, CO_2 and electricity price trajectories and other input variables were obtained from published data and the NPV distributions and NPOV calculated.

The 2010 ATSE study relied on:

- Projections of costs and efficiencies of various technologies from the Australian Energy Market Operator (AEMO) based on data provided by the Electrical Power Research Institute (EPRI)[16,17]. (These costs are now dated and it is understood that AEMO is undertaking a new analysis of these costs in 2012); and
- The CO_2 and wholesale electricity price trajectories to 2040 were taken from the October 2008 Treasury analysis.

Option values of new power generating technologies in 2010

Figure 2 shows the NPOV of a variety of new electrical power generating technologies using 2010 forecast data, as outlined above and reproduced with ATSE permission from the ATSE Low Carbon Energy Report.[18] The results shown are for investment in the new technologies in 2020, 2030 and 2040, taking into account the projected learning curves and other forecast trajectories in parameters, as described above. The descriptions of Figure 2 are essentially a précis of those contained in the ATSE report, where more detailed analysis is available.

Net present option values for investment in 2020

The net present option values calculated for 2020 shown in Figure 2 are less than 10 per cent of the exercise price (for example commercialisation investment). Only wind has values of S/X around 1.0 (i.e. positive NPV), with gas-based and geothermal technologies having S/X values around 0.7. It is noteworthy that both of the gas-fired technologies have a relatively high NPV. This is because they face increasing gas and CO_2 prices over their lifetime, with the volatility generated by uncertainty in gas and CO_2 prices in the future increasing the NPOV. For investment (exercise) in 2020, CCGT has a higher net present option value than CCGT with CCS. Other technologies have very low NPV for investment in 2020.

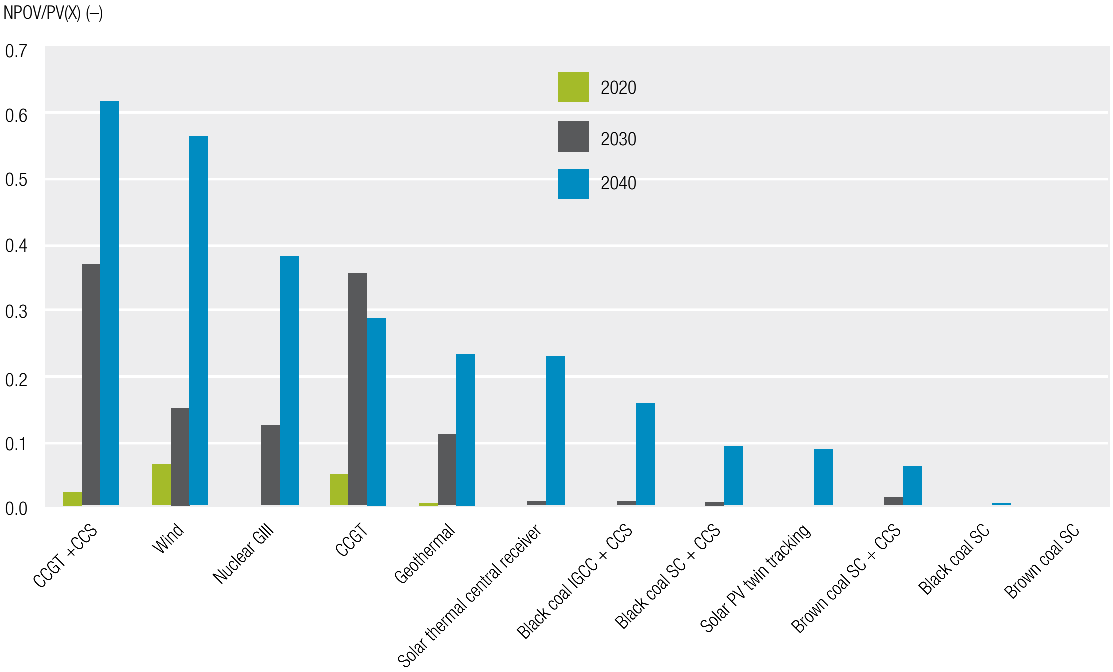
Proponents of solar technologies have challenged the result that solar currently has a negative NPV because they believe that the learning curves for these technologies are steeper than those published by AEMO. This may well be the case, which highlights the importance of undertaking ongoing analysis of this sort utilising the latest data and estimates of capital cost, as uncertainties are resolved through innovation (“learning-by-doing”) for all the new technologies.

As an example, new analysis has been provided by a solar thermal central tower roadmap produced by the USA Department of Energy Sandia National Laboratories. This has indicated that the capacity factor of this technology could be significantly increased through the timely development of energy storage technologies and improved efficiencies.[19] If this occurs, the NPOV would be substantially higher for this technology in 2020, leading to lower levelised costs of electricity and higher option values. ATSE *(ibid)* has calculated that the levelised costs of electricity for solar thermal central receiver energy generation are currently \$200-\$250/MWh.

FIGURE 2

NET PRESENT OPTION VALUES (NPOV) FOR DIFFERENT NEW ELECTRICITY GENERATING TECHNOLOGIES FOR INVESTMENT IN 2020, 2030 AND 2040, NORMALISED BY DIVIDING NPOV BY THE PRESENT VALUE OF THE CAPITAL EXPENDITURE, PV(X)

(With permission, Australian Academy of Technological Sciences and Engineering [ATSE], Low Carbon Energy: Evaluation of New Energy Technology Choices for Electrical Power Generation in Australia, December 2010, pp. 22)



These costs could substantially decline as further commercialisation of the technology occurs, but this requires a range of technological advances. According to the Sandia Laboratories roadmap, the following technological advances could cause the cost of producing energy from solar thermal towers to decline to about \$80/MWh by 2020:[20]

- High temperature receivers and hardware (increasing from 600 to 700 degrees C);
- Supercritical steam/ CO_2 turbine cycles;
- Heliostat (mirror) efficiency improvements;
- Improved high temperature molten salt storage;
- Reduced parasitic power load;
- Reduced capex and operations and maintenance; and
- Increased capacity factor (30 to 72 per cent).

This example shows that "purchasing the option" to commercialise a technology in the future through research development and deployment can be a powerful financial strategy.

Net present option value for investment in 2030

The NPOV for investment in 2030 in Figure 2 are significantly higher than those in 2020. This is because the exercise price "X" has decreased due to technology learning, and the positive cash flows "S" have generally increased due to increased wholesale electricity prices. Also, the REC benefit has now ended and the added price for CO_2 has increased for those technologies emitting CO_2. Thus, the net present option values of gas fired CCGT and CCGT with CCS are almost equal by 2030, with both having $S/X > 1$.

Wind and favourably located geothermal technologies have relatively high ranking NPOVs in 2030 and NPV>0. Nuclear power is also relatively highly ranked and NPV positive. This is because nuclear power, although having higher capital costs, has a high capacity factor, a relatively low fuel price, and is not burdened by a CO_2 price.

Net present option value for investment in 2040

By 2040, the option values of the technologies have increased significantly under the influence of higher real wholesale electricity prices. Figure 2 shows that the technologies that have relatively high NPOVs in 2030 continue to have high NPOVs in 2040. These include CCGT with CCS, wind, favourable-region geothermal, nuclear and CCGT. Some other technologies are now also achieving higher NPOVs, including solar thermal tower with energy storage and solar PV due to their steep learning curves relative to the other technologies.

Portfolio option value

As discussed previously, one way to look at option value is that it is a measure of the price that an investor should pay in NPV terms now to "stay in the game" and have the option to exercise a commercial investment in the future.

The ATSE Low Carbon Energy study shows (see Figure 2) that the mean of the NPOVs of a range of technologies in for example 2040 is around 25 per cent of the commercial investment. Another study by ATSE showed that approximately $240 billion in energy capital investment (real: assuming no inflation) will be necessary to provide the required generating capacity for Australia through to 2050.[21] The $240 billion was for a hypothetical 2050 technology portfolio, with solar technologies requiring $124 billion of capital investment, wind $24 billion, geothermal $12 billion, coal with CCS $51 billion, and gas technologies $21 billion, to achieve a 50 per cent reduction in CO_2 emissions by electric power generation by 2050. This study took into account projected learning curves for costs and efficiencies.[22]

Assuming $120 billion is invested in 2030 and $120 billion is invested in 2040 on these technologies, then the NPV of these investments today may be calculated to be about $50 billion (assuming a seven per cent real after-tax cost of capital as the discount rate). If the NPOV overall is 25 per cent of the exercise price (capital investment), then the net present option value in monetary NPV terms now is about $12 billion. This is a slightly higher number than the value of $10 billion in the ATSE report, due to the progress of time since the report was prepared and therefore less discounting to obtain the present value.

By drawing in the analogy with a stock-market call option, this indicates that Australia purchasing up to $12 billion in carbon mitigation activities, such as R&D, technology demonstration, infrastructure development, and so on, would represent a valuable investment. This is of the same order as, or larger than, current government investment in the enabling of low-carbon technologies. Although the above rough calculation has been done for the overall portfolio of new technologies, at this point in time, analysis of the option value of the portfolio contribution of the different technologies to a generating fleet has not been undertaken. Such a study would provide important insights to positive policy settings that would enable effective carbon mitigation.

Conclusions

Understanding the risks that exist for investors in delivering Australia's energy needs is crucial. Much analysis and policy recommendations are made through simple comparisons of levelised costs of electricity. They do not take into account the full trajectory of CO_2 and electricity prices into the future and the uncertainties associated with these price trajectories. The LCOE approach gives an inaccurate impression of the risks and uncertainties involved, and is an imperfect means of developing policy or making investment decisions.[23]

> "By drawing in the analogy with a stock-market call option, this indicates that Australia purchasing up to $12 billion in carbon mitigation activities, such as R&D, technology demonstration, infrastructure development, and so on, would represent a valuable investment."

The analysis of probabilistic NPV in the context of new technologies for electrical power generation yields new financial insights that provide important guidance for both policy setting and investment decisions. This is especially true of the calculation of NPOV. The simulation of risk to an investor and how it changes with technological innovations, the price of carbon dioxide, or other real world developments, provides valuable insights into the way in which decisions can be made today that add to the net wealth of the nation as a whole. It enables a real options approach to be implemented in Australia's efforts at minimising carbon emissions with more nuanced policy decision making.

Clearly, more analytical work could be done in applying option value theory to new technology investment in electrical power generation. For example, option value could be calculated for different scenarios and fleet portfolios for different levels of CO_2 emission reduction, including factors such as the transmission infrastructure required and provision for electrical energy storage. The method could also be applied to energy efficiency measures, especially those in industry where a significant capital investment could be required. ATSE is currently undertaking such a study and it is likely that the NPOV method will be extended into the further analysis of portfolio option value of the type described.

Endnotes

1 Combined Cycle Gas Turbine (CCGT) – a gas turbine generator where the hot exhaust gases are used to generate steam in a heat exchanger and then, for added efficiency, drive a second steam turbine.

2 Capacity Factor – Ratio of actual power of a generating plant over time to its output if it had operated at its full capacity for the entire time.

3 REC – Renewable Energy Certificate, a tradable market instrument to ensure Australia achieves 20% renewables in its electricity supply by 2020.

4 *Australia's Low Pollution Future: The Economics of Climate Change Mitigation*, 2008, Australian Government Treasury, October.

5 *Strong Growth, Low Pollution: Modelling a Carbon Price*, 2011, Australian Government Treasury.

6 *Cost Estimation Methodology for NETL Assessments of Power Plant Performance*, National Energy Technology Laboratory, US Department of Energy, DOE/NETL-2011/1455.

7 A supercritical coal fired boiler is one in which the steam has a temperature above the thermodynamic supercritical point of water and is therefore more efficient than earlier designs.

8 *National Carbon Mapping and Infrastructure Plan – Australia*, 2009, Concise Report, Carbon Storage Taskforce, September, Department of Resources, Energy and Tourism, Canberra.

9 The *"Levelised Cost of Electricity (LCOE)"* is the constant wholesale price of electricity over the life of a facility that enables the facility to just earn its cost of capital, or in other words achieves a net present value of zero.

10 Higgins R C, 2001, *Analysis for Financial Management*, Irwin McGraw-Hill, Boston, pp. 326

11 Luehrman T A, 1998, *Investment Opportunities as Real Options: Getting Started with the numbers*, Harvard Business Review, July-August, Reprint No. 98404.

12 Luehrman T A, 1998, *Strategy as a Portfolio of Real Options*, Harvard Business Review, September-October, Reprint No. 98506.

13 Black, F. and M. Scholes (1973). The Pricing of Options and Corporate Liabilities. *Journal of Political Economics*, 81, 637-659.

14 Luehrman T A, 1998, *Strategy as a Portfolio of Real Options*, Harvard Business Review, September-October, Reprint No. 98506.

15 *Low Carbon Energy: Evaluation of New Energy Technology Choices for Electric Power generation in Australia*, 2010, Australian Academy of Technological Sciences and Engineering (ATSE), November.

16 *National Transmission Network Development Plan: Consultation Paper*, 2010, Australian Energy Market Operator (AEMO), See: http://www.aemo.com.au/planning/0418-0002.pdf , Modelling Assumptions – Supply Input Spreadsheets, See: http://www.aemo.com.au/planning/ntndp.html

17 *Assessment of Electricity Generation Technologies in Australia*, 2010, Electical Power Research Instituite (EPRI), Australian Government Department of Resources, Energy and Tourism.

18 *Low Carbon Energy: Evaluation of New Energy Technology Choices for Electric Power generation in Australia*, 2010, Australian Academy of Technological Sciences and Engineering (ATSE), November.

19 Klob G J, Ho C K, Mancini T R, Gary J A, *Power Tower Technology Roadmap and Cost Reduction Plan*, 2011, Sandia National Laboratories, USA Department of Energy, SAND2011-2419, April.

20 *Ibid*, pp. 29.

21 *Energy Technology for Climate Change: Accelerating the Technology Response*, 2008, Australian Academy of Technological Sciences and Engineering (ATSE), December.

22 *Ibid*, pp. 29.

23 The determination of LCOE assumes a constant electricity price over the life of the facility. An assumption must also be made about the CO_2 price over the same facility life (normally that the CO_2 price is constant). This tends to favour technologies that have a cost penalty associated with CO_2 emission, since generally the price of CO_2 will increase over the life of the facility as CO_2 emission targets are increased. This was shown in the ATSE analysis, where coal fired facilities without CCS had a relatively favourable levelised cost of electricity (LCOE), but a very low option value (NPOV).

4. The outlook for energy: A view to 2040

John Dashwood

John Dashwood, Chairman of ExxonMobil Australia, describes the importance of energy efficiency to meeting the world's future energy demand.

John Dashwood joined Esso Australia in 1982. He has held a series of technical, planning, marketing and managerial assignments in Australia, including as Production Operations Manager for Esso Australia. John had several international assignments including the Houston-based role of Strategic Planning Manager for ExxonMobil's global gas marketing company. He has twice worked in London, to manage ExxonMobil's gas sales business in Europe and later as the UK-Netherlands Joint Interest Manager for ExxonMobil International Limited.

He was a Council member of Oil & Gas UK, the upstream industry association, where he provided leadership for fiscal and economic activities. In May 2009, John returned to Melbourne as the Chairman of the ExxonMobil group of companies in Australia. He is a Member of the Business Council of Australia and is a board member of the Australian Petroleum Production and Exploration Association.

How will we fuel the future? We know from centuries of history that reliable and affordable energy is essential to human progress. To sustain progress, we must continue to expand the world's energy supplies, improve the ways in which we consume energy sources, and address attendant environmental challenges.

The connection between affordable energy and improved standards of living is undeniable. Energy heats and cools our homes. It enables people and goods to travel across town and around the globe. It powers the technologies that improve our health, well being and economic lifestyles.

Energy's benefits extend far beyond what individuals use at home, at work and on the road. A range of essential activities such as agriculture, computing, manufacturing, construction, and health and social services, depend on access to modern energy.

Yet, according to the International Energy Agency (IEA), 1.3 billion people around the world lack access to even the most basic forms of energy.[1] With the world's population expected to grow from around seven billion people today to nearly nine billion by 2040, expanding access to affordable, reliable supplies of energy will be critical to continued global prosperity.

By 2040, the vast majority of the world's people will live in developing (non-OECD) countries where economic development and increased prosperity are improving living standards. In fact, daily life in many developing countries will mirror that of Australia, the US or Europe – urban, modern and interconnected. More people - with greater affluence – will mean more cars on the road, more modern appliances and conveniences, more technology, and more travel. Burgeoning industries will need fuel for manufacturing; people and businesses will need reliable electrical power. Maria van der Hoeven, Executive Director of the IEA, puts it simply when she stated:

> *"Nobody can do without energy. The relationship between economic growth and the demand of energy is crucial, and the availability of energy sources to economies is crucial."*

ExxonMobil studies these types of trends to help plan for the future. Each year, the findings are published in a report called *The Outlook for Energy*. This wide-ranging document is created through a rigorous, ongoing assessment that includes a detailed analysis of approximately 100 countries, 15 demand sectors and 20 fuel types. It is underpinned by economic and population projections as well as projections for energy efficiency gains that stem from ongoing improvements in technologies and energy management policies, along with imposed costs from carbon policy. Building on many decades of experience, ExxonMobil conducts this work utilising in-house modelling tools, as well as input from a wide variety of third-party organisations such as the International Energy Agency and the US Department of Energy.[2]

ExxonMobil's *Outlook* – which has many similar findings to other long-term energy projections – predicts that over the next three decades, increases in energy demand will be driven by population growth and economic development. The dramatic transformation that is taking place around the globe is setting the stage for a future in which all affordable and reliable forms of energy will be needed.

A glimpse of the future

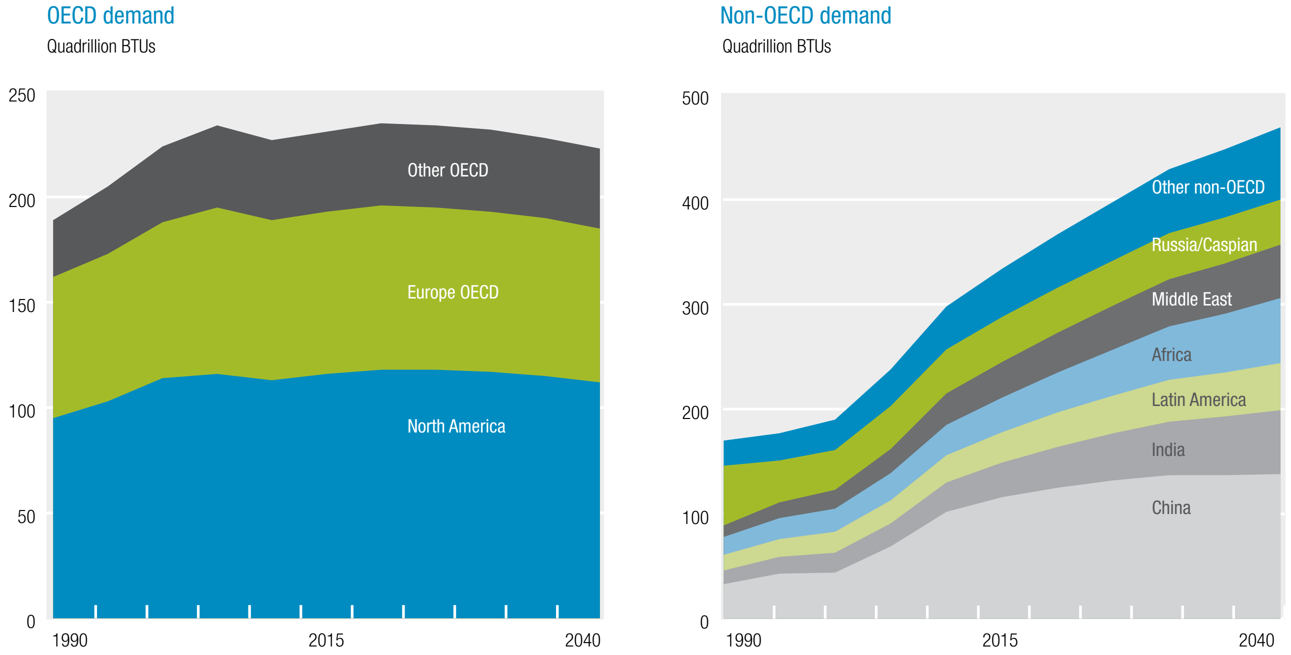
Today, the countries of the Organization of Economic Cooperation and Development (OECD), which includes 34 developed nations, consume about 225 quadrillion British Thermal Units (BTUs) of energy per year, accounting for roughly 45 per cent of the world's energy demand. OECD demand will remain essentially flat through 2040, even as GDP nearly doubles.

Meanwhile, non-OECD energy use will expand by more than 60 per cent, reaching close to 500 quadrillion. Again, this increase in demand will be driven by population growth and booming economies – five-sixths of the world's population will reside in non-OECD countries, and economic growth will be strong, with economies expanding by about 4.5 per cent a year, compared with about two per cent a year growth in mature economies. However, even by 2040, per-capita energy use in developing countries will still be about 60 per cent less than in OECD countries.

ExxonMobil expects worldwide energy demand will be about 30 per cent higher in 2040 than it was in 2010. This presents an enormous challenge - the world will need to expand energy supplies in a way that is safe, secure, affordable and environmentally responsible. Trillions of dollars of investment and major advances in technology are required. Yet, despite the challenge, this is a good news story, because it means that people everywhere are seeking – and achieving – higher standards of living and the health, education and social benefits of modern living.

FIGURE 1
ENERGY DEMAND

Without improved energy efficiency and intensity gains, OECD demand would grow by nearly 90 per cent, and non-OECD by more than 250 per cent.



Source: ExxonMobil 2012 Outlook for Energy

Looking to the past

What about the role of renewable energy sources, such as solar, wind and biofuels? Can these fuels help us meet growing demand for energy while limiting our reliance on carbon-based fuels? The simple answer is yes, although it will take time – and further technology development – before renewables can achieve significant market penetration. To better understand the process by which renewables will develop and grow, it helps to look to the past.

Through the years, the world's use of various energy sources – what we call the "energy mix" – has changed due to a wide range of factors, such as technology, scale, cost and availability.

In 1800, the primary source of energy was wood. When steam was introduced as a source of horsepower for both transportation and industry, the world needed a denser, easier-to-transport fuel, and coal was the natural solution. Yet it took several decades before coal overtook wood as the world's largest source of energy.

Oil was discovered in 1859, but initially it was only used in lighting, as a replacement for whale oil. It wasn't until the rise of the internal combustion engine that fuels produced from oil began to replace coal.

Natural gas was discovered even before oil, but there were limited ways to transport it from source to market. It wasn't until developments in technology made it possible to construct steel pipelines that gas markets could be developed in any significant way. And in recent times, new technology in shipping has allowed gas to be transported as liquefied natural gas to markets even further away from the supply source.

The lesson from the past two centuries is that shifts in the global energy mix *are* possible. However, substantial change – even change driven by economic or efficiency reasons – typically occurs over *decades*, not years. It takes significant amounts of time and investment for an energy *idea* – even one that is proven in the laboratory or in small field applications – to become an everyday energy *reality*.

The growth path for renewables will follow a similar trajectory as the traditional hydrocarbons that preceded them. First is the development of the fuel source itself, along with enhancements in how we employ it to power vehicles or machinery. However, just as important is the technology and infrastructure development for producing the fuel source on a commercial scale – so that it is affordable, accessible and reliable for people and businesses around the world.

As we moved from wood to coal to oil and natural gas, we had to invent, create and develop coal mines, oil extraction processes, refining techniques, processing plants, pipelines, transportation methods and other forms of infrastructure – including, for example, the corner petrol station. We also had to develop the end users of the energy – the machinery and engines that ran on the fuel itself.

Renewables today require significant investment, research and technological advancements to improve their reliability and accessibility – and lower their costs – so that they can compete with more traditional fuels.

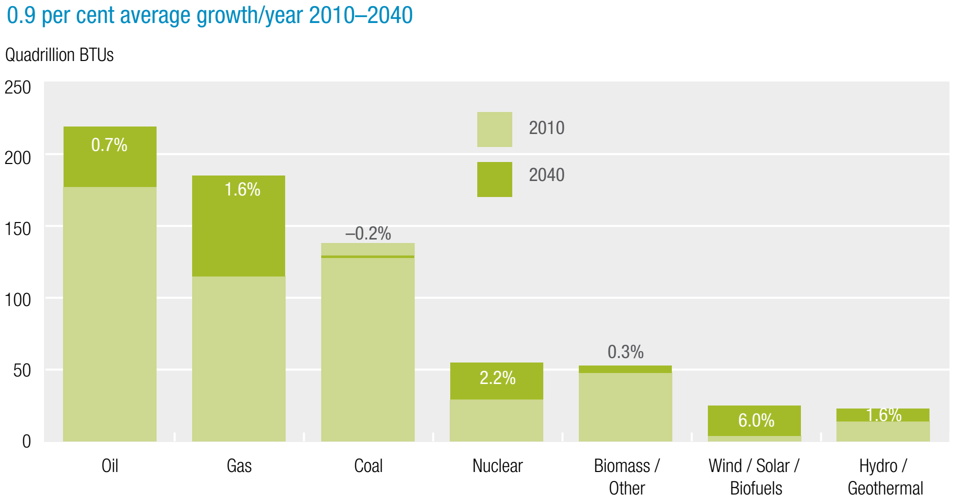
It is worth noting here that ExxonMobil does not factor "breakthrough" technology into its Energy Outlook. Yet technology has historically been a "game changer" in terms of energy supply, and this will continue into the future. For example, a breakthrough in low-cost, large-scale storage of electricity would greatly improve the prospect for wind and solar for electricity generation. Faster-than-expected drops in battery costs would likely make electric cars less expensive and could lead to faster adoption by consumers than currently anticipated. And of course, new combinations or incremental enhancements of existing technologies can also result in significant changes.

> "The growth path for renewables will follow a similar trajectory as the traditional hydrocarbons that preceded them."

Low-carbon fuels will grow rapidly

To be certain, even without major technology breakthroughs, renewables will grow rapidly over the next three decades. By 2040, wind, solar and biofuels will provide about four per cent of the world's energy needs, compared to about one per cent today. Growth in wind power will be especially strong, rising at about eight per cent a year, or more than 900 per cent, from 2010 to 2040.

FIGURE 2
WORLD ENERGY MIX



Yet – as Figure 2 shows – other fuels with low carbon intensity will grow rapidly too, including natural gas, with demand increasing about 60 per cent by 2040, and nuclear power, which is expected to grow at a rate of 2.2 per cent per year.

In 2040, oil will still be the world's largest energy source, led by the 70 per cent increase in demand from non-OECD nations, where growing prosperity is leading to an increase in the movement of goods and people. In other words, the strong growth of renewables will be impressive, but starting from such a small base – and given the huge scale of global energy demand – it will take more than a few years before renewables can come close to the scale and contribution of traditional fuels.

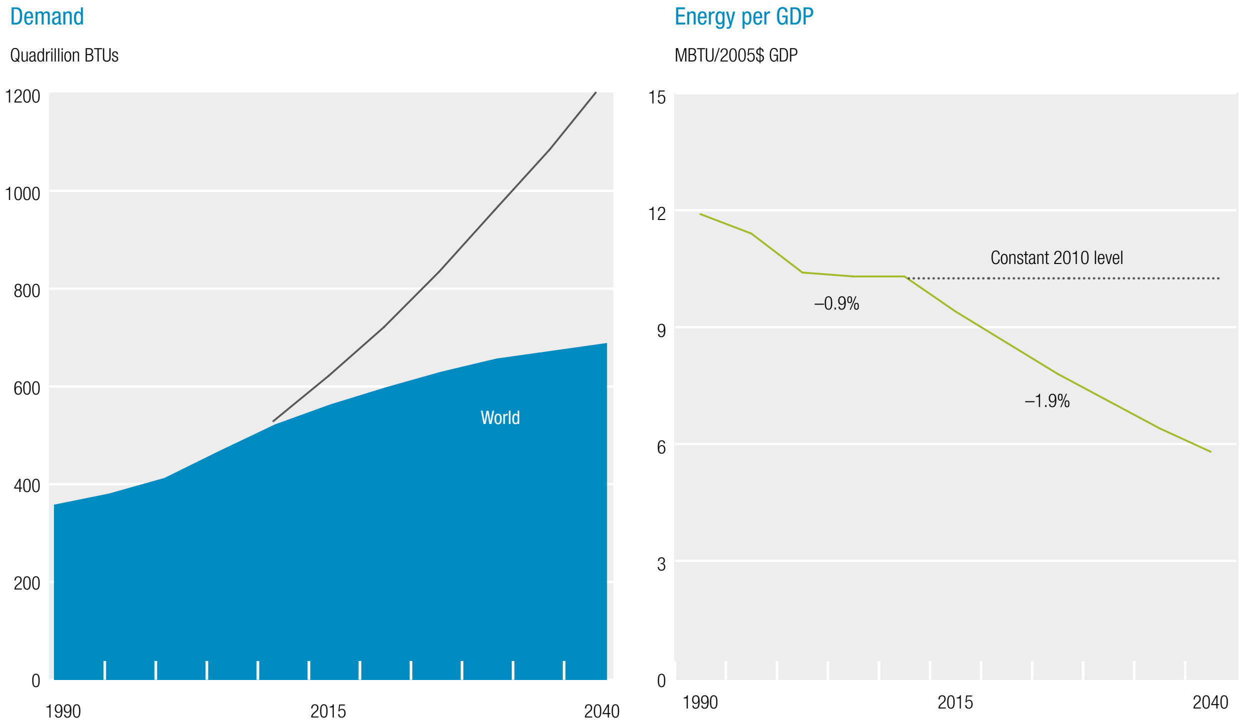
It is important to note that government policy has a significant impact on both energy demand and supply. A contributing factor to these projections is the expectation that OECD and leading non-OECD countries, like China, will gradually adopt policies that impose a cost on CO_2 emissions – in the form of taxes, caps, mandates, subsidies and other measures. The Energy Outlook assumes a cost on carbon rising from around $30/tonne in 2020 to $60/tonne by 2030, and $80/tonne by 2040. As higher carbon fuels such as coal become more expensive, demand shifts to the lower-carbon energy options of natural gas, nuclear and wind.

Efficiency – the "silent supply"

There is another approach to meeting tomorrow's energy needs that often gets overlooked. Improving the efficiency of the fuels we currently use – through technology enhancements and energy management practices – can have a dramatic impact on demand. In fact, demand growth in global energy use by 2040 would be more than four times greater than projected – that is, growth of about 130 per cent – were it not for expected gains in energy efficiency across the world's economies. For this reason, I often refer to efficiency as "our most powerful energy source."

FIGURE 3

GLOBAL EFFICIENCY MINIMISES DEMAND GROWTH



Finding more efficient ways to do things is part of human nature. It's what led to the first wheel and eventually 18-wheelers – examples of technologies that boosted efficiency and made us more productive.

When it comes to energy use, businesses and individuals want to achieve their desired results while minimising the amount of energy required. In the past, this was primarily a cost-saving mechanism – switching to a more fuel-efficient car makes sense during times of high petrol prices, for example. Today, however, energy-saving technologies are seen as delivering dual benefits for both businesses and consumers as they save money and reduce their carbon footprint.

> "…demand growth in global energy use by 2040 would be more than four times greater than projected – that is, growth of about 130 per cent – were it not for expected gains in energy efficiency across the world's economies."

Transportation is one of the most fertile areas for efficiency gains. It is likely that the cars on the world's roads in 2040 will consist of a very different mix than what we have today, with hybrids and other advanced vehicles accounting for nearly 50 per cent of light duty vehicles, compared to only about one per cent today. The world's personal automotive fleet will include conventional gasoline and diesel vehicles, hybrids that use gasoline plus a small amount of battery power, plug-in hybrids, electric vehicles and cars/light trucks that use compressed natural gas or liquefied petroleum gas.

The shift in the global vehicle fleet is primarily driven by tightening government standards on vehicle fuel economy. Improvements to the conventional vehicle, including internal combustion engine improvements such as turbocharging, higher-speed automatic transmissions, improved aerodynamics and reduced weight can improve fuel economy and reduce CO_2 emissions by more than 30 per cent.

These types of efficiency improvements can also have a large impact in industrial settings. To give an example, the global energy industry will see its energy use rise by only five per cent over the next three decades as a result of ongoing enhancements to efficiency and reductions in natural gas flaring.

Finally, we can continue lowering the carbon intensity of the energy supply mix by expanding the use of natural gas, because it is abundant and affordable, and emits up to 60 per cent less CO_2 than coal when used for electricity generation. Using natural gas is currently the lowest cost alternative to reduce CO_2 emissions on a large scale.

Here in Australia – as in many parts of the world – natural gas is plentiful. The enormous amount of natural gas and liquefied natural gas infrastructure built in Australia over the past 30 years is a testament to the value that this resource provides us, both here at home and as an export. It also proves that energy infrastructure will get built if it is economic and supported by a stable legal framework – an important lesson for the future growth of renewables.

An integrated energy mix

Long-term forecasts show that the world's energy supplies will continue to grow more diverse.

Successfully meeting future demand will require foresight, sound energy policies and effective long-term planning, followed by huge investments and years of work to build the infrastructure required to produce and deliver energy and chemicals. It will also take an ongoing ability to understand and manage an evolving set of technical, financial, geopolitical and environmental risks in a dynamic world.

There is no one "magic bullet", no single energy source that is the answer to our energy challenge. It will take more energy – of all economically viable types – to meet the world's demand and ensure that economic development and prosperity are available to all.

In fact, it is not a competition between traditional forms of energy and renewables. They are all complementary and all necessary. Along with improved efficiency, hydrocarbons and renewables will work together to meet growing demand – while minimising environmental impacts in Australia and around the world.

Endnotes

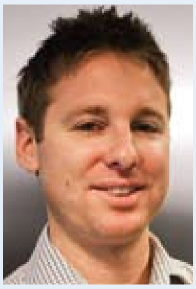
1 International Energy Agency, 2011 World Outlook for Energy (2009 data).

2 The Outlook and this paper include forward looking statements. Actual future conditions (including economic conditions, energy demand, and energy supply) could differ materially due to changes in technology, the development of new supply sources, political events, demographic changes, and other factors discussed herein and under the heading "Factors Affecting Future Results" in the Investors section of www.exxonmobil.com. Material is used in this article with the permission of Exxon Mobil Corporation.

5. Dealing with peak demand: The potential of an energy services model

Andrew Pickford

Andrew Pickford, Managing Director, ISSA Indo-Pacific, discusses options for transitioning the energy market structure from one based on energy as a commodity to one based on providing an energy service.



Andrew Pickford works in the area of policy and strategy across a range of institutions, industries and governments. His expertise is in the electricity sector, strategy formulation, scenario-based planning and Indo-Pacific security issues. Mr Pickford is the inaugural ISSA Indo-Pacific Managing Director and holds a number of other positions including Senior Fellow, Mannkal Economic Foundation; Senior Fellow, International Strategic Studies Association and is currently a Center for Strategic and International Studies-Pacific Forum Young Leader. He is the former Vice President of the Australia-India Business Council (WA Branch). He also sits on the management committee of the Australia Day Council of Western Australia and the Australian Institute of International Affairs (WA Branch). He has a Master of Accounting from Curtin University of Technology and is completing a Master of Advanced Studies from the Australian National University's Strategic and Defence Studies Centre. Mr Pickford recently co-authored *Energy Security 2.0: How Energy is Central to the Changing Global Balance in the New Age of Geography*.

Introduction

Historically energy markets have developed to deliver a commoditised product. However, there is growing recognition that in order to manage the electricity peak, and to defer rising electricity prices, alternative market structures should be adopted. This paper describes the emerging problem of fast growing peak demand; outlines one approach to address this growth; and introduces the broader concept of an energy services model which has significant potential to achieve major efficiency gains for producers and consumers.

Peak demand and efficient markets

Over the past decade, the growth of peak demand has resulted in the need for expensive capital investment, a key driver behind electricity price rises.

Providing electricity to consumers requires the capacity to generate and shift electrons when the consumer flicks a switch on. This capacity is the actual generation (be it coal, gas or hydropower) and the power lines to move the electrons from site of generation to consumption. The underlying infrastructure which enables this are commonly referred to as transmission and distribution networks. At present, network costs can equate to slightly less than half the total end cost of electricity.[1] Sophisticated regulatory and planning mechanisms aim to facilitate the building, in advance, of the necessary transmission and distribution networks to account for energy usage, even if it is only used for a very short period. The cost for this capacity, which can be unused for as much as 364 days a year, is factored into the price paid by consumers.

The Federal Government's draft energy white paper noted the 2008–09 Victorian case study where: "About 25 per cent of network capacity was used for only 10 days."[2] The cost of financing, building and maintaining access to this infrastructure is ultimately borne by the consumer. Quantifying the actual cost for this peak capacity is a difficult exercise. However, the following example of two local energy distributors highlights the large amount of money involved:

> *"Ergon Energy and ENERGEX must build infrastructure capacity that is only required a few days a year to meet this [increasing] peak demand. In south-east Queensland it is estimated that, in the next three years, it will cost $1 billion to meet the top one per cent of energy demand. By way of example, currently 11 per cent of the ENERGEX network is required to meet a level of demand which occurs only one per cent of the time."* [3]

These low productivity outcomes are driven by Australia's institutional framework which ensures Australians have a reliable electricity system and that capacity is built before it is needed.

Historically, electricity systems were state-based and owned. They operated as a single entity encompassing generation, transmission, distribution and retail functions. A key part of the competition reforms of the 1990s (implemented to varying degrees in different states) saw the disaggregation of these entities into sector-specific roles, such as only generation or only transmission, as well as some privatisation. Simultaneously, there was the emergence of state-based economic regulators to oversee monopoly components, such as transmission infrastructure.[4]

The result of disaggregation, privatisation and prudent economic regulatory oversight introduced competitive forces where once there was a bureaucratic decision making process. The previous large electricity bureaucracies built additional assets when planners deemed fit. The reforms introduced competition into parts of the market, such as generation, and limited the "gold plating" and over-building of monopoly infrastructure by diligent regulation.[5] However, in achieving these positive results, there were a number of unintended consequences. In an integrated entity, efficiency was often considered across the entire system. In growth scenarios, where there were alternative options (such as demand management), they were compared against, for example, building more transmission or distribution lines and the cheaper option would be adopted. For the newer, stand-alone, disaggregated businesses, not only does this not make economic sense (i.e. why invest in something if you cannot capture the benefits) it is often not permitted by the economic regulator and acts against the commercial reality of a profit-maximising firm.[6]

Overall, disaggregation and privatisation were successful in providing lowest marginal cost energy, but they also introduced new problems. As the focus shifted to competitive tension in generation and retail markets, and regulation of the monopoly infrastructure, the opportunities for system-wide efficiencies decreased. This unintended consequence has been exacerbated by the relatively fast growth of peak demand compared to average demand growth. This has partly been driven by cheaper and higher uptake of high use consumer goods, such as plasma televisions and air-conditioners. In particular, the use of air-conditioners aligns with a traditional high point of electricity use, i.e. late afternoon. Given transmission and distribution capacity has to be built for peak conditions, this has resulted in escalating costs paid by all consumers and an increasingly inefficient system, as some of this capacity is only used for a day, or even an hour a year.

The problem of growing peak demand has been succinctly highlighted in the Federal Government's draft energy white paper,[7] when it noted:

> *"[W]hile it may cost around $1500 to purchase and install a two kilowatt reverse cycle air conditioner, such a unit could impose costs on the energy system of $7000 when adding to peak demand."*[8]

A proposal to address peak demand

One way to address the increasing peak load growth is to incorporate, within the national electricity market, on a locational basis, a mechanism for an open competition to address or mitigate network peaks.

This proposal would require an alignment of transmission and especially distribution planning cycles and associated regulatory mechanisms. Locational-based needs would be identified through demand forecasting and subsequent identification of capacity limitations on the distribution and transmission network. Based on a set time period, perhaps 10 years[9], energy service providers (including network companies) would be invited to bid to address locational-based constraints. It could formally open the market to non-network solutions, such as demand-side participation (DSP) based on a competitive bidding process. Importantly, it would not lock in a particular technology or approach, but needs to be of a sufficient time frame to encourage commercial investment.

"One way to address the increasing peak load growth is to incorporate, within the national electricity market, on a locational basis, a mechanism for an open competition to address or mitigate network peaks."

At the time of writing, the Australian Energy Market Commission (AEMC) was conducting the *Power of Choice* review. A supplementary paper titled *Demand Side Participation and Profit Incentives for Distribution Network Business*, looks at regulatory decisions for distribution and transmission businesses based on all the costs and benefits of DSP. It also flagged potential options, realigning the regulatory incentives of DSP, including:

- An equalisation scheme which establishes parity in the incentive power and treatment of capital and operating expenditure;
- Expanding existing demand management schemes;
- Permitting network businesses to keep all of the savings of any capital expenditure which is avoided by a DSP project;

- Providing more certainty on how DSP-expenditure is treated in the rules; and
- Extending the regulatory control period past five years.[10]

The proposal outlined in this paper for addressing peak demand is consistent with the approach of the AEMC review. However, this proposal takes the next step and uses the regulatory-led process over a set period of time to bid for solutions. Transmission, and especially distribution, entities would be one bidder in the process, but not be the sole provider of solutions.

The mechanism for open competition to mitigate or address network peaks would be through creating a market for energy services. This approach is agnostic as to whether the network peak is shifted, deferred or satisfied by another service. By conceptualising the provision of an energy service to deal with the peak, it is possible to apply the concept to the entire energy supply chain. Proving the energy services concept for peak demand could allow it to be trialled on a broader basis for all energy demand.

"If an energy services model is implemented properly, the demand for system-wide efficiency would be the driver and options to provide energy efficiency outcomes would expand to include cheaper alternatives than currently exist within mandated state-based schemes."

While the outlined proposal would not be dependent on smart meters, once they are deployed they would provide additional options to mitigate localised network peaks and could provide lower cost options. Winding back and closing state-based energy efficiency schemes, or, at the very least, rolling them into a federal equivalent would further enhance the effectiveness of this approach.[11] These state-based energy efficiency schemes are bolted on to the existing market framework as they impose liabilities on large retailers to achieve a similar outcome to that proposed in the energy services model. However, if an energy services model is implemented properly, the demand for system-wide efficiency would be *the* driver and options to provide energy efficiency outcomes would expand to include cheaper alternatives than currently exist within mandated state-based schemes.

An energy services model

Significant gains could be achieved in transitioning to an energy services model, which is a mechanism for creating a marketplace that encourages efficiency on the demand side similar to the efficiency created on the supply side.

Dr Peter Fox-Penner, Principal and Chairman of The Brattle Group, provides one of the simplest explanations of energy services to date:

> *"To put it simply, customers would pay for each lumen of light generated rather than each watt of power consumed. The cellular industry provides a crude analogy: Your mobile phone service charges you for minutes, text messages, and video downloads rather than for bits per second, which is the underlying commodity. In the new model, utilities would charge you for the amounts of light, computer time, heat, cooling, and so forth that you use."*[12]

While this concept may seem straightforward, it would be a radical departure from existing patterns of electricity provision.

Applying Peter Fox-Penner's mobile phone industry model to the electricity industry would yield substantial benefits. Creating a market that involves selling energy services rather than just selling kilowatt hours would realign the incentive structures of service providers to provide efficient solutions to consumers (such as heating, cooling or charging an electric vehicle), rather than just offering electricity as a commodity. This model would also provide a mechanism for a range of participants to invest in capital equipment which could improve energy efficiency (and customer satisfaction), because it would allow for them to capture the financial benefits.

> "Creating a market that involves selling energy services rather than just selling kilowatt hours would realign the incentive structures of service providers to provide efficient solutions to consumers (such as heating, cooling or charging an electric vehicle), rather than just offering electricity as a commodity."

Overall, an energy services model could expand consumer choice; monetise energy efficiency investments; limit the need for government involvement in electricity grids; flatten and reduce overall energy use; and have numerous environmental benefits. Given these advantages, the following question arises: Why is it not being used? The main reason it has not been introduced is that the present industry structure and profit drivers are linked (and regulated) to incentivise making, shifting and selling kilowatt hours. Electricity is priced as a physical commodity, not for its actual purpose.

Electricity was not always sold as a commodity. For a brief period at the dawn of the electrical era, industry pioneer Thomas Edison offered light and heating as a service on Manhattan Island. Soon after, the economies of scale derived from treating energy as a commodity dominated. While legacy and related regulatory systems (as well as profit motives) remain in place, a series of subtle changes have revealed cracks in the existing approach. Current circumstances are now allowing the re-emergence of a viable energy services model due to a range of subtle, interconnected forces, namely:

- Increasing structural costs of hydrocarbon fuels;
- An explosion in the take up of consumer goods such as plasma televisions and air conditioners, making the Australian peak load sharper and higher;
- Increasingly common and cheaper technologies such as Smart Meters and "smart appliances" allowing greater levels of communication and control;
- The high cost of accommodating intermittent renewables and pricing carbon;
- Public resistance towards further price increases needed to modernise and expand the existing grid; and
- Greater public acceptance of buying services (for example a mobile phone) rather than simply a commodity.

These trends are already resulting in some companies trialling a service-type approach to electricity sales. A large US utility, NRG Energy, is already offering a flat monthly fee to access its fast electric vehicle charging stations in Houston.[13] This is occurring outside of existing regulatory settings for, as yet, an undefined market.

> "These trends are already resulting in some companies trialling a service-type approach to electricity sales. A large US utility, NRG Energy, is already offering a flat monthly fee to access its fast electric vehicle charging stations in Houston."

A broader re-introduction of the energy services model would require substantial changes to market frameworks and regulatory mechanisms to quantify the gains of reduced energy demand necessary to incentivise market participants.

In the Australian context, the energy services model would be applied by having a long-term roadmap to transition from the current market, which is structured on the provision of energy as a commodity, to one based on providing an energy service. By setting a transition approach, existing entities could prepare for the new structure. While large parts of the existing network will still be needed, perhaps as a core backbone of the new energy services model, competition (such as in peak time periods) could introduce innovation between retailers, demand-side aggregators and potential electric car consortiums.

The following conditions would need to prevail to implement fully the energy services model:

- There would need to be a shift to cost reflective prices as is the case already in Victoria, with other jurisdictions limiting the true cost of power to be borne by the consumer;
- There would have to be time-of-use pricing (enabled by Smart Meters);
- Restrictions on retail regulation would need to be removed; and
- There would be the need for a facility to address the small percentage of homes and businesses affected when the model does not produce a price outcome similar to that of larger markets.

The mobile phone industry is a good example of how an energy services model would be experienced by the consumer. Free or heavily discounted equipment (phones) are currently provided under varying contracts according to need, usage and desire to hedge against risk. In the case of an energy service approach, a consumer would buy an energy service, much in the same way they subscribe to a high use mobile phone service. The hardware (which produces significant energy efficiency gains) would be underwritten by the service provider as they could then deploy such assets with a guaranteed cash flow, under a service contract. Under certain conditions, this model may result in different prices set on air-conditioners depending on agreed reliability standards. Technological advancements, such as efficient storage devices, could offer greater opportunity for innovation. Having a market incentive for such technological advances will help facilitate them.

Endnotes

1 Reserve Bank of Australia, *"How are electricity prices set in Australia"* accessed at http://www.rba.gov.au/foi/disclosure-log/pdf/101115.pdf on 4 March 2012.

2 Department of Resources, Energy and Tourism 2011, *Draft Energy White Paper 2011 – Strengthening the Foundation for Australia's Energy Future*, Australian Government, p.172, accessed at www.ret.gov.au/energy/facts/white_paper/draft-ewp-2011/Pages/Draft-Energy-White-Paper-2011.aspx, 9 January 2012.

3 Queensland Government, Office of Climate Change, accessed at: http://www.climatechange.qld.gov.au/pdf/factsheets/1energy-b1.pdfon 4 March 2012.

4 The Australian Energy Regulator has taken over many of these functions and is Australia's national energy market regulator.

5 Energy Networks Australia 2008, *"Demand Management Regulatory and Policy Framework"*, p. 15.

6 These problems have been illustrated in the Australian Energy Market Commission report *Power of Choice: Directions Paper,* Supplementary Paper: Demand Side Participation and Profit Incentives for Distribution Network Businesses, 23 March 2012, in particular page 1.

7 Department of Resources, Energy and Tourism 2011, *Draft Energy White Paper 2011 – Strengthening the Foundation for Australia's Energy Future*, Australian Government, p.175, accessed at www.ret.gov.au/energy/facts/white_paper/draft-ewp-2011/Pages/Draft-Energy-White-Paper-2011.aspx, 9 January.

8 Ibid, p. 175.

9 The time period for consideration would be important. The Australian Energy Market Commission report *Power of Choice: Directions Paper*, Supplementary Paper: Demand Side Participation and Profit Incentives for Distribution Network Businesses, 23 March 2012, noted: "A key factor in determining this [potential savings] amount will be the length [Demand Side Participation] is implemented to the next regulator test. Stakeholders raised concerns about the five year regulatory period being too short to encourage such innovation."

10 The Australian Energy Market Commission report *Power of Choice: Directions Paper,* Supplementary Paper: Demand Side Participation and Profit Incentives for Distribution Network Businesses, 23 March 2012, p 25-26.

11 For example, the New South Wales Energy Savings Scheme operates by imposing a legal liability on large energy retailers in NSW to contribute to energy efficiency measures by acquiring and surrendering Energy Saving Certificates.

12 Fox-Penner, P 2009, 'Fix Utilities Before They Need Fixing', *Harvard Business Review*, July, accessed at http://hbr.org/2009/07/fix-utilities-before-they-need-a-rescue/ar/1, 9 January.

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