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Submission to the

Energy White Paper Issues Paper

by

The Australian Academy of Technological Sciences and Engineering

(ATSE)

to

Department of Industry
Australian Government

February 2014

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President
Dr Alan Finkel AM FTSE

The Secretary
Energy White Paper Taskforce
Department of Industry
GPO Box 1564
CANBERRA ACT 2601

7 February 2014

Dear Sir/Madam

ATSE Submission: Energy White Paper Issues Paper

The Australian Academy of Technological Sciences and Engineering (ATSE)[1] welcomes this opportunity to provide some high-level input to the Government's Energy White Paper Issues Paper. In doing so, ATSE has limited its comments to the terms of reference of the issues paper. ATSE is in the process of developing an Energy Policy Statement, which will be made available to the Government in the coming months.

Given the complexity of energy policy into the future, ongoing consultation by the Government with robust, independent, and evidence based sources of advice will be essential. ATSE is well qualified to assist government in developing evidence-based policy and has undertaken a large amount of relevant research, including *Green Growth Energy: Industry Opportunities for Australia*; *Nuclear Energy for Australia?*; and *Low-Carbon Energy: Evaluation of New Energy Technology Choices for Electric Power Generation in Australia*. Further details of ATSE's work in this area can be found on the ATSE website: www.atse.org.au.

Energy is essential to Australia's economy and therefore an effective energy policy is critical to Australia's competitiveness, economic growth and national productivity. ATSE notes that the issues paper correctly identifies an extensive list of issues, all of which must be incorporated into a comprehensive energy policy for Australia's future. Thus, the key challenge will be to integrate the many interconnected aspects that are involved in the generation, deployment, and utilisation of energy into a policy approach that will deliver long-term sustainable, affordable, reliable energy supply. These aspects cannot be considered in isolation.

ATSE welcomes the approach being taken by the Government, in which the development of the Government's Energy White Paper will be overseen by an Expert Reference Panel, to consult a range of relevant stakeholders. However ATSE notes the need for wide policy dialogue with industry, governments and community.

[1] ATSE advocates for a future in which technological sciences, engineering and innovation contribute significantly to Australia's social, economic and environmental wellbeing. The Academy is empowered in its mission by some 800 Fellows drawn from industry, academia, research institutes and government, who represent the brightest and the best in technological sciences and engineering in Australia. The Academy provides robust, independent and trusted evidence-based advice on technological issues of national importance. ATSE fosters national and international collaboration and encourages technology transfer for economic, social and environmental benefit. www.atse.org.au

There are 4 key themes to ATSE's submission:

- Energy Policy is multifaceted and needs appropriate balance, national coordination and a long-term framework;
- New technology investment and expertise is required;
- Australia must transition to low emission energy; and
- Regulation and market design matters.

In this submission, ATSE has taken the opportunity to provide two brief case studies to illustrate the complexities of individual components of an energy policy (Appendix 1: Support for commercial adoption of new technologies; and Appendix 2: The low voltage exchange network).

ATSE has identified three key national technology priority areas for energy that align with those flagged by the Government:

- Systems to deliver affordable, secure and reliable electricity supply with low life-cycle impact;
- Supply systems for low life-cycle impact transport energy; and
- Identify and support new measures to improve energy efficiency.

These three areas need to be developed concurrently in building a long-term, stable energy policy setting for Australia's transition to economic low environmental impact energy supply and use.

ATSE is developing implementation Action Plans for each of these areas that we will provide to the Taskforce in due course.

ATSE looks forward to continued participation in the Government's Energy White Paper consultation process.

The contact at ATSE is Dr Lauren Palmer (Senior Research and Policy Officer) on (03) 9864 0903 or via email at Lauren.Palmer@atse.org.au.

We look forward to ongoing constructive dialogue with the Energy White Paper Taskforce Secretariat. I assure you that the expertise of the Academy will be made available to the government on this important activity.

Yours faithfully

Dr Alan Finkel AM FTSE
President

Energy White Paper 2014 – Issues Paper submission template

Details of person making the submission

First Name	
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Country (if not Australia)	
State	**Victoria**
Company or Organisation (if relevant)	**The Australian Academy of Technological Sciences and Engineering (ATSE)**
Position in Organisation (if relevant)	
Type of Organisation. Please choose from the dropdown list right	**Non-Government Organisation**
Sector. Please choose from the dropdown list right	**Professional, Scientific and Technical Services**
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Confidentiality

☐	**Submissions may be published on the Department of Industry website.** **If you do not wish to have your submission made public, please tick the box.**

Issues for comment are listed against each of the Chapter Headings. In making your submission, you are welcome to make comment against some or all of issues in the fields provided. A field for general comments is provided at the end of the template.

Executive Summary

The Australian Academy of Technological Sciences and Engineering (ATSE)[2] welcomes this opportunity to respond to the call for submissions to the *Energy White Paper Issues Paper*. This ATSE submission draws on input from a number of ATSE Fellows and has limited its comments to the terms of reference of the issues paper.

Historically, energy and energy technology transitions have always required a long, difficult and complex journey before successful achievement. The private sector has brought, and will continue to bring, to market new energy technologies and products for a low emissions future. This provides governments with options that can utilise local energy resources, and energy users with choices for the management of their energy supply, use and cost.

The investment horizon of energy production, generation, and transmission projects is very long, typically several decades. In recent years, Australia's energy and climate policies have been in a state of flux, which has failed to underpin a favourable investment environment.

No one policy aspect will achieve sustainable and affordable energy. Energy efficiency and consumer behaviour will deliver approximately one third of the target, transition to new technology and research and development (R&D) about one third and market reform, intelligent grids and smart meters the remainder.

The following key themes (points 1-4 below) therefore emerge throughout this submission. They are based on the fact that an effective energy policy is critical to Australia's competitiveness, economic growth and national productivity and that the cost of energy is embedded in all goods and services that Australia produces.

1. **Energy policy is multifaceted.**
    - *Appropriate balance*. The Commonwealth Government must determine the most appropriate balances between the key issues of energy security and reliability; affordability and international competitiveness; universal availability and sustainability, and embed these core values into long term policy.
    - *National policy coordination.* Australian Governments must develop a comprehensive energy policy that, integrated with industry policy and aligned with emission reduction targets, will deliver reliable, affordable and sustainable energy supply.
    - *Long term policy framework***.** A long-term and consistent policy framework is required to facilitate the least-cost energy transition; this is a crucial role for governments.

2. **New Technology Investment.** Existing technologies are currently unable to meet the Government's emissions reduction targets. New low-emission energy supply and use technologies will need to be developed and deployed. However, the existing structure of Australia's energy supply industry is such that it is unlikely to generate sufficient investment in innovation on its own. For Australia to be a developer, adopter and smart buyer of technology, it is imperative that there is research, development and demonstration (RD&D) investment and an expertise base here in Australia to harness new technologies and adapt these to Australian conditions.

[2] ATSE advocates for a future in which technological sciences, engineering and innovation contribute significantly to Australia's social, economic and environmental wellbeing. The Academy is empowered in its mission by some 800 Fellows drawn from industry, academia, research institutes and government, who represent the brightest and the best in technological sciences and engineering in Australia. The Academy provides robust, independent and trusted evidence-based advice on technological issues of national importance. ATSE fosters national and international collaboration and encourages technology transfer for economic, social and environmental benefit. www.atse.org.au

3. **Transition to low emission energy.** There is a critical role for government to foster and support the transition to low-emission energy technologies. New low-emission technologies generally will, at least initially, cost more than existing high emission ones. Coal will remain a predominant energy resource as Australia transitions its energy sources. Natural gas, including coal seam and shale gas, can be a transitional fuel until lower emission technologies become economically competitive.

4. **Regulation and market design matters**. Desired sectoral changes must be driven by market forces and enabling regulatory regimes. For example, should Government regulatory and tax regime policies allow (or even encourage) rapid retirement of Australia's low-efficiency, high emission coal-based electricity plants, then deployment of options such as high efficiency coal and gas plants, renewable electricity and nuclear power generation will be facilitated.

Energy is a complex field that underpins our economy and way of life. Australia now has to have a mature discussion about our energy policy, including how it is connected to industry, climate and social policies.

To achieve this, ATSE encourages wide dialogue among suppliers and users of energy together with governments to develop solutions for Australia's long-term energy future. Without such a mature dialogue, Australia's energy future will continue to be dominated by competing vested interests and a lack of significant investment for that long-term future.

1. The Security of Energy Supplies

The Government seeks comment on:

- ways community expectations can be better understood and reflected in reliability standards;
- the value of developing fuel reserves to meet Australia's international oil security obligations, and augment domestic security;
- ways to increase new gas sources to meet demand and measures to enhance transparency in market conditions; and
- issues relating to the regulation of energy infrastructure.

Please provide any comments on The Security of Energy Supplies below:

Ways community expectations can be better understood and reflected in reliability standards;
Australian consumers expect energy supply to be assured and will react harshly if they cannot access the energy they feel they need. However, as has become increasingly clear in recent years, high reliability standards can come at a significant cost. To make informed decisions that trade off the costs and reliability of supply, consumers need access to good information. However there is currently little understanding of the implications of meeting existing reliability standards, or the cost implications of changes to those standards. For example, the cost of providing high reliability in the context of variable supply-types (wind and solar) should also be made apparent.

The present reliability standards are whole-of-system and do not inform most energy users. Energy reliability standards should be consumer centric and not favour the supply side. Access to reliability information that reflects actual energy user inconvenience is essential before any decision is made to reduce standards.

To this end, Australia's energy suppliers (electricity, gas, and liquid fuels) should be required to provide clearly articulated information to energy users about the trade off between costs and reliability of supply. ATSE believes that energy suppliers should have a very high understanding of their customers' energy needs and the implications of changes in reliability standards. If not, they should take steps to obtain that information and make it available to their customers.

The value of developing fuel reserves to meet Australia's international oil security obligations, and augment domestic security;
Australia is currently not meeting its International Energy Agency (IEA) treaty obligations to hold the equivalent of 90 days of net oil equivalent demand.

The Australian Government needs to determine what value it places on meeting these obligations. Since Australia is an international price taker, one option is to be a 'free rider' relying on the IEA emergency sharing mechanism to use other member countries' stocks to alleviate the impacts of short-term market disruptions. Other countries may not be happy with this approach.

However, there are a number of options if the Government wants to meet its international obligations. For example on the supply side Australia could use one or more of the following:

- requiring fuel importers to hold more stocks
- building its own stockholding facilities
- leasing stocks from other countries

The Government could also reduce the amount of stocks that would need to be held by encouraging or accelerating:

- changes to the mix of transport modes and technologies for the mobility needs of people and goods.
- precompetitive exploration and the release of acreage in new frontier offshore basins and exploration of on-shore unconventional resources.
- enhanced research, development and demonstration of alternative liquid fuels technologies including biofuels, oil shale, coal-to-liquids and gas-to-liquids, etc.

Ways to increase new gas sources to meet demand and measures to enhance transparency in market conditions; and
Australia has significant conventional gas resources. However they are often in remote locations and far from potential markets.

New technologies provide the opportunity for the discovery and development of new (unconventional) oil and gas reserves. However, the oil and gas industry faces many challenges and, especially for on-shore developments, an at times fragile social licence to operate.

The recent Australian Council of Learned Academies (ACOLA) report, *Engineering Energy: Unconventional Gas Production – a study of shale gas in Australia*[3], examined in detail the potential technological, environmental, social and economic impacts of an Australian shale gas industry. This ACOLA Report highlights that the shale gas industry must first earn then retain a social licence to operate if it is to succeed.

Many factors are crucial to building community confidence including effective regulations, codes of practice, monitoring and verification, transparency and the requirement to remediate problems quickly if they arise.

The Government has a crucial role to play in the gas industry to streamline effective regulations and codes of practice and to facilitate industry operation at international best practice in order to build social licences to operate.

Issues relating to the regulation of energy infrastructure.
See response to Question 3.

2. Regulatory Reform and Role of Government

The Government seeks comment on:

- priority issues, barriers or gaps within the COAG energy market reform agenda;
- possible approaches and impacts of review of tariff structures including fixed network costs, further time-of-use based electricity tariffs and the use of smart meters;
- possible measures to promote greater price transparency in gas markets; and
- areas where further privatisation of government-owned assets would contribute to more effective regulatory frameworks and better outcomes for consumers.

[3] Cook, P., Beck, V., Brereton, D., Clark, R., Fisher, B., Kentish, S., Toomey, J., and Williams, J., *Engineering Energy: Unconventional gas production,* Report for the Australian Council of Learned Academies, (2013). http://acola.org.au/index.php/projects/securing-australia-s-future/project-6

Please provide any comments on Regulatory Reform and Role of Government below:

Priority issues, barriers or gaps within the COAG energy market reform agenda
Regulatory frameworks and incentives influence behaviour. Hence they should be designed with clear objectives in mind, such as encouraging efficient behaviour by both suppliers and users of energy, enhanced levels of innovation and more sustainable outcomes.

For example, price setting regulations should apply a CPI-x type[4] approach to price increases to incentivise companies to improve efficiency through investment in new processes, technologies and other means.

Regulations should ideally be designed with clearly stated, long-term, strategic objectives rather than reacting to the emergence of short-term issues. The business sector stresses the need for market and regulatory stability. However, this does not mean that policies and regulation should not be reviewed or allowed to evolve as technologies change and new solutions are offered.

Possible approaches and impacts of review of tariff structures including fixed network costs, further time-of-use based electricity tariffs and the use of smart meters; and possible measures to promote greater price transparency in gas markets.
Despite rising electricity prices (more than doubling since 2005), peak demand continues to grow. Meanwhile, the uptake of variable renewable energy including wind and rooftop solar photovoltaics (PV) supported by Commonwealth, State and Territory subsidies has contributed to reducing average demand. The effect of these trends is to require increased network infrastructure investment to meet peak demand within existing reliability standards, which is paid for over a lower annual energy demand.

The changing nature of both the demand for electricity and the supply of domestically generated electricity is putting financial pressure on some of the incumbents in the electricity sector and leading to calls for changes in the ratio of revenue gained from service connection charges and consumption charges. While consumers should pay for the capacity that they may require at any given time as well as a premium for energy that they choose to use at high cost times, designing tariff structures is a challenging task, and it is extremely important to get the structure right. Tariff structures do influence behaviour and drive change not only at the user/customer end but also throughout the supply chain.

Hence any response to such calls for changes to tariffs needs to be considered very carefully. This includes considering what message any changes might send about the role that new technology can play and whether it implies that some energy firms can be put in the same 'too big to fail' category as was applied to some financial institutions during the global financial crisis.

Ongoing support for existing business models in favour of new approaches can have significant long-term implications for innovation and the uptake of new technology. It is usually shown to be both politically difficult and economically inefficient to try to 'hold back the tide' when new technologies that can deliver better and or cheaper outcomes are available to consumers.

Ultimately, it is important that tariff structures should appropriately reflect the production and delivery costs of energy supply, including external costs such as emissions, if they are to send a message to consumers.

[4] CPI-x: is a term that is used to refer to price cap regulation that determines a utility's return on investment by linking the price they obtain to the rate of inflation (measured by the Consumer Price Index (CPI)) minus some amount (x) to encourage efficiency.

Areas where further privatisation of government-owned assets would contribute to more effective regulatory frameworks and better outcomes for consumers.
Provided energy firms operate in a corporate and competitive manner, the regulator is independent and regulations encourage efficiency in energy production and delivery, then the ownership structure is largely a political decision. ATSE would not expect that the private ownership of energy firms would make much difference to most consumers.

3. Growth and Investment

The Government seeks comment on:

- commercial or market initiatives that could enhance growth and investment in the energy and resources sectors;
- areas where approvals processes could be further streamlined while maintaining proper environmental and social safeguards;
- further ways that regulatory burdens could be reduced while maintaining appropriate levels of disclosure and transparency in energy markets; and
- the impacts of variable land access policy and ways the community could be better informed and engaged on development in the energy sector.

Please provide any comments on Growth and Investment below:

Australia is dependent on international investment for the long term development of our energy infrastructures.

Investment decisions are driven by an investor's view of investment risks versus their return on that investment. Firms will assess a whole range of risks and how they each can be managed/mitigated.

Stability of policy is one such risk. Perceptions of the likelihood of policy change will be dependent on Government decisions. There is a balancing act in the policy arena that should be driven by high-level strategic choices about the factors that relate to energy security and local industry development.

Again, Government decisions matter. *Government funded R&D is a key driver for the development of new energy technologies. Similarly, higher costs for new technologies (at least initially) means that incentive schemes have been—and remain—key drivers for the uptake of low-emission energy technologies. These funding schemes also help grow skills and related businesses*.

4. Trade and International Relations

The Government seeks comment on:

- how to grow the export of value-added energy products and services;
- ways to remove unnecessary barriers to continued foreign investment in Australia's energy sector;
- ways to strengthen support for access to export markets; and

- ways to support business to maximise export opportunities for Australia's energy commodities, products, technologies and services, including the value of Australia's participation in the variety of international forums.

Please provide any comments on Trade and International Relations below:
Please see response to Question 7. We also note that Australia has many specialist technological products and related services to export. However, all too often the businesses involved (typically small to medium sized enterprises (SMEs)) or even individual entrepreneurs do not have the knowhow or confidence to 'cold call' in international markets. The Australian Government Trade Commission and diplomatic support can enhance meaningful contacts with overseas counterparts, either as customers or prospective local joint venturers.

5. Workforce Productivity

The Government seeks comment on:

- the nature of any current skills shortages being experienced and how these could be addressed by and with industry;
- the capacity of industry and education sector-led programs to meet long-term training and skills development needs of the energy and resources sectors; and
- specific long-term training and skills development needs for alternative transport fuel, renewable energy, energy management and other clean energy industries.

Please provide any comments on Workforce Productivity below:
There is likely to be future science, technology, engineering and mathematics (STEM) skill shortages with the current decline in STEM skilled graduates for particular industries. A recent STEM Education Action Statement from ATSE highlights the need to improve the quality and reach of STEM education and skills for an innovative, knowledge-based workforce that is able to meet national challenges.[5] In addition, this Action Statement states that universities must provide broader attribute training in undergraduate and postgraduate STEM courses such as project management, research translation and critical thinking, in addition to established professional standards and requirements. The government needs to address this issue as a matter of importance to prevent a shortage of a future STEM skilled workforce. There are some areas where Australia has good strengths in energy development, and there is potential for Australia to learn from the overseas experience. We need to keep encouraging industry and academia to have a dialogue to identify potential future skill shortages. We need to ensure Australia is producing science, maths and engineering graduates and technicians who can fill these gaps in workforce skills and meet the needs for the adaptation, operation and maintenance required for new, more efficient and lower emissions electricity generation and delivery, alternative transport fuels, renewable energy, energy management and other clean energy industries. *A national energy innovation policy must encourage improved education and training to maintain a competitive advantage as well as to pursue internationalisation through mobility*. This should focus on both developing home-grown R&D talent as well as attracting international talent to Australia, and

[5] ATSE, *Advancing STEM Education*, Science and Technology Action Statement, September 2013, http://www.atse.org.au/Documents/Publications/science-technology-action-statement.pdf

fostering a culture of globally connected researchers and industry to encourage inward streams of investment, information and skills.

6. Driving Energy Productivity

The Government seeks comment on:

- the current suite of energy efficiency measures, ways these could be enhanced to provide greater energy efficiency or possible new measures that would enhance energy productivity;
- the use of demand-side participation measures to encourage energy productivity and reduce peak energy use; and
- measures to increase energy use efficiency in the transport sector.

Please provide any comments on Driving Energy Productivity below:

Decisions on energy productivity policy directions in the Energy White Paper should be informed by experience from past and current programs such as the *Solar Cities Demonstration Programme*, the *Smarter Grids, Smarter Cities Ausgrid Trial,* and the *Energy Efficiency Opportunities Program*.

The current suite of energy efficiency measures, ways these could be enhanced to provide greater energy efficiency or possible new measures that would enhance energy productivity.
Energy efficiency measures would be enhanced by consumers (residential and commercial in particular) having access to additional and better information on consumption. Smart meters and smart appliances will assist consumers to identify when and where energy is being consumed and to make more informed decisions on saving energy and reducing costs. Existing energy efficiency standards need to be complemented by appropriate oversight and enforcement.

Recent significant electricity price increases have encouraged enhanced energy efficiency, reduced discretionary consumption and also encouraged product manufacturers to improve the efficiency of their processes and products. Putting a price on any environmental externalities associated with energy use provides an appropriate signal for producers and consumers to change behaviour.

Policies and programs that increase the flow of information about opportunities for energy efficiency are an appropriate area for governments to play a role, while regulations will be an important strategy for widespread implementation and impact. Any financial support for implementing energy efficiency (or emissions reductions) projects must be targeted in a way that ensures that the project outcomes are additional to business-as-usual.

The use of demand-side participation measures to encourage energy productivity and reduce peak energy use.
Ideally the use of smart meters in conjunction with voluntary demand management would be complemented by Dynamic Demand management in which individual, variable loads can switch on or off during times of system stress to balance the overall system load with generation.

Australian Governments need to encourage research and development of demand side management technologies and systems including investment into their deployment and integration into the distribution network and power system using smart network technologies. In particular, R&D into energy storage technologies should be an area of focus. Sales of air-conditioning units will continue to drive peak demand. Increased investment in efficient and inexpensive storage technologies could go a long way in helping reduce peak demand.

In addition, enabling and encouraging communities, businesses and industries to make changes to their electricity use during peak periods, could help alleviate the peak load problems. A recent IEA report[6] suggests that deployment of smart grids could reduce projected peak demand increases by 13-24% during the timeframe of 2010-2050 for certain regions. The Government should build awareness on the benefits of smart grids (to utilities and consumers) and ensure consumers are engaged in the development and deployment of smart grids.

Measures to increase energy use efficiency in the transport sector.
Improving the efficiency of energy use in the transport sector can bring many benefits, including reduced reliance on imported liquid fuels, lower emissions of greenhouse gases and reduced stock holding obligations under the IEA's emergency oil sharing arrangements.

The ability to reduce fuel costs ought to provide a natural incentive for efficient energy use in all sectors, including the transport sector. However, experience has shown that the demand for transport fuel is relatively inelastic. The short term transport task that consumers are seeking is not greatly affected by fuel price. Decisions on what vehicles to buy are usually long term ones.

Fuel economy standards are one (longer term) measure to encourage efficiency in the transport sector.

There is considerable global R&D being conducted to develop transport options that use alternative liquid fuels or electric storage systems. The widespread deployment of the latter could have significant implications for areas outside the transport sector. The widespread adoption of battery electric vehicles and plug in hybrid electric vehicles could be an important driver of efficient, low cost, energy storage devices and will demand substantial changes to the low voltage exchange network. That storage capability could have important implications for the electricity sector both as a demand management tool and by potentially enabling consumers with PV panels to store and use the electricity that they have generated. This is further discussed in the case study provided in Appendix 2.

Australia can be a fast follower in all transport sectors—including aviation, maritime and land transport—if Governments' priorities and polices encourage the accelerated adoption of new technologies. If encouragement is not provided, then change in the transport sectors will occur on a natural, but much longer, timeframe.

7. Alternative and Emerging Energy Sources and Technology

The Government seeks comment on:

- ways to encourage a lower emissions energy supply that avoids market distortion or causes increased energy prices;
- the need to review existing network tariff structures in the face of rapidly growing deployment of grid-backed-up distributed energy systems, to ensure proper distribution of costs;

[6] International Energy Agency (IEA), *Technology Roadmap: Smart Grids*, 2011
http://www.iea.org/publications/freepublications/publication/smartgrids_roadmap.pdf

- additional cost-effective means, beyond current mandatory targets and grants, to encourage further development of renewable and other alternative energy sources and their effective integration within the wider energy market;
- how the uptake of high efficiency low emissions intensity electricity generation can be progressed;
- any barriers to increased uptake of LPG in private and commercial vehicles and CNG and LNG in the heavy vehicle fleet; and
- any barriers to the increased uptake of electric vehicles and advanced biofuels.

Please provide any comments on Alternative and Emerging Energy Sources and Technology below:

Making the transition to a lower carbon economy is a long and expensive process. New technologies will need to be developed and deployed. Given the Government's target for the reduction of emissions, development and deployment of low emission energy supply and use technologies must be accelerated.

For this to occur it is widely accepted that both 'technology push' and 'market pull' measures are required. Examples of the former include support for R&D and demonstration programs, while market pull measures include policies such as feed in tariffs, mandated targets with financial certificates and a price on carbon emissions. Feed in tariffs in particular need to be regularly adjusted as the price of new technologies come down.

Ways to encourage a lower emissions energy supply that avoids market distortion or causes increased energy prices
The objective of achieving lower emissions energy supply while avoiding market distortion or higher energy prices is certainly a desirable one. Some might argue that it is the 'holy grail' of energy policy. Unfortunately, that outcome is as likely to be as difficult to achieve as finding that fabled grail because, as noted in the introduction to this submission, new technologies will almost invariably cost more than existing ones (at least initially).

The challenge then is to develop and deploy new lower emissions energy technologies with as low as possible impact on prices.

There are many different energy technology options under development. It is unlikely that Australia can provide support for all of them. Decisions on which technologies to support need to be taken in the context of the scale of emissions reductions they might enable, their impact on industry development within Australia and Australia's ability to contribute to the global and local effort to bring them down the cost technology learning curves.

The transition to a low emissions energy sector will not be possible without affordable, technologically reliable solutions. This requires research and technical innovation. *In the absence of stable policy settings and a strong signal on the future price of carbon, the energy industry has little incentive to invest in low emissions energy R&D*.

Large energy suppliers need to be encouraged to invest in more R&D and to support SMEs who are prepared to do so, particularly where the work is either unique to Australia (in areas nobody else is interested in) or where it is of particular value to Australia (such as underpinning more sustainable use of coal). ATSE recently provided a submission on the Governments proposed Tax Laws Amendment (Research and Development) Bill in which the Government proposes the withdrawal of the R&D support measures from companies with revenue of over $20 million. Technological innovation, underpinned by R&D is a key driver of productivity and international competiveness for

Australia and ATSE is concerned that passing this Bill would have severe impacts on Australia's productivity.

Furthermore, the Australian energy industry is generally not a supplier of technology and equipment; rather it deploys technologies developed and manufactured overseas. It is appropriate in these circumstances for Governments, both Commonwealth and State, to intervene to stimulate Research, Development and Demonstration (RD&D). Governments need to take a strategic approach to investments in RD&D for new energy technologies. Technologies where Australia can play an active role in their development (such as enhanced geothermal systems, carbon capture and storage, microgrids and aviation biofuels[7]) and where Australia can be a fast adopter and where there are advantages to doing so (such as concentrated solar thermal, grid stability and energy storage).

There are various ways to support RD&D into low emissions energy technologies, including:

- direct R&D grant funding;
- R&D tax concessions;
- accelerated depreciation of investments in exploration, plant and infrastructure; and
- support for demonstration projects (either in Australia or in collaboration with overseas partners).

These mechanisms operate at different points across the innovation continuum. The design of support measures to encourage progression of low emissions technologies from development through to commercial deployment is crucial. Getting the design of any support measures right is critical because the measures are by their nature seeking to drive the market in a particular direction, or in a direction it might not otherwise go. Things to consider are:

- setting caps on incentives;
- having limited duration for incentives; and
- specifying required levels of co-investment from the private sector.

These points are considered further in Appendix 1.

Implementing large-scale demonstration projects has proven to be extremely challenging in Australia and worldwide. National and international collaboration with private and public sector organisations and initiatives should be an important efficiency and effectiveness element to any large-scale demonstration program and projects.

For large-scale demonstration projects (e.g. solar flagships, Carbon Capture and Storage (CCS) flagships and the like), in order to ensure that the activity remains demand driven and outcome focussed, costs should be shared with the private sector. The appropriate cost sharing ratio will vary according to the perception of the level (and nature) of risks associated with a particular technology. For example, first-of-a-kind (FOAK) demonstration plants may require higher levels of public support.

There are many different support mechanisms that can be used to support large scale demonstrations. All have different strengths and weaknesses. Having a good understanding of these is vital as choices about which support mechanisms are appropriate are important and need to be carefully made.

The timeframes for R&D need to be aligned with realistic and risk optimised schedules for

[7] ATSE, *Green Growth Energy: Industry Opportunities for Australia; Nuclear Energy for Australia?*, 2013, http://www.atse.org.au/atse/activity/energy/reports/atse_green_growth_report_2013/content/activity/energy-content/atse_green_growth_energy_report_2013.aspx

demonstration projects. Inevitably there will be some overlap between the commercial deployment of new technologies and the development of emergent technologies. Whilst there should be flexibility in allowing projects access to multiple programs, measures should be taken to avoid duplicate funding of projects from the public purse.

The need to review existing network tariff structures in the face of rapidly growing deployment of grid-backed-up distributed energy systems, to ensure proper distribution of costs
Great care should be taken in this area, as poorly designed or implemented measures to this end could have significant unintended (negative) consequences. Please see earlier comments.

Additional cost-effective means, beyond current mandatory targets and grants, to encourage further development of renewable and other alternative energy sources and their effective integration within the wider energy market
Early movers already face higher investment costs and greater technical risk. Any regulatory uncertainty would only serve to exacerbate the barriers to new technology deployment. Without a revenue advantage (such as provided by a price on carbon or the Renewable Energy Target (RET)) the higher technical and revenue risks will make financial backing for these projects much more difficult or impossible to obtain.

Therefore Australia's energy policies must include interim financial support for low carbon technologies if we are to see the necessary deployment of capacity needed to meet our clean energy targets. For example, offering revenue support through a Contract for Difference (CFD) structure may provide the government with a lower cost burden in light of future carbon price uncertainty, relative to providing supplementary revenue streams of fixed value, for example, feed in tariffs. CFD's could support the full suite of low emissions technologies including renewable power projects, thus eliminating the need for the Renewable Energy Target and feed in tariffs. The United Kingdom Department of Energy and Climate Change selected CFD's as a support mechanism to stimulate investment of low emissions technologies in the power sector.

Understanding the implications of increasing penetration of variable energy sources will be important. Since the introduction of the RET, the penetration of renewable energy into Australian power systems has increased, and according to forecasts, the share of renewable energy sources is expected to continue to grow—and grow rapidly. Increased penetration of renewable energy production will require renewable generators to become more active participants in maintaining the stability of the grid during power system contingencies.

As noted earlier, energy storage will become increasingly important for the management of supply from variable sources. *Encouraging the development and demonstration of energy storage at various levels throughout electricity networks is important to gain confidence in their operation and to participate in the global learning curve for energy storage technologies*. We would expect that the increasing penetration of electric vehicles will be an important driver of storage technology and help push costs down. The decline in cost could be similar to that already seen for PV cells. This would have very important implications for electricity system.

How the uptake of high efficiency low emissions intensity electricity generation can be progressed
There needs to be an incentive to lower emissions. There are various mechanisms that can create that incentive, for example:

- by mandating shares of lower emissions technologies (such as with the RET)
- by mandating generation efficiency standards (as has been done in the USA)

- by establishing a pricing mechanism to create a market signal to drive behaviour (such as setting a price on carbon emissions).

Coal

Australia will rely on coal for electricity supply for a long time to come. To reduce emissions, we need to move more quickly from the current subcritical power generation to available (supercritical and ultra-supercritical) and emerging high efficiency technologies.

New technological developments in cost-effective dewatering and drying; new developments in significantly lower emission power generation technologies; and new transport infrastructure for export of dewatered dry brown coal from the Latrobe Valley could provide a paradigm shift to higher efficiency, lower greenhouse gas intensive brown coal fired processes. The uptake of high efficiency low emissions electricity generation could also be progressed through the following: direct injection carbon engine; micronized refined coal (MRC) slurry from Latrobe Valley brown coal; or dewatering and drying brown coal.

However, *it is difficult to see how transition to low emission coal utilisation can occur in the absence of some form of carbon price signal, tougher generation efficiency standards and/or policies to accelerate the retirement of old, less-efficient plants*.

Gas

The ACOLA[8] report highlighted that increased use of gas, particularly shale gas, in place of coal for electricity generation could significantly decrease Australia's greenhouse gas emissions. However, with most of the announced coal seam gas reserves committed to the LNG industry from 2015/16, there is the potential for domestic gas shortages in Eastern Australia. This is a potential driver for the development of a shale gas industry in Australia. However, shale gas will not be cheap gas. Production costs are likely to be significantly higher in Australia compared to North America. That and the fact that export parity pricing will apply is likely to ensure that gas prices remain high.

Australia must act quickly to assess its shale gas reserves and resources, as well as consider the potential social, economic and environmental impact of shale gas production. However, Australia should not simply follow the North American example of shale gas development. There was a gas and petroleum shortage in America, but not in Australia. We need to find ways to (1) better distribute gas in Australian markets to achieve immediate emissions reduction while (2) maximising Australia's financial benefit from our gas exports.

Nuclear

ATSE believes that nuclear energy should be considered as part of Australia's future energy generation portfolio. ATSE recently held a conference on *Nuclear Energy for Australia?* The ATSE Conference Communiqué[9] addresses Australia's necessary preparatory steps for the adoption of nuclear energy, the importance of social and political acceptance and the key issues of pollution reduction and risk management. The more detailed *Nuclear Energy for Australia? Conference Report*[10] identifies key policy issues including the need for a low emission generation portfolio mix and a long term stable bi-partisan policy. The Conference Communique notes that nuclear energy is

[8] Cook, P., Beck, V., Brereton, D., Clark, R., Fisher, B., Kentish, S., Toomey, J., and Williams, J., *Engineering Energy: Unconventional gas production,* Report for the Australian Council of Learned Academies, (2013). http://acola.org.au/index.php/projects/securing-australia-s-future/project-6

[9] ATSE, *Nuclear Energy for Australia?*, Conference Communique, 2013 http://www.atse.org.au/Documents/Events/ATSE-Nuclear-Energy-for-Australia-Communique.pdf

[10] ATSE, *Nuclear Energy for Australia?*, Conference Report, 2013 http://www.atse.org.au/Documents/Events/ATSE-Nuclear-Energy-for-Australia-Conference-Report.pdf

a viable candidate to replace ageing coal power stations in Australia.

Renewables

Renewable technologies, including wind and solar, are an important element of Australia's energy mix and will play a crucial role to moving to very low or zero intensity energy sources. Growth in renewable power generation will be dependent on the Government having policies that are conducive to investment in the sector.

Governments particularly should support appropriately the development of renewables in regional and remote communities where it is more expensive (and less efficient and more emission intense) to supply grid electricity services.

However, while renewable technologies are increasing market share in absolute terms, their share in the total energy mix is relatively small and likely will remain so for a long time ahead. Renewables should not be relied upon to deliver large-scale emissions reduction alone.

Any barriers to increased uptake of LPG in private and commercial vehicles and CNG and LNG in the heavy vehicle fleet; and any barriers to the increased uptake of electric vehicles and advanced biofuels.

Any barriers to the increased uptake of LPG, CNG, LNG, electric vehicles and advanced biofuels are chiefly related to cost (vehicles, vehicle conversions and/or fuel) and the availability of refuelling infrastructure. *If the Australian Government wants to encourage the use of these local fuels then it needs to develop policies to foster and support their supply and use.*

The uptake of compressed natural gas (CNG) and liquefied natural gas (LNG) in the heavy vehicle fleet will remain limited by infrastructure constraints – production, distribution and filling stations. Government incentives to facilitate investment in such infrastructure would seem to be important to increase the uptake of CNG and LNG.

In the coming years there will be an increasing number of electric vehicles in Australia. If the Government wants to accelerate the uptake of electric vehicles it will need to develop a policy on it. If Government does not do this, change will occur in a natural, longer timeframe.

For example, there currently is not a strong business case for motor vehicle purchasers to invest in electric vehicles. An increase in uptake of electric vehicles would be facilitated only by reducing the capital required to invest and by expansion of critical recharging infrastructure. In the near term, until electric vehicles and battery costs come down, Government may need to provide incentives through grants or other concessions to reduce the capital costs. Government will also need to lead the investment in public charging stations. Australia needs to encourage research and development into the electricity grid integration challenges of electric vehicles, including smart network technologies.

General Comments

Any further comments?
The Issues Paper does not sufficiently address the issue of emission reduction targets and sustainable/renewable energy sources, or how these should be integrated into energy policy. National energy policy cannot be formulated in isolation from the rest of the world nor in isolation from other policies. An integrated, whole of government approach is essential, for which there are both horizontal and vertical dimensions. National energy policy should be coordinated to the optimal extent with environmental policy, technological innovation policy and economic policy. This is the horizontal dimension of energy policy integration. National energy policy should also be calibrated to the optimal extent with foreign policy and trade policy and with all levels of government. Domestically, this should include Commonwealth, State, Territory and local governments. This is the vertical dimension of energy policy integration. *Creating a market and regulatory environment that encourages domestic and foreign investment in new, low emissions energy supply and use infrastructure and in innovation is crucial for Australia—and a clear role for Australian governments in conjunction with energy suppliers and users*.

Appendix 1: Support for Commercial Adoption of New Technologies

The Australian National Electricity Market (NEM) is one of the world's most competitive although that may be counter-productive in introducing high-risk, high-cost, first-of-a-kind (FOAK) technologies. Without special policy arrangements, to date applying only to a narrow category of renewables, new technologies must compete against established businesses with mature technologies, written down capital and lower production costs. This has been acknowledged in the past with the establishment of various Government support programs, though funds have usually been insufficient to make a material difference to industry decisions to adopt new high-risk technologies. The black coal industry has committed major funding ($1billion) to CCS demonstration as have some State governments, notably Victoria via its Energy Technology Innovation Strategy (ETIS) program, however, to reinforce the point and with a few notable exceptions, very little funding has actually flowed to demonstration projects in the past.

There will be perverse impacts in increasing the interruptible renewables component of the NEM which have a very low marginal cost, unlike base generation such as CCS and nuclear. Some minimum price needs to be established if the large investments in these technologies are ever going to take place.

Higher funding is required to establish previously planned demonstration plants. Promising programs have been reduced to more modest outcomes and longer timelines. Committed funding, or prospective funding based on pre-feasibility success, may relate only to major systems (for example sequestration) of the project, while funding attaches only to the FOAK component. It is well-known (and well evidenced with renewables development) that multiple demonstrations, typically five or more, are needed to approach maturity. Thus emerging technologies such as IGCC-CCS, PV or CST may require far more significant financial support, both capital and operating, than is presently envisaged (see Figure 1).

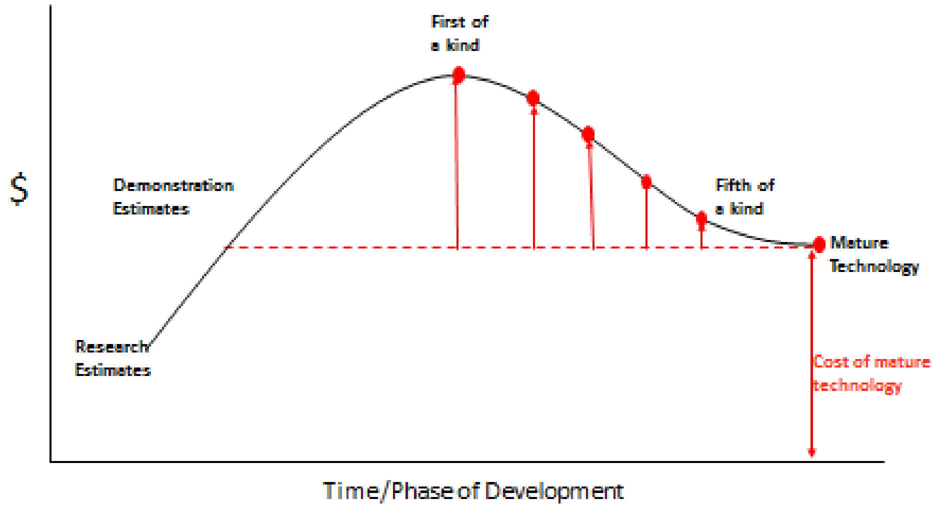

Figure 1: Cost Differential in Demonstrating New Technology and Additional Costs for Multiple First Movers

On-going operational support is critical. FOAK plant invariably has lower availability and higher O&M costs than the mature technology with which it must compete. Other first mover cost disadvantages include permitting and technology integration. Overall the first mover disadvantage applies not only to the first mover, but in reducing amounts to first n-movers where n is expected to be of the order of 5.

The principle incorporates plants of a similar kind demonstrated overseas, but local cost structures and technology knowledge do not mean that all such learning translates fully to Australia.

In a very competitive market such as the Australian NEM, each of these first movers will carry a greater financial burden than later movers and be at a commercial disadvantage. They will also be competing against existing players which have capital associated with a mature and different technology with known and likely lower operating costs.

The latter is important because first-of-a-kind plant invariably has lower availability and higher operating and maintenance costs than the mature technologies with which it will be competing in the NEM, for the life of the plant. Therefore achievement of maturity of a new technology such as IGCC-CCS, PV or CST may require significant financial support for up to (say) five fully integrated plants incorporating all the systems required to achieve low emissions power generation (Figure 1).

The issue is further complicated as new low emissions technologies with high Australian IP content, are at different places on the maturity cost curve. A modelling study is warranted to estimate the support needed to achieve a level playing field for new NEM entrants.

Such a model could be based on current mature Australian coal power costs, escalated for future carbon costs, discounted by the value of forecast lower carbon emissions, and incorporating capital and operating costs to be competitive in the NEM.

Introduction of the government’s Direct Action policy could provide some of the proposed funding support, but as currently proposed is unlikely to provide sufficient support to materially impact on industry decisions regarding adoption of new high-risk FOAK technology. Other options may include guaranteed feed in tariffs or supported power purchase agreements that apply to all other new lower emission power technologies, taking into account carbon emissions intensity.

Appendix 2: The Low Voltage Exchange Network: Can electric vehicle energy storage improve the effectiveness and uptake of rooftop solar PV?

Introduction

Battery-powered vehicles pre-date the internal combustion engines (ICEs) that have dominated road transport evolution over the past century. After a number of false starts, the world is again entering an era of unprecedented development of electric vehicles. The primary enabler is the combined reliability, improved performance and durability of Li-ion batteries. Over the last ten years of battery development both specific energy (Wh kg^{-1}) and cycle-life have risen dramatically while manufacturing costs have fallen markedly. Australia must prepare intelligently and appropriately for the inevitable advent of electric vehicles (EVs).

This paper is a broad examination of the many system changes that widespread use of EVs will call for in Australia's electricity supply grid, particularly to the local typically 415 V 3-phase distribution 'layer'. Consideration is also given to synergies between extensive ownership of EVs and the enhanced installation of rooftop PV systems for electricity generation.

The transition to efficient and economic use of these technologies will need well-informed planning in the early stages of their more universal uptake. The sum of the prospective economic and environmental benefits are substantial, when taken together from a holistic national point of view, but the challenges too are significant and need to be properly evaluated and managed.

The purpose of this Appendix is to outline the key issues and point the way to their effective assessment and sound economic management.

Findings and Recommendations

The paper concludes that the technological and economic issues that would accompany a rapid take up of EVs in Australia are substantial. These issues impact not only on EVs, their batteries and their owners, but also on the evolution of battery charging systems and improvements in grid operation, notably at the low-voltage (LV) level. Of particular interest, and consistent with government policies for promoting renewable technologies, is the unique opportunity offered for substantial growth in rooftop PV installations. Rooftop PV, now installed on over 1 million Australian homes, becomes significantly more attractive when combined with co-located energy storage. To this end, the paper references a number of high-quality Australian and international studies that relate to the uptake of EVs.

In summary, ATSE recommends the formation of an independent expert advisory panel, *inter alia,* to:

- consult widely with potential EV and support system stakeholders, both Government and industry;
- examine, model and report on the range of technological and economic impacts, both to EV owners and electricity system operators, that would arise from the extensive adoption of EVs in Australia;
- examine the impacts of EVs on the LV domestic distribution layer, typically 415 V 3-phase, of the electricity grid with particular reference to enhanced take up of rooftop PV;
- undertake stochastic electrical, financial and behavioural modelling;
- develop a roadmap for Australia, including broad costings and timings;
- advise on the broad quantum and appropriate sources of capital for necessary infrastructure modifications and upgrades; and
- submit a comprehensive report on the above actions to Government and industry stakeholders.

Towards adoption of Australian low-emissions-intensity power generation
The widespread installation of rooftop PV systems provides an attractive solution for low-emissions intensity charging of 'plug-in' electric vehicles – comprising Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs).

BEV propulsion is provided by one or more electric motors in the drive-train. There is no fuel tank and no emissions. Drive energy, stored in the on-board battery, is provided exclusively from the electricity grid or, possibly, a stand-alone PV or other charging facility. Overall system carbon intensity is dictated by that of the supply.

A PHEV is also driven by one or more electric motors but with the addition of an ICE with fuel tank that offers direct drive to the wheels or indirect drive by way of a generator. The battery can thus be charged by the grid or by the onboard generator, thus extending the vehicle's range. PHEVs are classified as 'series hybrid', in which the ICE powers only a generator for battery recharging, or 'parallel hybrid' in which the ICE is either continuously or intermittently mechanically connected to the vehicle drive-train to optimise the drive cycle by offering improved acceleration and less emissions under higher loads.

PHEVs are not only more fuel-efficient (to an extent, that depends on traffic conditions) than conventional vehicles of similar mass, but also produce substantially lower NO_x emissions than turbo-diesel vehicles. BEVs produce no direct emissions.

Production of EVs worldwide is still minute compared with the 65 million conventional cars manufactured annually. In January 2014, Nissan reached, after four years, the milestone of the 100,000th world-wide sale of its Nissan *Leaf* BEV; in total this model took a 45% share of the BEV market[11]. In early 2014, only two BEV models (Nissan *Leaf* and Mitsubishi *i-MiEV*) and one parallel-hybrid PHEV (GM *Volt*) were available in Australia with only around 100 of the Nissan *Leaf* sold in Australia to date. Over the next four years, a far wider range of BEVs and PHEVs will become available and, given an accompanying increase in sales volumes, at progressively lower prices.

In 2013, an Energy Supply Association of Australia (ESAA) paper[12] discussed the technological advantages of BEVs and PHEVs, their expected uptake in Australia and the best ways of incentivising this. Based on 2012 CSIRO data[13], the report concluded that the penetration of such vehicles will be modest. CSIRO modelling predicts that BEVs and PHEVs could comprise 12–23% and 21–24% respectively of the total Victorian vehicle fleet by 2033 depending on the level of Government incentives (in the form of rebates) offered for their purchase.

It should be realised that EV adoption promises huge benefits to the electricity grid. Both PHEVs and BEVs incorporate batteries of significant energy capacity (typically 10–20 kWh and 20–50 kWh, respectively). Hence, for the first time, there is real potential for a true 'smart electricity grid'[14] with substantial distributed electrical energy storage embedded in the LV layer of the system.[15,16] This will, *inter alia*, expand the installation of more practical and purposeful PV systems on the rooftops of Australia's homes, shopping centres, public buildings, and factories. Although beyond the scope of this paper, it should also be noted that EV charging at times of low system demand, notably at night,

[11] Smart Fleet website 21 January 2014: http://www.smartfleetaustralia.com.au/news/nissan-leaf-tops-100000-global-sales
[12] Energy Supply Association of Australia (ESAA), "Sparking An Electric Vehicle Debate in Australia", November 2013. www.esaa.com.au/policy/sparking_an_electric_vehicle_debate_in_australia
[13] CSIRO, "Spatial Modelling of Electric Vehicle Charging Demand and Impacts on Peak Household Electrical Load in Victoria, Australia", 2012
[14] "Smart Grid – The New and Improved Power Grid", X. Fang, S. Misra, G. Xue, and D. Yang, Communications Surveys & Tutorials, 2012, Vol: 14, Iss: 4, Pages: 944 – 988.
[15] Clean Energy Council report entitled "Energy Storage in Australia, Commercial Opportunities , Barriers and Policy Options", Version 1, prepared by Marchment Hill Consulting, 2 November 2012
[16] Analysis of European/German and Chinese Regulations regarding electric vehicle infrastructure for road traffic", report commissioned as part of the German Chinese Sustainable Fuel Partnership (GCSFP), 20 December 2010.

can provide an attractive electrical demand for base-load generation, including for nuclear energy should it be adopted within a future low emissions generation portfolio.[17]

Through the creation of an appropriate enabling regulatory and economic environment (including intelligent metering, time-of-use pricing and connection standards) coupled with the possible application of economically justified incentives, much of this increased energy generation and effective grid storage capability would be funded privately by business and individuals with a corresponding reduction in new funding for conventional generation capacity. 'Plan-based' business models could develop, similar to mobile phone plans, and thereby encourage private PV generation. Energy storage and optional 'vehicle-to-grid' (V2G) resupply of electricity back to the grid at times of high demand (and thus premium price) could become attractive, depending on the individual end-user power usage profiles and transport needs. With or without such plans, EV owners could be enabled, and indeed be economically motivated, to arbitrage the buying and selling of electricity based on tariffs and time-of-use spot prices that might be available over the overall system supply-demand cycle. While detailed modelling is needed, *prima facie* it is not unreasonable to conjecture that benefits could accrue both to EV owners and supply utilities.

Should the above scenario develop it is perhaps appropriate that incentives be offered for the initial uptake of BEVs and PHEVs. Not only could benefits accrue within the electricity supply system, but demand could lessen the costly import of liquid fuels, improving national energy security. For instance, financial incentives could include sales tax and luxury car tax concessions, import duty reductions and concessions on vehicle registration charges. Dedicated lanes and the provision of charging facilities in CBD buildings, parking stations and shopping centres could also prove attractive as has been shown in Europe and more recently in China[6].

Advantages of vehicle-to-grid (V2G) architecture

V2G-enabled BEVs and PHEVs communicate intelligently with the grid to sell demand-response services, either by delivering electricity into the grid or by reducing battery charge rates at times of high demand from the grid.[18,19] Most private vehicles remain parked for over 90% of the time. Their batteries and electrical architecture can readily be configured to allow electricity to flow not only from grid to vehicle (G2V) during charging but also from vehicle to grid (V2G) under controlled battery state-of-charge conditions.

Thus V2G-enabled vehicles can, if permitted by the owner, supply power to balance grid loads by accepting charge at night when demand and hence prices are low and selling power back to the grid when demand and prices are high. This facility can provide electrical utilities with battery power on demand with the means to improve both voltage and frequency regulation and with effective 'spinning reserve' to meet sudden ramp demands for power. V2G-enabled vehicles, in sufficient quantity, could also help buffer the variable renewable energy supply obtained via PV arrays and wind turbines by storing excess energy at times of high insolation and strong wind speed, and then returning it at times of high grid demand or reduced renewable supplies. The value of PV and wind resources is likewise enhanced by economically driven time-of-use pricing.

Notwithstanding these attributes, V2G architectures are still embryonic. In the USA, for example, Pacific Gas and Electric[9] and Xcel[4] are presently conducting trials by converting commercially available PHEVs into V2G configuration for interfacing with the grid. The University of Delaware is studying direct battery to grid (B2G) technology from both technical and economic modelling standpoints[20]. In Denmark a consortium of IBM, Siemens, EURISCO, Dong Energy, Østkraft, the Technical University of Denmark and the Danish Energy Association is using B2G technology[21] to

[17] "Electricity and Cars", World Nuclear Association, January 2014 http://www.world-nuclear.org/info/Non-Power-Nuclear-Applications/Transport/Electricity-and-Cars/

[18] Cleveland, Cutler J.; Morris, Christopher, "Dictionary of Energy", Amsterdam: Elsevier, 2006, ISBN 0-08-044578-0, Page 473

[19] "Pacific Gas and Electric Company Energizes Silicon Valley With Vehicle-to-Grid Technology", Pacific Gas & Electric, 7 April 2007

[20] University of Delaware "The Grid-Integrated Vehicle with Vehicle to Grid Technology" webpage: www.udel.edu/V2G/

[21] EcoGrid EU: From Design to Implementation", report sponsored by the European Union FP7 Program, obtainable from the IBM – Zurich SmartGrid website www.zurich.ibm.com/edison/

determine how best to balance the intermittent electricity supplies generated by Denmark's extensive wind farms which currently deliver 20% of the country's electricity production.

The intermittency issue
Domestic PV electricity is supplied to the grid via DC/AC inverters at low-voltage (typically 200V - 400V DC to 240V AC). Supply is intermittent due to the variability of incident solar radiation as dictated by local weather conditions, shading and geographical location. Australia's Clean Energy Council (CEC) states that at September 2013 there were close to 1.1 million domestic PV systems across Australia; i.e., around one system to every ten homes[22].

In mid-latitude Australian metropolitan cities such as Sydney or Melbourne, a relatively large (20 m^2) PV installation will, on a sunny day, deliver about 4 kW of electrical power and, over an average of 12 daylight hours, produce around 15 kWh of electrical energy[23] at a capacity factor (the ratio of actual energy delivered to that which could be delivered if operating at 100% of nameplate rating) of around 15-16%.

An average Australian household consumes about 18 kWh per day although this varies widely. A realistic range is 10–40 kWh as determined by the size of the family and their house, its location, its insulation and its heating and cooling needs. On hot summer days, city peak loads understandably coincide with domestic air-conditioning loads, usually in the afternoon. To a significant extent, this is synergistic with PV output which is at a maximum on sunny days, although may be lower on very hot days due to inherent reduction in PV efficiency. PV panels can of course be selectively oriented to best meet peak afternoon demand.

The energy storage and re-supply capability provided by BEVs and PHEVs is also intermittent at the individual vehicle level, as determined by the owner's driving and recharging practices. Moreover not all EVs are plugged in at the same time — some will be fully charged, some owners may not wish to accept any discharge, no matter how financially attractive arbitrage may be, while yet other owners will be happy to maximise their arbitrage income and accept the risk of a lower driving range. Time and experience, combined with a clear economic understanding of the advantages and disadvantages of home based charge–discharge cycles, will establish reliable models of the quantum and value of benefits available to both EV owners and system operators alike.

This leads to the sensitive topic referred to in the automotive industry as 'range anxiety', one of the major barriers to widespread uptake of BEVs. The PHEV approach is one solution to this problem. Nevertheless there is a clear requirement for robust, stochastically-based electrical, financial and behavioural modelling of energy availability from BEV and PHEV batteries in the light of the expected usage patterns of owners. There also needs to be greater technical evidence and operational assurance that batteries can meet their anticipated cycling duties reliably, safely and economically. Failure to meet these conditions will inhibit the market from reaching its full potential. Confidence will emerge with experience. To help allay such concerns, some EV manufacturers now considering offering lease-based battery models.

Structural problems with vehicle and grid architectures
Even if the intermittency issues associated with PV supply are ameliorated through averaging over many customers distributed over large areas, there remain fundamental structural problems with BEV and PHEV charging and grid architectures that must be resolved to achieve true 'smart grid' architecture. Key issues are as follows:

EV charging architectures
The current physical and electrical standards for charging BEVs do not yet provide for V2G. The following paragraphs are relevant if 'rail gauge' problems are to be avoided, or at least minimised, from the outset.

[22] Clean Energy Australia website 29 January 2014: http://www.cleanenergycouncil.org.au/technologies/solar-pv.html
[23] Clean Energy Australia Consumer Guideline Vol 21, 19 Dec 2012, "Consumer guideline to buying household solar panels (photovoltaic panels)": www.solaraccreditation.com.au/consumers/purchasing-your-solar-pv-system.html

IEC 62196[24] is an international standard defining charging modes and relevant electrical connectors for BEVs and PHEVs. It is maintained by the International Electrotechnical Commission (IEC).

The current North American standard SAE J1772 (based around the Yazaki SAE J1772-2009 plug connector) and the European standard VDE-AR-E-2623-2-2 (based around the Mennekes plug connector) comply with particular (but not necessarily all) subsections of IEC 62196 for charging BEVs and PHEVs[14,25] but are designed only for either AC or DC charging, not for discharging the battery back into the grid. For example the DC charging connection capability in SAE J1772 (Mode 4 under IEC 62196) stipulates the incorporation of 'charge contactors' in the EV architecture that isolate the charge connection as soon as the battery is fully charged. Thus, under the SAE standard, there is no capability of achieving V2G despite the DC interface plug standard having two high current capacity connector pins. Electrically at least, these could enable not only very fast charging but also fast discharge to the grid, provided it is permitted by owner software managing the handshake between wall and EV control systems.

To facilitate V2G it is more logical to use a DC interface between grid and EV, thus avoiding the need for a vehicle charge–discharge inverter. Instead a wall-based DC/AC inverter–controller can, to an extent, be adapted from an existing inverter–controller to deliver AC from PV's DC output. Together they can feed AC power into the LV layer of the electrical grid.

Seven automotive OEMs have agreed to use HomePlugGreenPHY as the communications protocol between charger and vehicle. This is competing with a CAN Bus proposal from Japan (including the CHAdeNO standard) and China (using a separate DC connector proposal), but an agreed standard has still to be reached. The trend is undoubtedly away from AC towards DC fast-charging, certainly at charging stations and eventually at the home. There is, however, still no international agreement on a common cross-compatible plug connector. The trend towards DC charging and shorter charge times will nevertheless encourage development of V2G interface standards.

Until the marketplace demands that BEV and PHEV electrical interface standards evolve to the point that will allow V2G, at least one alternative solution is available; namely the use of stationary batteries rather than BEV batteries for local energy storage[5]. Stationary household lithium-ion battery packages are now offered by companies such as SolarCity in the USA, in this case using modules manufactured by Tesla on its Californian automotive production line[26]. This is a promising business proposition for BEV OEMs such as Tesla, since its battery production volume is now significantly higher than that required solely for its EV production, thus yielding economies-of-scale for vehicle batteries. Also of note is continued interest in fast automated battery swapping from Tesla and Nissan, with purpose designed robots able to achieve battery replacement times less than equivalent refill times for conventional vehicles.[27]

In addition to batteries, many other technologies and business models are contemplated for the stationary storage of energy in domestic and industrial premises but these fall outside the scope of this paper.

- ***Grid architectures***
  The low-voltage (LV) electrical infrastructure of Australia's capital cities and suburbs is insufficiently robust for the widespread exchange of electrical energy between sources (such as PV cells) and storages (such as BEVs, PHEVs and stationary batteries).

  Thus, at present, any significant local expansion of PV could potentially overload the local LV grid and result in unacceptably high voltage and phase swings, excessive harmonic content and unacceptable drift of neutral voltages. Likewise the large-scale adoption of BEVs and PHEVs at the local level could overload existing LV systems.

[24] Wikipedia (English) extract titled "IEC 62196" www.en.wikipedia.org/wiki/IEC_62196
[25] SAE Standard J1772, October 2012, entitled "Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler"
[26] "Tesla's Industrial-Grade Solar Power Storage System", Bloomberg, Business Week, 6 December 2013.
[27] Forbes. "Tesla and Nissan: EV Battery Swap Replaces Anxiety With Peace Of Mind". 21 June 2013 http://www.forbes.com/sites/joannmuller/2013/06/21/tesla-and-nissan-ev-battery-swap-replaces-anxiety-with-peace-of-mind/

Nevertheless, since average household electricity consumption in Australia's capital cities is 10–40 kWh per day (averaging about 18 kWh per day), it is unlikely that most households could install sufficient PV capacity or adequate battery storage (whether in BEVs, PHEVs, or stationary facilities) to have the confidence to disconnect their property from the grid. Should this trend emerge, the fixed costs inherent in grid maintenance would need to be met by fewer customers at increased charges — both a politically and socially unacceptable outcome.

A further constraining problem relates to the existing suburban 'cell' of the LV grid which is typically served by a single 1–2 MW pole mounted or street- level (kiosk) 11 kV transformer delivering a 415 V 3-phase 50 Hz AC supply with floating neutral. Normally each third property in the street taps off one of the three phases plus the neutral to provide the conventional 240 V single-phase domestic supply. Such cells can comprise fifty or so properties over one or more suburban streets.

The grid is electrically sized from the top down from the power station through the grid in a pyramidal network of step-down transformers from 500 kV or 330 kV at the power station down through 33 kV and 11 kV and ultimately to the 415 V level of suburban distribution.

Current LV distribution grid architecture provides only for the flow of electricity in one direction – from supplier to customer – with safety protection arrangements in place at each transformer to prevent reverse flow. If, however, with enhanced penetration of EVs and rooftop PV there is the scope for electricity feed- back to the 11 kV system, arising a surplus of generation or in response to system demand for stored battery energy, it would be constrained from doing so. Thus the scope for grid averaging would be limited, even though an individual cell could allow local averaging. While this is not today an issue of concern it could well become so if the benefits alluded to in this paper are to be realised while retaining a high level of system safety and security. Study is warranted.

The ESAA report[28] notes that:

> *'in the short to medium term the modest uptake of EVs is unlikely to pose significant impact on the network or on its operation'* and *'controlled charging, combined with V2G capabilities....has the potential to lower peak demand on the system, improving the utilisation or load factor of networks'.*

Nonetheless it cautions that:

> *'significant uncontrolled charging of EVs could have adverse consequences for the electricity system, in terms of peak demand, as well as creating system instability'.*

Concluding remarks

It is apparent that the LV layer of the grid will evolve into what is becoming termed a 'low voltage exchange network', analogous to LANs in computer communications.

As cities grow they demand more electricity. Provided LV system constraints are removed to enable the grid to become a true exchange network, albeit requiring significant engineering design and capital investment, it is not unrealistic to opine that enhanced domestic and commercial PV capacity associated with storage offered by BEVs and PHEVs could contribute substantially to meeting urban electrical load growth, while reducing the need for new base-load generation to meet system peaks.

The potential offered by enhanced uptake of EV and PV technologies, notwithstanding the significant levels of further engineering analysis and financial modelling needed, based on current and projected BEV and PHEV performance and cost parameters, warrants that a substantial study (or series of interlinked studies) be undertaken.

[28] Energy Supply Association of Australia (ESAA), "Sparking An Electric Vehicle Debate in Australia", November 2013. www.esaa.com.au/policy/sparking_an_electric_vehicle_debate_in_australia

Contributors to Appendix 2

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John Baxter was previously joint Managing Director of the Bishop Innovation, involved in automotive steering product and process R&D, IP management and international IP licensing. He was inventor or co-inventor for many of Bishop's patents families and has authored and co-authored numerous published technical papers on automotive steering and related vehicle dynamics. In 2009 he joined Baxter IP Patent and Trade Mark Attorneys where he is now a consultant specialising in IP commercialisation and, in particular, the structuring of patents and licence agreements to maximize the commercial value of IP.

Professor Alan Finkel AM FTSE FIEAust Chancellor, Monash University and President, Australian Academy of Technological Sciences and Engineering

Alan Finkel is the former Chief Technology Officer of Better Place Australia, an organisation dedicated to the uptake of electric vehicles and their battery systems. His PhD and business career is in electrical engineering, the dissemination of advanced scientific concepts and the provision of imaginative science, technology, engineering and mathematics education. He was the founder and, for 24 years, Chief Executive of the successful California based, successful biotech and pharmaceuticals supply company Axon Instruments.

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Graeme Pearman is the former CSIRO Chief of Atmospheric Research and a past Acting Director of three CSIRO Institute of Natural Resources & Environment. He was a co-author of the 2010 Jamison Group report *Fuelling Future Passenger Vehicle Use in Australia*. His interests lie in describing and developing holistic emissions reduction strategies that build resilient energy futures appropriate for specific nations or communities.

Dr David Rand AM FTSE MA ScD Chief Research Scientist Emeritus, CSIRO Energy Technology

David Rand joined CSIRO in 1969 to further his fuel cell research. He established and led the CSIRO Novel Battery Technologies Group (1977–2003) aiming to develop improved batteries for road transport (ICEVs, BEVs, HEVs). He is a co-inventor of the UltraBattery®. He helped form the Australian Association for Hydrogen Energy becoming its Vice-President. He has been Chief Energy Scientist of the World Solar Challenge since inception in 1987. His books include *Batteries for Electric Vehicles (1998), Understanding Batteries* (2001*)*, *Clean Energy* (2004) and *Towards Sustainable Road Transport* (2014, in press). He continues his research as a CSIRO Honorary Fellow.

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John Sligar was formerly the Chief Scientist of the Electricity Commission of NSW (later becoming Pacific Power). During his career he was responsible for a number of world leading innovations developments in large black coal power stations which today operate a the highest levels of plant availability supplying the majority of Australia's electricity generation. Since his formal retirement he has established Sligar and Associates, a consultancy service providing high level advice in the electricity supply industry. He travels abroad frequently to maintain currency in international power system developments.

Dr Brian Spies FTSE PhD *ATSE NSW Program Coordinator*
Brian Spies has served as Chief Research Scientist at CSIRO where he led a CRC in mineral exploration, and as Director of Physics at ANSTO. He also spent 15 years in the USA working in petroleum research. He has held academic posts at the University of California at Berkeley and Western Connecticut State University. His current research interests include the interface between water, energy, climate change and the Australian economy. He was lead author of the 2012 ATSE report *Sustainable water management: Securing Australia's future in a green economy*

Martin Thomas AM FTSE MA HonFIEAust HonFAIE Immediate Past Chairman, ATSE Energy Forum

Martin Thomas was a Principal of consulting engineers Sinclair Knight Merz, responsible for the engineering power and energy projects in Australia and overseas, particularly specialising in industrial energy efficiency. Outside the firm he served as President of the Institution of Engineers Australia and the Australian Institute of Energy, the NSW Electricity Council, the export agency Austenergy and the 2000 Olympic Energy Panel. Following retirement he was Managing Director of the Australian CRC for Renewable Energy. He is a past Vice President of ATSE and immediate past Chairman of the ATSE Energy Forum, leading the Academy’s work in the energy sector.