



MELBOURNE  
ENERGY INSTITUTE

*Switching off gas -  
An examination of  
declining gas demand in  
Eastern Australia*

*26 August 2015*

*Tim Forcey - Energy Advisor, Melbourne Energy Institute (MEI)*





# Table of Contents

<b>1. Executive Summary</b>	<b>4</b>
<b>2. Full List of Key Points</b>	<b>7</b>
<b>3. Background - the eastern-Australian gas supply system</b>	<b>10</b>
<b>4. The rising price of gas in eastern Australia</b>	<b>12</b>
<b>5. Gas demand peaked in 2012 and will continue to decline</b>	<b>13</b>
The MEI Scenario – where gas demand declines more steeply than AEMO’s “low” forecast	14
<b>6. Declining gas demand dampens calls for new infrastructure</b>	<b>14</b>
<b>7. Less gas to be used for electricity generation</b>	<b>15</b>
<b>8. Gas demand declines in the Larger-Industrial sector</b>	<b>17</b>
In the MEI Scenario, industry’s <u>share</u> of gas demand grows	18
Fuel-switching potential in manufacturing	18
Energy-efficiency gas-savings in manufacturing	19
<b>9. The MEI Scenario includes declining demand for gas in buildings</b>	<b>20</b>
<b>10. Economic fuel-switching in the residential sector</b>	<b>23</b>
Householders can start saving immediately by heating with their air conditioner	24
Residential gas and electricity prices are converging	26
Rampant penetration of RCACs, for space-cooling and heating	27
Ducted-gas space-heating is often an ineffective way to warm a home	29
Modern reverse-cycle air conditioners are efficient renewable-energy generators	31
Householders can save by replacing all old gas appliances with new electric	33
Governments can now save on gas infrastructure costs	33
Hot water fuel-switching options	34
Induction cooktops, gas-free homes, and the gas grid death-spiral	35
AEMO have only begun to model fuel-switching	36
New ATA modelling, done for MEI, confirms fuel-switching reduces gas demand	36
<b>11. Energy efficiency and other factors reducing gas use in buildings</b>	<b>37</b>
Energy-efficiency measures: “exploring” for gas in your attic	37
Consumer behavioural and price responses	38
Winters are getting warmer	39
Electricity-only retailers actively promoting fuel-switching from gas	39
<b>12. Switching off gas in buildings frees up gas for industry</b>	<b>40</b>
<b>13. Switching off gas in buildings aids decarbonisation</b>	<b>41</b>
<b>14. Declining gas demand decelerates gas reserves depletion</b>	<b>42</b>
<b>15. New industries? Biogas and gas for transport</b>	<b>43</b>
<b>16. Needed: An Integrated Resource Plan that considers demand-side opportunities</b>	<b>44</b>
1990 Gas and Fuel least-cost supply planning never completed	44
AEMO focus has been on the supply side	44
<b>17. Summary of ways to ease the transition to higher gas prices</b>	<b>46</b>
<b>18. References</b>	<b>47</b>



## About the University of Melbourne Energy Institute (MEI)

The University of Melbourne Energy Institute (MEI) is an access point for industry, government and community groups seeking to work with leading researchers on innovative solutions in the following areas: new energy resources; developing new ways to harness renewable energy; more efficient ways to use energy; securing energy waste; and framing optimal laws and regulation to achieve energy outcomes.

## About the Author

Tim Forcey has over 30 years of experience in industrial energy with ExxonMobil, BHP Billiton, and Jemena, including specific experience with assets such as the Bass Strait Joint Venture and the Queensland Gas Pipeline.

During his time at the Australian Energy Market Operator, Tim led the publication of the 2011 Gas Statement of Opportunities, the 2012 South Australian Electricity Report, and the AEMO 100% Renewable Energy Study - Modelling Inputs and Assumptions.

With MEI, Tim has published reports and articles covering gas and electricity demand, gas-to-electricity fuel-switching, and pumped hydro energy storage technology and commercial applications.

Tim has also worked part-time as a home energy consultant with the Moreland Energy Foundation – Positive Charge and has volunteered with the Alternative Technology Association and Beyond Zero Emissions.

## Acknowledgements

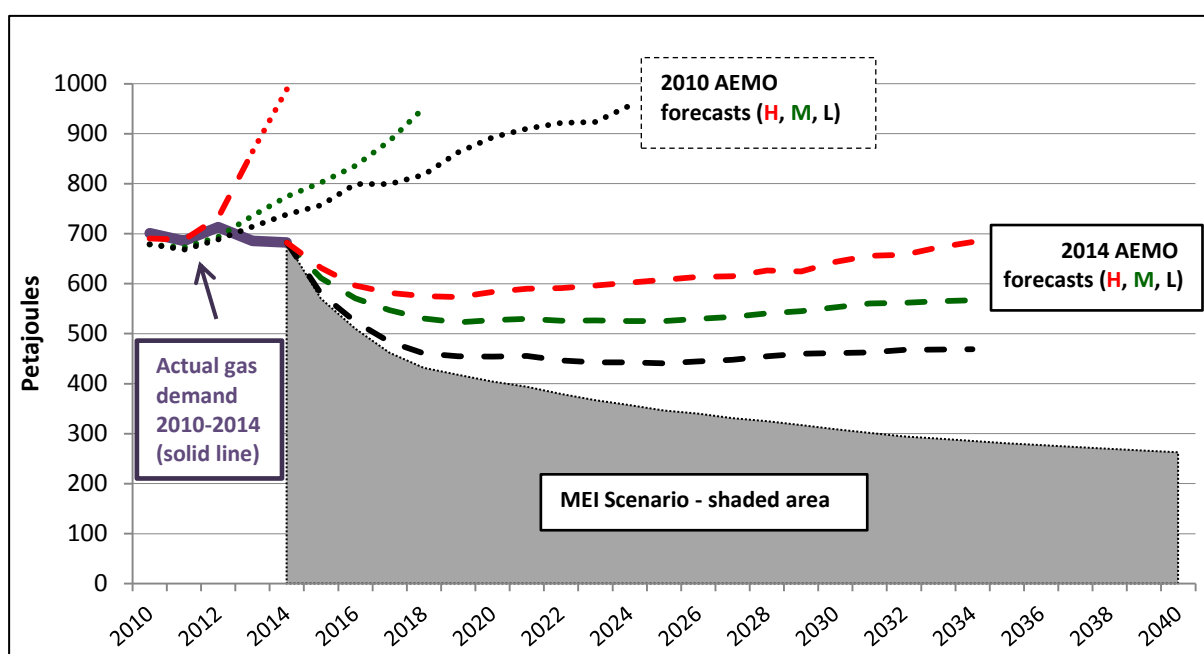
The University of Melbourne Energy Institute acknowledges The Australia Institute (TAI) for their support of this research and also specific individual donations made to the University of Melbourne.



## 1. Executive Summary

Following on from our research into “domestic gas”<sup>1</sup> demand specific to New South Wales (1) (2), the University of Melbourne Energy Institute (MEI) have examined the future of domestic gas across the entire interconnected eastern-Australian gas market. Our key findings are as follows.

Dramatic changes in the eastern-Australian gas market are prompting projections of sharp declines in domestic gas demand. Data from the Australian Energy Market Operator (AEMO) indicate that gas demand in eastern Australia peaked in 2012 and has declined since. Gas demand will continue to decline, possibly falling to half of the peak by 2025, according to a scenario prepared by MEI. (See Figure A.)



**Figure A: Gas demand in eastern Australia – actual demand and scenarios of future demand.**

Already domestic gas prices in eastern Australia have increased as they become linked to overseas prices following the start of gas exports to Asia from Gladstone Queensland, and also because of the high costs of producing coal seam gas. Rising gas prices and other factors are having a large negative impact on the use of gas in the electricity generation and industrial sectors.

<sup>1</sup> The term “domestic gas” means gas consumed within eastern Australia and excludes gas exported from



Furthermore in the buildings sector, gas faces increased competition from efficient-electrical appliances: heat pumps and induction cooktops. Renewable-energy-harvesting heat pumps, used for space and water heating, are a disruptive technology especially when applied in Australian homes and climate zones. Rather than burning one unit of gas energy to recover less than one unit of heat energy (i.e. < 100% efficient), heat pumps use electricity to leverage a refrigerant cycle and recover up to five units of free, renewable-ambient heat thereby achieving efficiencies of up to 500%. Heat pump space heaters, widely known in Australia as reverse-cycle air conditioners, have the added advantage of providing space-cooling during summer and other warm-weather periods and as a result are already in place in millions of Australian homes.

Rising gas prices and other factors are driving “economic fuel-switching” from gas to electricity as building owners and managers install heat pumps and replace gas stoves with efficient and controllable induction cook-tops. Increasing uptake of rooftop solar photovoltaic (PV) systems and fast-evolving electric-battery storage technologies will further accelerate economic fuel-switching.

Economic fuel-switching results in significant energy-cost savings for former domestic gas consumers. Based on analysis by MEI and the Alternative Technology Association, people living in up to one million homes across eastern Australia (and most particularly in Victoria) can start saving hundreds of dollars on their heating bill tomorrow if they switch off their gas heater and turn on their reverse-cycle air conditioner.

Space-heating cost savings of \$1,733/year (a savings of 77%) were modeled for a large home in Canberra and \$658/year (63%) for a large home in Melbourne. Unfortunately, householders are unaware of these remarkably-large and quick savings because of out-of-date and inaccurate information. It is possible that in Victoria alone, households could collectively and immediately save on the order of \$250 million/year by using as a space-heater the reverse-cycle air conditioners they already have in their homes.

Over the longer-term, these new economic drivers mean that many households will progressively replace old gas appliances with new electric appliances and some will see the advantages of leaving the gas grid completely. This “second-electrification of the Australian home” may lead to a “death spiral” where more and more customers leave the gas grid, which then leads to increased costs for those customers that remain connected.

The changing economics of gas-use in buildings and industry have important implications for infrastructure planning. There is now no economic need for any new house or suburb in eastern Australia to be connected to the gas grid. Governments, housing developers, and homeowners can now look for opportunities to cut spending on gas infrastructure.



Complementing economic fuel-switching, the benefits of building energy-efficiency measures are well known yet many highly-economic opportunities remain. This means we can also “explore” for gas in eastern-Australian attics and lounge rooms by deploying insulation, draught-proofing, and improved windows and window treatments (e.g. drapes, and blinds).

Ending gas waste in the buildings sector, where often up to 50% of purchased gas is immediately “thrown-away” because of inefficient use, will make available large volumes of gas for higher-value industrial uses. There are also many economic fuel-switching and energy-efficiency opportunities available to industry, as eastern Australia enters this new era of high-price gas.

Ending gas waste will also extend the depletion of conventional gas reserves in eastern Australia for at least an additional decade, as illustrated by Figure B. In AEMO’s medium scenario, approximately 10,000 petajoules of domestic gas is consumed by 2032 whereas in the MEI Scenario, that amount of gas is not used until more than a decade later.

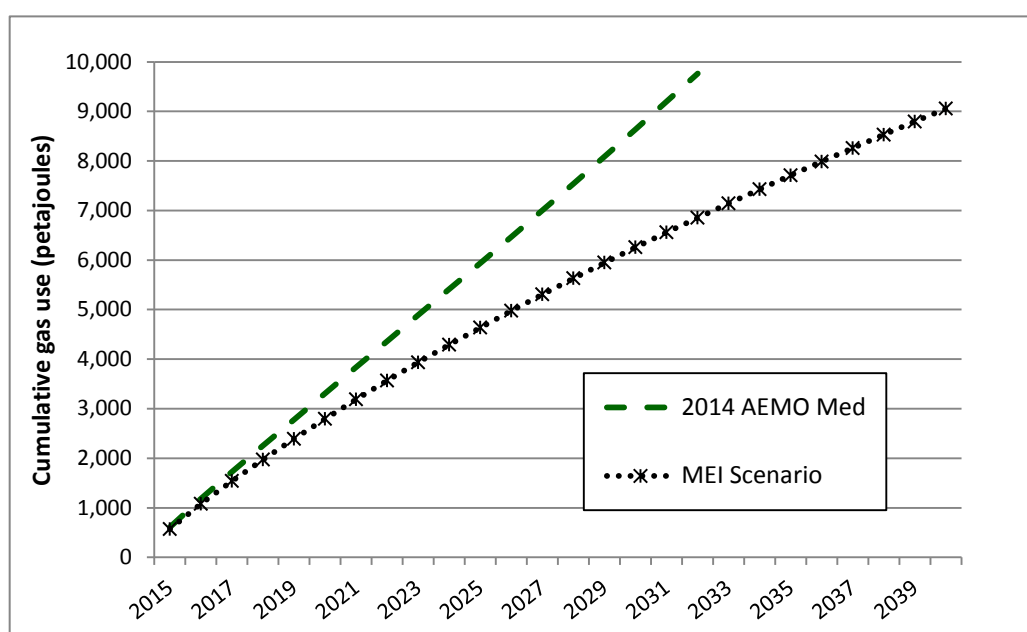


Figure B: Eastern Australia cumulative “domestic gas” consumed / reserves depletion. (MEI)

Similarly to the electricity industry, for decades strategic management of gas in eastern Australia meant looking only at the supply side rather than taking into account opportunities for gas demand reduction. This report recommends that eastern-Australian governments develop an **Integrated Resource Plan (IRP)** that considers not just gas-supply options but also includes gas-demand-management options such as economic fuel-switching and energy-efficiency measures.



## 2. Full List of Key Points

The following is a full list of key points that are detailed in this report:

- 1) According to data from the Australian Energy Market Operator (AEMO), **the amount of gas consumed in eastern Australia peaked in 2012.**
- 2) According to AEMO data and forecasts, since 2012 the amount of **gas consumed** in eastern Australia has declined each year and **will continue on a declining trend.** AEMO's high, medium, and low demand scenarios indicate that by 2025, gas demand in eastern Australia will have fallen from the 2012 peak by 15%, 26%, or 38% respectively. AEMO forecasts that gas demand will decline in the industrial and electricity generation sectors.
- 3) With the recognition of declining demand, AEMO's previous **concerns about gas supply shortfalls** and suggestions of gas infrastructure expansion have been **withdrawn.**
- 4) For decades, the eastern-Australian gas market was a buyer's market where consumers enjoyed access to some of the cheapest gas in the developed world. However, in recent years, **wholesale and retail gas prices have dramatically increased.** The economics of gas for eastern Australia have changed and a **"seller's market"** now prevails. This change is driven by the new capability, commencing in 2014, for LNG to be exported to Asia from Queensland. This has allowed "domestic gas" prices to be linked to **world-parity gas prices.**
- 5) **Developing coal seam gas** has proven to **not** be as **easy nor** as **cheap** as had been expected. This has also contributed to rising gas price pressures. The development of other unconventional gas in eastern Australia (shale gas and "tight" gas) is also not expected to be "cheap".
- 6) Retail gas prices are increasing not only because of increasing wholesale gas prices but also because of **increasing gas distribution and retailing costs.**
- 7) To date, AEMO has not forecast that the amount of gas used in buildings will change much over the next 20 years. MEI's view is that economic **fuel-switching in buildings will to be a significant** near and medium-term **phenomenon.** AEMO have indicated that their next version of gas forecasts will acknowledge fuel-switching from gas to electricity in the residential sector.
- 8) **In eastern Australia, there are potentially 500,000 to 1,000,000 homes where residents are unaware that they can immediately start to save hundreds of dollars per year on their heating bill by using their existing reverse-cycle air conditioners (RCACs) instead of gas. This economic fuel-switching frees up gas for industry.**
- 9) Many **people lack information** about the cheapest way to heat their homes and water. Communication is hampered by incorrect or insufficient information in the community and marketplace.





- 10) The efficiency of ducted-gas space-heating systems in Australian homes can be as poor as 50% or less. In some cases, **half or more of the purchased gas is immediately wasted** and not used to effectively warm people in their homes.
- 11) Contrasting with the poor performance of ducted-gas, some non-ducted RCACs achieve efficiencies of more than 500% when they capture more than **four units of free renewable heat** from the outside air for every one unit of electricity applied. Though not eligible for renewable-energy credits, **reverse-cycle air conditioners are very significant harvesters of renewable energy** in eastern Australia, rivaling rooftop-solar panels in their output.
- 12) Some homeowners can **save hundreds of dollars per year by switching from a gas hot water service to a heat-pump water heater (HPWH)**. HPWHs act as “energy-storage hot-water-batteries” when charged at night, when grid-supplied electricity is cheap, or at mid-day if a home’s solar PV panels generate excess electricity.
- 13) Installing reverse-cycle air conditioners, heat-pump water heaters or other gas-free water heaters, and induction cooktops allows “all-electric” Australian homes to become gas free and **eliminate the gas bill**.
- 14) With the wide availability of efficient-electrical appliances, there is **no longer any economic need to connect gas to new Australian homes and suburbs**.
- 15) In eastern Australia, gas “exploration and mining” can, in a sense, occur in eastern-Australian attics and lounge rooms via the deployment of economic **energy-efficiency measures** such as insulation, draught-proofing, improved windows and window treatments (e.g. drapes, and blinds).
- 16) As a result of AEMO not yet reflecting economic fuel-switching in their gas demand forecasts, AEMO’s “low” gas demand scenario may not be low enough to bracket all reasonably-possible outcomes. The **“MEI Scenario”** presented in this report takes fuel-switching and energy-efficiency measures into account. As a result, in the MEI Scenario **gas demand in eastern Australia falls to approximately half** of the 2012 peak over the next ten years.
- 17) Providing warmer and cheaper-to-operate homes can lead to **improved home health outcomes**, especially for the sick and elderly.
- 18) Ending **gas waste**, particularly in the buildings sector, **will free up large volumes of gas for higher-value industrial uses**. For example, in twenty years time, approximately 70% of the gas used in the Larger-Industrial sector could be sourced from gas “saved” in the Residential, Commercial, and Smaller-Industrial sector.





- 19) The large volume of gas that can be saved via economic fuel-switching and energy-efficiency measures in the buildings sector (up to 1,000 petajoules) rivals the volumes of gas that might be produced from large gas-field developments.
- 20) There are also many fuel-switching and energy-efficiency **opportunities available to industry** as eastern-Australia enters this new era of high-price gas.
- 21) Energy-efficiency measures and economic fuel-switching in buildings from gas to electricity can help Australia to economically **decarbonise**, especially as eastern Australia's electricity is increasingly produced with renewable energy.
- 22) As gas demand declines in all market sectors, eastern Australia's remaining **gas reserves stretch out** for more than an additional decade.
- 23) As gas prices rise and the preference for lower-carbon energy and chemical feedstocks increases, the distributed production of **renewable biogas** may become a viable industry in eastern Australia and a replacement for fossil gas.
- 24) Eastern Australia needs **an Integrated Resource Plan (IRP)** that considers not just gas-supply options, but also gas-demand-management options, including economic fuel-switching and energy-efficiency measures. To date the focus of the Australian Energy Market Operator has been on the gas supply-side.



### 3. Background - the eastern-Australian gas supply system

As shown by Figure 1 (3), gas is supplied to eastern-Australian demand centres by a pipeline network connecting Queensland (QLD), New South Wales (NSW) including the Australian Capital Territory (ACT), Victoria (VIC), Tasmania (TAS), and South Australia (SA). No gas pipelines connect eastern Australia to Western Australia or the Northern Territory.

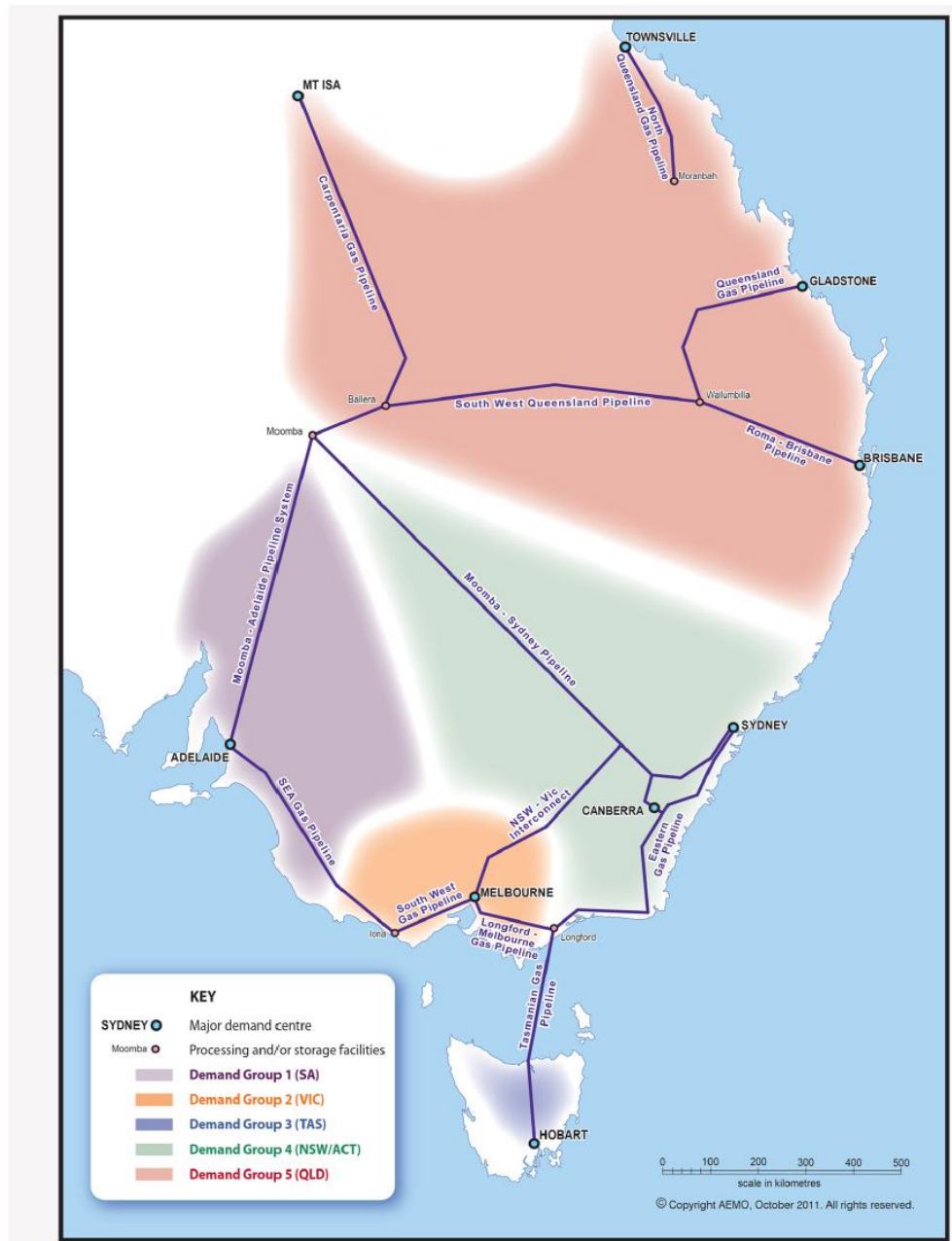


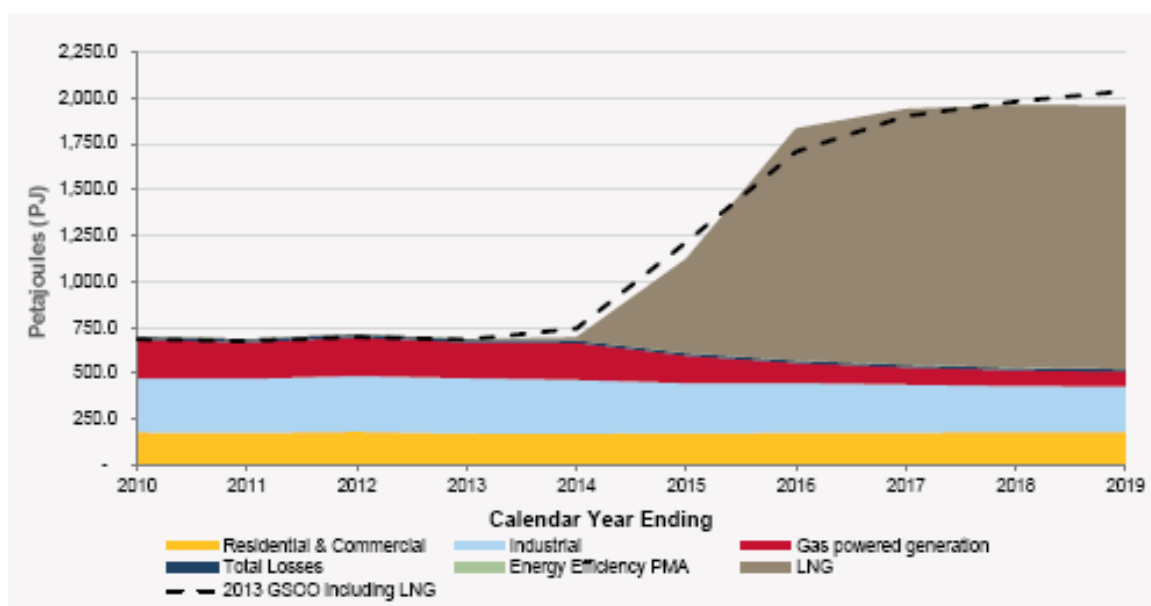
Figure 1: The interconnected eastern-Australian gas market (3).



*LNG exports are not included in this “domestic gas” demand study*

Starting in December 2014 (4), increasing volumes of liquefied natural gas (LNG) are being exported from Gladstone, Queensland, as illustrated by Figure 2. Eventually, export gas volumes will exceed the amount of “domestic gas”<sup>2</sup> used in eastern Australia by approximately three times. However, this report describes only the future of eastern Australia “domestic gas” demand.

Figure 2 also illustrates actual past “domestic gas” use by demand sector and AEMO’s “medium” forecast of future demand.



**Figure 2: Annual gas consumption in eastern Australia including “domestic gas” and LNG exports, AEMO medium forecast. (AEMO (5))**

Table 1 shows actual gas consumption figures for 2014 in petajoules per year (PJ/yr). In 2014, the greatest use of gas was in the Larger-Industrial sector, consuming 42.9% of the total.

**Table 1: 2014 actual gas used in eastern Australia, by demand sector**

Gas Demand Sector	PJ/yr in 2014	%
Gas used in the Larger-Industrial (LI) sector	292.5	42.9
Gas used for electric gas-powered generation (GPG)	201.5	29.5
Gas used in residential, commercial, and smaller-industrial (RCSI)	171.9	25.2
Losses	16.3	2.4
Total	682.2	100

<sup>2</sup> The term “domestic gas” refers to the gas used within eastern Australia and does not include gas that is exported.



## 4. The rising price of gas in eastern Australia

For decades, the eastern-Australian gas market was a buyer's market. Consumers enjoyed access to some of the cheapest gas in the developed world. However, the economics of gas in eastern Australia have changed. A "seller's market" now prevails. This change has been driven by the new capability, commencing in 2014, for LNG to be exported to Asia from Gladstone, Queensland. This has allowed "domestic gas" prices to be linked to world-parity gas prices. In recent years, eastern-Australian wholesale and retail gas prices have dramatically increased, and analysts expect gas prices to continue to rise over the next ten to twenty years (6) (7) (8) (9) (10) (11) (12). Wholesale gas prices, formerly in the range of \$3 to \$4 per gigajoule, are increasing to as high as \$7 to \$8 per gigajoule, and possibly higher in Queensland (13).

Gas prices will be unaffected by increased domestic gas supply, according to a report published in February 2015 by the New South Wales Legislative Council Select Committee on the 'Supply and Cost of Gas and Liquid Fuels in New South Wales' (2) which states:

"...increased domestic supply of gas will not by itself lead to reductions in gas prices, or even in the rate of price increases. This is because the predominant driver of domestic gas prices will be the international gas price..."

Also contributing to rising gas-price pressures is that producing coal seam gas (CSG) in eastern Australia, primarily for LNG export, has proven to be more expensive than expected (14). CSG production costs have risen from estimates of \$3 to \$4 per gigajoule in 2011 (3) to as high as \$7 to \$8 per gigajoule in 2015 (15). Esso Australia expressed concerns about there not being enough gas to supply the needs of the new LNG plants, as the Santos "GLNG" project sought access to third-party supply (16). The development of other unconventional gas in eastern Australia (i.e. shale and "tight" gas) is also not expected to be "cheap", and rather is estimated to cost "at least \$7 per gigajoule" (17).

Another factor cited as contributing to rising gas prices is "the lack of competitive and transparent domestic gas industry" (18) which is the subject of an inquiry by the Australian Competition and Consumer Commission (ACCC) (19).

Wholesale gas costs represent only 20 to 25% of total retail gas prices in most eastern-Australian jurisdictions (20). In Victoria, current residential gas prices (energy-unit costs only, excluding fixed costs) can range from \$16 to \$22 / gigajoule (including GST). Retail gas prices can rise not only because of rising wholesale gas prices, but also because of increasing gas distribution (21) and retailing costs. In 2014, the Consumer Utilities Advocacy Centre (Victoria) reported that retail gas prices had increased 66% since 2008 and would increase another 24% in the next year (22). Recently ANZ reported that gas costs for an average Melbourne household could rise from \$1,200 per year (in 2014) to \$1,600 per year by 2020 (13).



In late 2014, the Grattan Institute reported that the average household gas bill in Sydney will, “in the next few years”, rise by \$100/year and that in Melbourne bills might go up by \$320 to \$435 per year (8).

## 5. Gas demand peaked in 2012 and will continue to decline

According to data from the Australian Energy Market Operator (AEMO) (5), the amount of gas consumed in eastern Australia<sup>3</sup> peaked in 2012 at 713 PJ/yr. (See Figure 3 and also (23).)

According to AEMO’s most recent data and 20-year forecasts<sup>4</sup>, the amount of gas consumed in eastern Australia has declined each year since 2012 and will continue on a declining trend. AEMO’s high, medium, and low demand scenarios indicate that by 2025 gas demand in eastern Australia will have fallen from the 2012 peak by 15%, 26%, or 38% respectively.

AEMO’s most recent gas demand forecasts differ markedly from forecasts published by AEMO five years ago. As shown on Figure 3, in 2010 each of AEMO’s “high”, “medium” and “low” scenarios pointed to rapidly rising gas demand (24). It is apparent that AEMO’s 2010 gas demand scenarios failed to bracket all reasonably-possible future outcomes. Similar shortcomings have been documented regarding AEMO’s electricity demand forecasts (25).

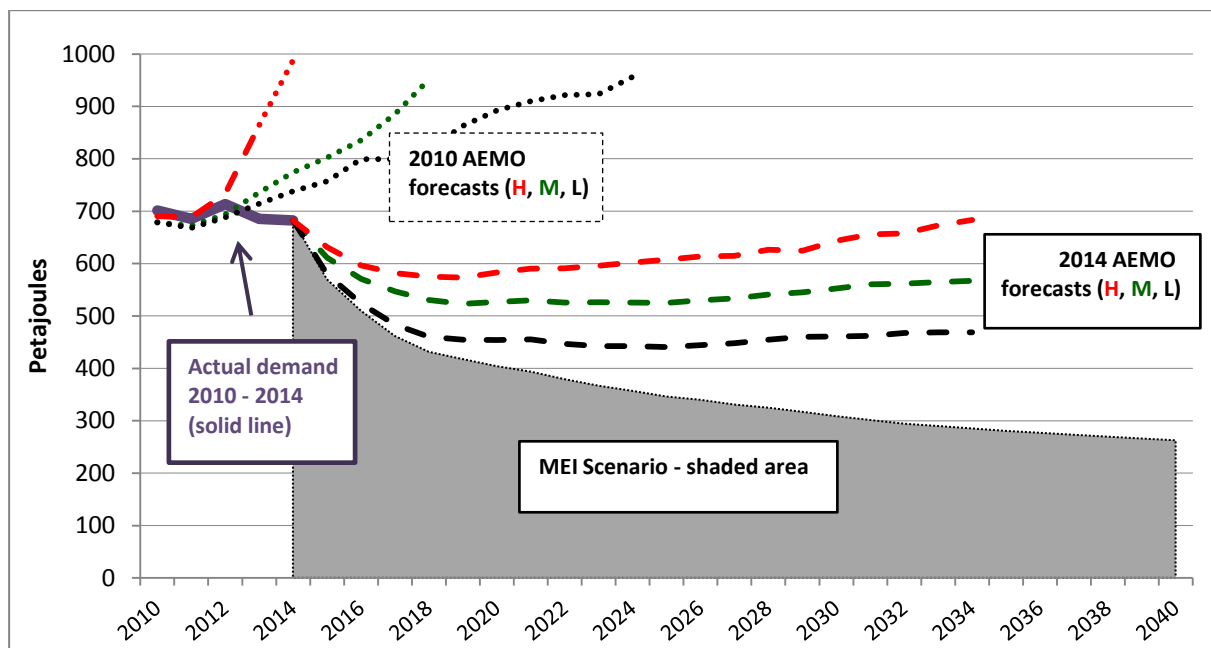


Figure 3: Gas demand in eastern Australia – actual demand and scenarios of future demand.

<sup>3</sup> This report covers only the gas used within eastern Australia, which is known as “domestic gas”. This report excludes analysis of gas used for LNG exports.

<sup>4</sup> Each year, AEMO provides a 20-year outlook for gas demand.



AEMO break “domestic gas” demand forecasts into the following four parts:

- gas used for electric power generation (GPG)
- gas used in the Larger-Industrial (LI) sector
- gas used in the Residential, Commercial, and Smaller-Industrial sectors (RCSI)
- gas lost from the gas transmission and distribution systems.

AEMO forecast that less gas will be used for generating electricity (see Section 7) and in the Larger-Industrial (LI) sector (see Section 8). However in the buildings sector, AEMO does not yet forecast that much change will occur over the next 20 years. Interestingly, AEMO recently indicated that their next version of gas forecasts will, for the first time, include acknowledgement of the practice of “economic fuel-switching” from gas to electricity in the buildings sector (26). (See Section 9.)

#### *The MEI Scenario – where gas demand declines more steeply than AEMO’s “low” forecast*

MEI’s view is that fuel-switching in buildings has the potential to become a significant near and medium-term phenomenon (see Sections 9 and 10). Because AEMO do not yet reflect fuel-switching in their forecasts, AEMO’s “low” gas demand scenario may not be low enough to bracket all reasonably-possible outcomes. The “MEI Scenario” presented in this report takes fuel-switching into account.

In the MEI Scenario (see Figure 3 above and Section 9), as a result of fuel-switching in buildings and declining gas demand in other sectors, demand for gas in eastern Australia falls to approximately half of the 2012 peak over the next ten years. Later sections of this report discuss some of the consequences of rapidly declining gas demand.

## 6. Declining gas demand dampens calls for new infrastructure

AEMO, in their 2013 Gas Statement of Opportunities (27), highlighted gas supply concerns for winter days in New South Wales starting in 2018. However, in their 2014 Gas Statement of Opportunities (28), AEMO declared there were no longer supply concerns for NSW or for anywhere in eastern Australia through until 2034. Contributing to this change was a reduction in AEMO’s gas demand forecasts, including a 17% reduction in forecast gas demand for NSW specifically. The view that no new supply infrastructure was required in eastern Australia was foreshadowed by research done by the University of Melbourne Energy Institute (1).



## 7. Less gas to be used for electricity generation

Over the next five years, according to AEMO forecasts, the amount of gas used for electrical power generation (GPG) will dramatically decline (5). (See Figure 4.) This occurs because of rising gas prices, the lack of a carbon price, and the expansion of renewable electricity generation (wind and solar). Also, the failure of electricity demand to grow at an historical pace has led to a surplus of existing coal-fired electricity generation capacity in eastern Australia against which gas cannot compete.

In the near term, significant volumes of low-cost “LNG ramp gas” are being disposed to electricity generation (29). However with the last of the six LNG production facilities in Queensland nearing start-up, low-cost LNG ramp gas is being removed from that market (30).

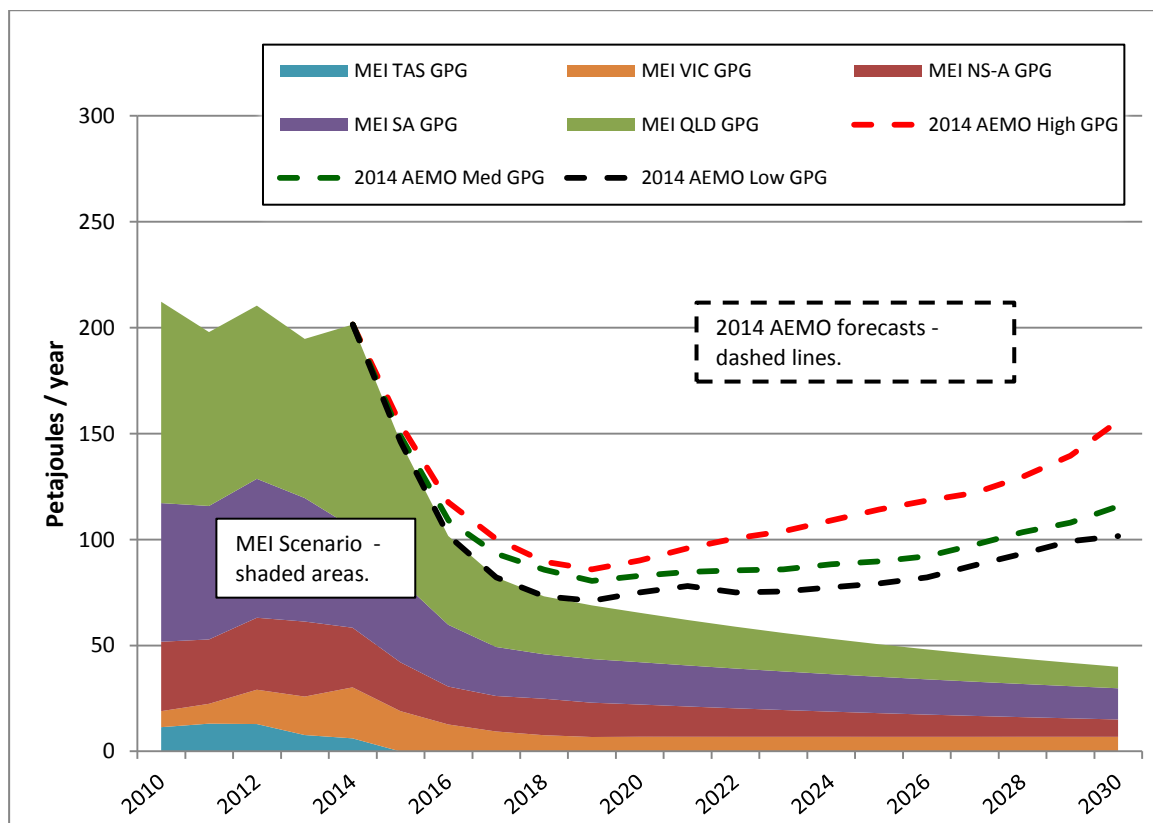


Figure 4: Gas used for electrical power generation (GPG), actual and forecasts<sup>5</sup>.

<sup>5</sup> “NS-A” refers to New South Wales and the Australian Capital Territory.

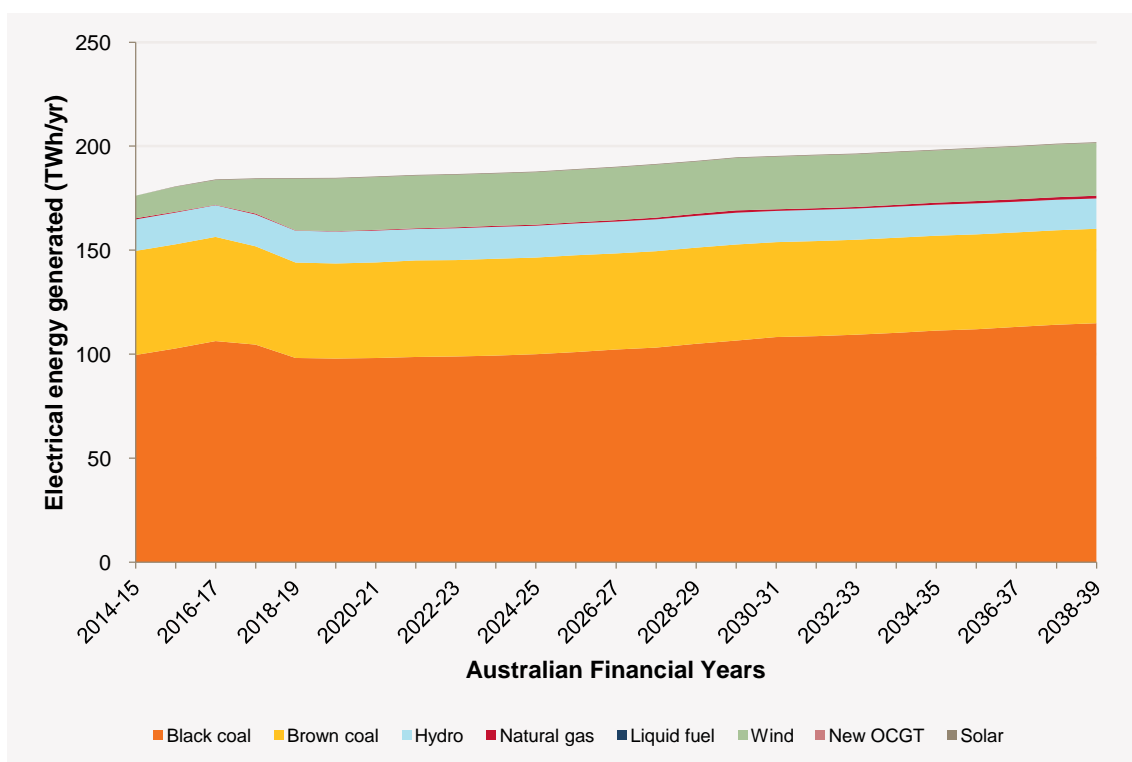




As shown on Figure 4, AEMO's forecasts for the electricity-generation sector show gas demand rebounding in around 2020 on the expectation that coal plants will be retired and gas-powered generators will be used to take their place (5). In contrast to AEMO's forecasts, the MEI Scenario projects the continuous decline of gas demand in this sector because the following factors prevent gas from returning to this sector in any significant way:

- high gas prices persist
- renewable energy and energy storage penetration increases<sup>6</sup>
- the implementation of electricity demand-management practices.

As shown by Figure 5, output from AEMO's electricity Generation Expansion Plan (31) is consistent with the MEI Scenario, where very little gas will be used for electricity generation.<sup>7</sup> However AEMO apply subsequent market modeling methods to arrive at the forecasts presented in Figure 4 (32).



**Figure 5: Gas will be used sparingly for electricity generation, according to the AEMO Generation Expansion Plan (31).**

<sup>6</sup> A recently announced policy of the Australian Labor Party would increase the use of renewable energy in electricity generation from 14% in 2014 to 50% in 2030. The Australian Government has not announced a target for 2030. AEMO's Generation Expansion Plan targets 41,000 GWh of electricity derived by large-scale renewables in 2020.

<sup>7</sup> In the Australian Financial Year 2020-21 (for example), Figure 5 shows just 0.34 TWh/yr of electricity which would have been generated by burning only ~ 3 PJ/yr of gas.



## 8. Gas demand declines in the Larger-Industrial sector

AEMO forecasts that gas demand in the Larger-Industrial sector<sup>8</sup> will decline because of industrial closures and less favourable economic conditions, including increasing gas prices (5).

The MEI Scenario adopts AEMO's "low" forecast, as shown in Figure 6. Gas demand in the Larger-Industrial sector (LI) declines by 40% from 2014 to 2030 (an average of over 3%/yr).

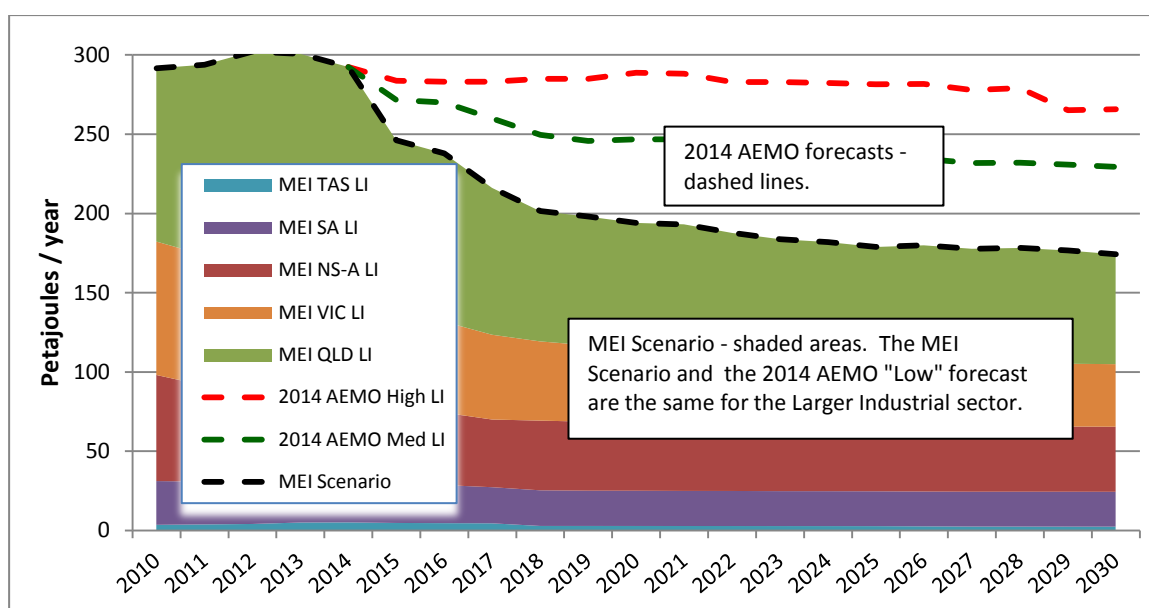


Figure 6: Gas used in the Larger-Industrial (LI) sector.

Eastern-Australian industries burn for process-heating approximately 93% of the gas they purchase. Chemical feedstocks are often cited as a critical market for gas. However, only about 20 PJ/yr<sup>9</sup> of reticulated gas<sup>10</sup> (~ 3% of all reticulated gas used in eastern Australia) is required as chemical feedstock.

<sup>8</sup> AEMO define "Larger-Industrial" as consumers of more than 10 terajoules of gas per year.

<sup>9</sup> (7) and other information sources.

<sup>10</sup> Reticulated gas is primarily composed of the molecule methane. A separate gaseous hydrocarbon product composed primarily of the molecule ethane is used as chemical feedstock in Altona, Victoria, and Botany Bay, NSW. However, given that ethane is generally more highly valued than the more-common methane, ethane is not generally used as fuel. Ethane is therefore not included in the figures above.



*In the MEI Scenario, industry's share of gas demand grows*

In the MEI Scenario, the fraction of all gas consumed in eastern Australia that is used in the Larger-Industrial (LI) sector increases from 44% in 2015 to 58% in 2030. This indicates a movement of gas-use away from sectors where economic substitutes are readily and economically available (gas used for electricity generation and in buildings) and toward sectors where economic substitutes are less available and gas is more highly valued. As will be shown in Section 12, in twenty years time, approximately 70% of the gas used in the Larger-Industrial sector can be sourced from gas “saved” in the Residential, Commercial, and Smaller-Industrial sector.

This contrasts with AEMO’s 2014 “low” demand forecast where the share of gas used in the Larger-Industrial sector *falls* from 44% in 2015 to 39% in 2030 as gas is preferentially consumed in lower-value applications such as for heating buildings and water. MEI’s view is that this outcome is unlikely.

*Fuel-switching potential in manufacturing*

In manufacturing, fossil gas is used to provide process heat at various temperature levels. As the price of gas rises, lower-temperature process heat can be economically provided by energy sources other than fossil gas. In those process applications where fossil gas is used to provide higher-temperature heat (e.g. greater than 1300°C), it is more challenging to find economic alternatives to gas. In a draft study for the Australian Renewable Energy Agency (ARENA), IT Power quantified the amount of gas-derived energy used at various temperature levels and potential renewable energy alternatives (33). (See Table 2.) Electricity-based technologies (e.g. heat pumps, electric-induction heating, electric-resistive heating, electric-arc heating) can be powered by renewable or non-renewable energy sources and some of these technologies can be used to achieve high process temperatures. However, as a result of increasing gas prices and the lack of a price on carbon, industrial fuel-switching from gas to coal may also occur (7).

**Table 2: Process heat supplied by fossil gas in manufacturing and renewable energy alternatives**

Process heat level used in manufacturing	Less than 250°C	250°C to 1300°C	Greater than 1300°C
Share of total process heat requirement (33)	9%	45%	47%
Applicable renewable energy technologies for process heat generation			
Electric heat pump – air source	yes		
Electric heat pump – ground source (geothermal)	yes		
Geothermal - direct	yes		
Biomass combustion	yes	yes	
Biogas combustion	yes	yes	yes
Solar thermal - direct	yes	yes	yes



### *Energy-efficiency gas-savings in manufacturing*

ClimateWorks described typical historical Australian-industrial energy-efficiency improvements that reduce energy demand by 1%/yr (34). Energy efficiency improvements of that order could reduce gas demand in the manufacturing sector by approximately 10% by 2025. Rapidly-rising gas prices could increase the uptake of energy-efficiency measures above the pace historically experienced in the manufacturing sector.

In its 2013 work for the Industrial Energy Efficiency Data Analysis (IEEDA) project commissioned by the Australian and state governments through the National Strategy on Energy Efficiency, ClimateWorks (35) summarised potential energy savings averaging 11% that were identified by the manufacturing industry across Australia, as shown in Table 3. Of the energy efficiency opportunities identified by industry, some will have been implemented already (many with a payback period of less than two years), implementation may be under way for others, but some were classified as not being economically attractive at the time. The onset of rising gas prices may mean that the economics of gas-saving projects has improved so that more projects can now proceed.

**Table 3: Potential energy savings in manufacturing**

<b>Manufacturing sub-sector</b>	<b>Potential energy savings (35)</b>
	(% of total energy used)
Chemicals and energy manufacturing	16 %
Other manufacturing, construction and services	14 %
Metals manufacturing	7 %
Average across all industries	11 %

Various case studies describing heat-energy-saving opportunities in Australian industry have been documented (36).



## 9. The MEI Scenario includes declining demand for gas in buildings

This and the following two report sections explore the concept that gas used in eastern-Australian buildings has begun a long-term decline, leading to a future where very little gas is used in buildings and light industry and rather is predominantly consumed by higher-value larger-industrial applications.

Figure 7 shows that the greatest part of demand in the residential, commercial, and smaller-industrial sector (RCSI<sup>11</sup>) sector is for residential gas use. According to AEMO (5), gas used in the RCSI sector peaked in 2012 and by 2014 had declined by 6%. Figure 7 also shows AEMO's high, medium, and low forecasts for the RCSI sector (dashed lines). Unlike AEMO's forecasts of gas demand in the electricity generation and Larger-Industrial sectors, the dashed lines indicate that AEMO are not yet forecasting any significant gas demand decline in the RCSI sector.

AEMO's forecasts for the RCSI sector (dashed lines in Figure 7) contrast with the MEI Scenario (shaded areas in Figure 7) in which significant economic fuel-switching from gas to electric appliances occurs.

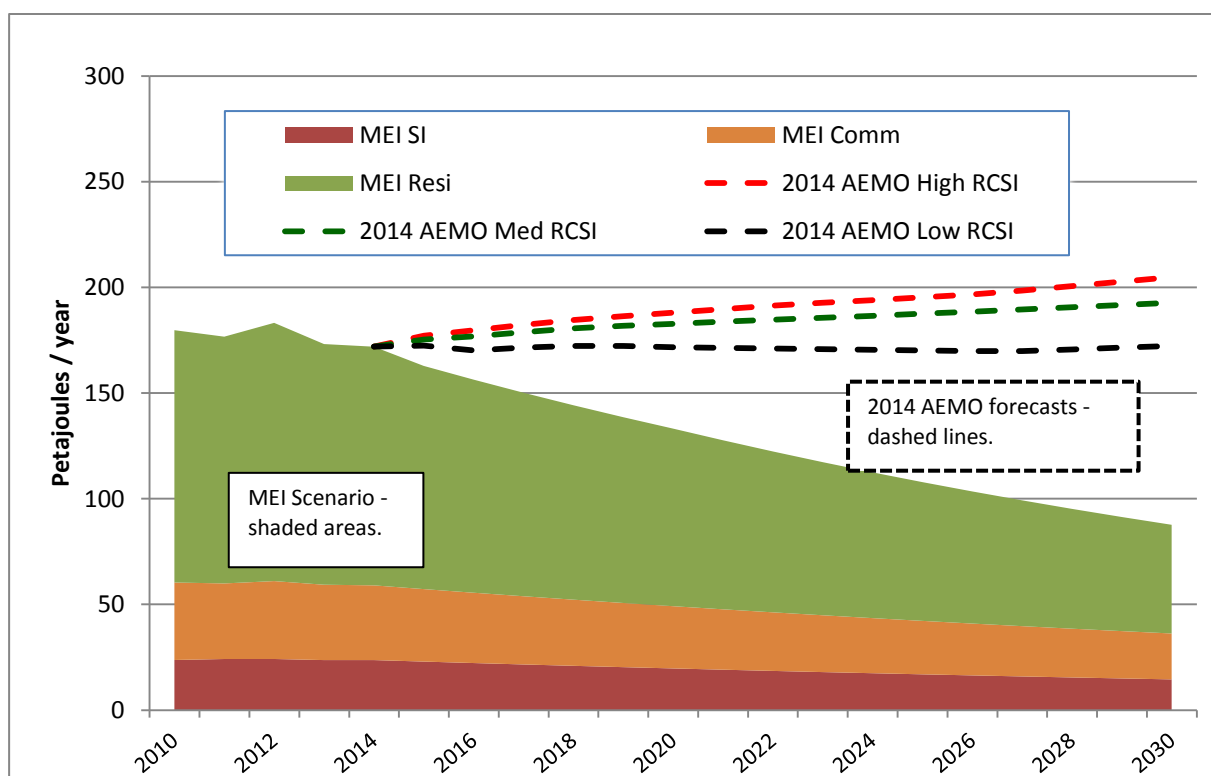


Figure 7: Gas used in the residential, commercial, and smaller-industrial (RCSI) sector.

<sup>11</sup> AEMO define "smaller-industrial" (SI) consumers as those using less than 10 terajoules of gas per year.



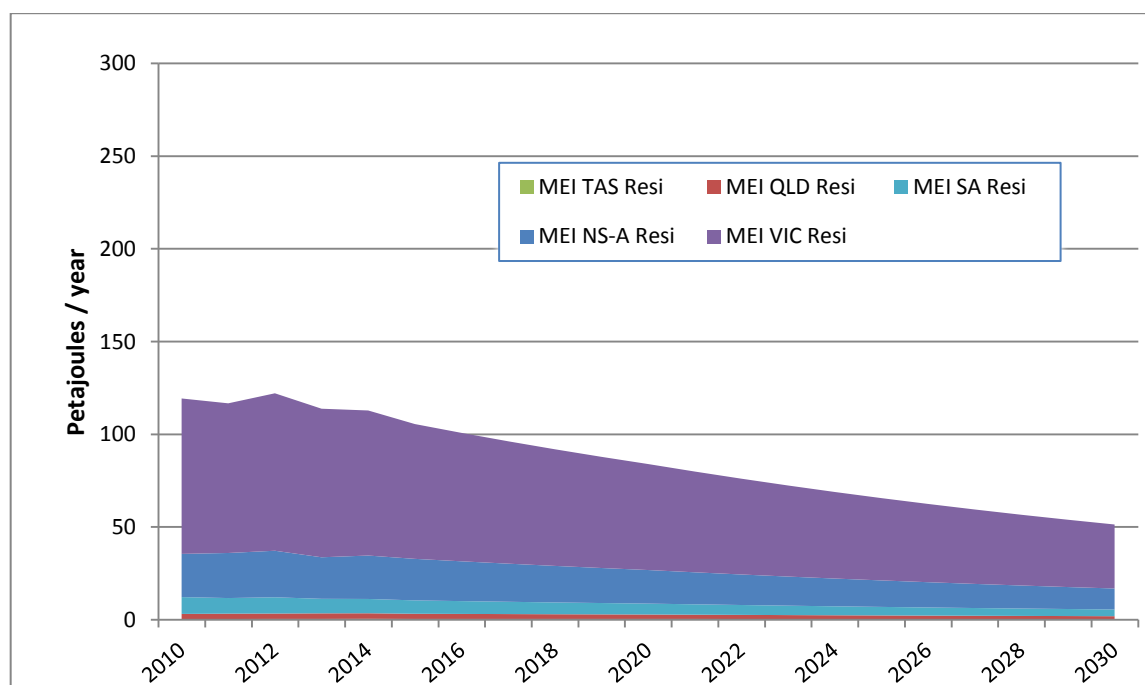
In the MEI Scenario, by 2025 gas demand in the RCSI sector declines by 40% from the 2012 peak. This is a decline of 75 PJ/yr. Compared with the AEMO “medium” forecast, the MEI Scenario consumes **~ 1,000 petajoules less gas** in this sector over the period 2015 to 2030, which is an accrued volume of gas equivalent to a large gas field. (See Section 16.)

As mentioned above, the greatest part of demand in the RCSI sector is residential gas demand, and this is shown for each state in Figure 8. Actual residential gas demand in eastern Australia is shown for the years 2010 to 2014.

As shown in Figure 8 and Table 4, in 2014 Victorian residential gas demand (76.3 PJ/yr) was greater than residential gas demand in all of the other eastern Australia states combined. This is because of Victoria’s greater population (compared with Tasmania and South Australia), more southerly latitude (compared to Queensland and New South Wales / Australian Capital Territory) and historical availability since the early 1970’s of relatively low-cost gas from the offshore Bass Strait oil and gas fields (37).

Residential gas demand in New South Wales (including the ACT) follows Victoria, at 20.6% of the total. Residential gas demand in Queensland (2.8%) and Tasmania (0.5%) is small compared with the other eastern-Australian states/territory.

Declining residential gas demand in South Australia has recently been forecast by Core Energy (38).



**Figure 8: Residential gas demand (actuals since 2010 and MEI Scenario for 2015 to 2030. (MEI)**  
Note, no AEMO forecasts of residential gas demand are available for comparison.



As shown in the following tables, residential gas demand can be broken down into four services: space-heating, water-heating, cooking, and other. Table 4 highlights that of all gas used in eastern-Australian residences in 2014, more than half (55.4 PJ/yr) was used just for Victorian space-heating. The next greatest use was for Victorian water-heating (16.9 PJ/yr).

**Table 4: Breakdown of 2014 residential gas demand (petajoules / year) (MEI)**

State/territory	Space-heating (PJ/yr)	Water-heating (PJ/yr)	Cooking (PJ/yr)	Other (PJ/yr)	Total (PJ/yr)
Queensland	0.1	1.7	0.5	0.5	2.8
NSW / ACT	7.8	9.3	2.3	1.2	20.6
Victoria	55.4	16.9	3.3	0.7	76.3
Tasmania	0.3	0.1	< 0.1	0.1	0.5
South Australia	2.4	3.5	1.0	0.3	7.2
Total	66.0	31.5	7.1	2.8	107.4

Table 5 shows gas demand for each service as a percentage of the state-total residential gas demand. In 2014 the greatest use of gas in Victorian and Tasmanian homes is for space-heating. On the other hand, in Queensland, New South Wales / ACT, and South Australia, gas used for water-heating is more dominant.

**Table 5: 2014 gas demand for four residential services, as a % of state-total residential gas demand (MEI)**

State/territory	Space-heating	Water-heating	Cooking	Other	Total
Queensland	4%	61%	18%	18%	100%
NSW / ACT	38%	45%	11%	6%	100%
Victoria	73%	22%	4%	1%	100%
Tasmania	60%	20%	~0%	20%	100%
South Australia	33%	49%	14%	4%	100%

Figure 8 illustrates that by 2025 in the MEI Scenario, residential gas demand has fallen to half of the 2012 peak. As described in the following sections of this report, the following drivers of gas demand in buildings are included in the MEI Scenario:

- economic fuel-switching from gas to efficient-electrical appliances
- economic energy-efficiency measures
- other consumer price and behavioural responses
- warmer winters.





## 10. Economic fuel-switching in the residential sector

This section describes how, in eastern Australia, there are potentially 500,000 to 1,000,000 homes where residents are unaware that they can immediately start to save hundreds of dollars per year on their space-heating bill. To do this, they need to turn on their existing reverse-cycle air conditioner (RCAC) heat pumps<sup>12</sup> and turn off their gas.

This section also describes how, longer-term, an increasing number of householders will economically invest in more RCACs and other efficient-electrical appliances that allow them to significantly reduce or totally eliminate their gas bill.

As described below, because of rising gas prices, falling electricity prices (energy-only component) especially for homes with access to rooftop-solar PV, and the emergence of highly-efficient-electrical appliances, the time is not far away when very little gas will be used in Australian homes and commercial buildings.

Economic fuel-switching in the buildings sector will free up significant amounts of gas for use by industry.

### *What is economic fuel-switching?*

In this report, “economic fuel-switching” is the concept where gas consumers switch to using electrical appliances for their space-heating, water-heating, cooking, and possibly other heating needs.

Residential fuel-switching from gas to renewables-based electricity, in concert with energy-efficiency measures (see Section 11), was proposed by Beyond Zero Emissions in 2013 as a way for homeowners and commercial building managers to reduce greenhouse gas emissions and move to 100% renewable energy (39). In 2014, ClimateWorks likewise suggested fuel-switching from gas to renewables-based electricity was key to a deep-decarbonisation scenario (34).

---

<sup>12</sup> Refrigerators and most home air conditioners are heat pumps that use a refrigeration cycle to move heat “uphill”, in a sense, from a cold location to a warmer location. A reverse-cycle air conditioner (RCAC, known simply as a “heat pump” in Tasmania and overseas) is a device that can shift heat from inside of a building to outside (usually in summer) and from outside of a building to inside (usually in winter). Heat pumps for residential space-heating have been sold in the United States since the 1970’s. Sales there are now on the order of two million per year.

An RCAC operating in heating mode is essentially recovering free renewable ambient heat (a form of solar energy) from the air outside of the building, raising the temperature of that heat, and shifting it to inside the building. In so doing, RCACs, with efficiencies of over 500% for top-of-the-line models, are far more efficient and have lower operating costs than simple electric-resistive heating devices (fan heaters, oil column heaters, panel heaters, etc.) that achieve efficiencies of only 100%, and also have superior efficiency to gas-fired heaters that are limited to efficiencies of less than 90% and perhaps as low as 50% or less.

Heat-pump water heaters (essentially RCACs that heat water) are eligible for renewable energy credits in Australia. RCAC space-heaters are eligible for renewable energy credits in the UK but not in Australia.



In 2014, the Grattan Institute found that following an increase in wholesale gas prices of \$5 per gigajoule, typical Melbourne, Sydney, and Adelaide homes can save \$1,024, \$628, and \$517 respectively on the combined running-costs of space-heating, water-heating and cooking if they switch from gas to efficient-electric appliances (8). (See Table 6.)

**Table 6: Running costs for space-heating, water-heating, and cooking are less with electricity (8)**

Capital City		Melbourne	Sydney	Adelaide
Gas	\$/year	\$1,606	\$942	\$1,071
Electricity	\$/year	\$582	\$314	\$554
<b>Savings with electricity</b>	<b>\$/year</b>	<b>\$1,024</b>	<b>\$628</b>	<b>\$517</b>

In 2014, the Alternative Technology Association (ATA) (20), funded by the Consumer Advocacy Panel, conducted a detailed region-by-region and appliance-by-appliance analysis identifying the economic benefits of householders switching from gas to efficient-electrical appliances for space heating, water-heating, and cooking. Covering all of eastern Australia, the ATA published results for 156 region/zone and dwelling-type combinations.

*Householders can start saving immediately by heating with their air conditioner*

Table 7 shows gas-versus-RCAC space-heating cost comparisons for just five of the ATA's modelled regions and home-types in eastern Australia. The largest savings identified apply to a large house in Canberra (\$1,733 per year). A large home in Melbourne might save \$658 per year. In every case, heating with an RCAC involved lower running costs. In no region or home type was gas heating found to be the cheapest option.

**Table 7: Gas-versus-RCAC space-heating running costs, derived from analysis done by the ATA (20). (MEI)**

Location	Home Type	Gas space-heating costs (energy- only, excludes fixed supply charges)	RCAC space-heating costs (energy- only, excludes fixed supply charges)	Heating cost savings with RCAC	% savings with RCAC
		(\$/year)	(\$/year)	(\$/year)	(%)
Canberra, ACT	large	\$2,255	\$522	\$1,733	77%
Melbourne, VIC	large	\$1,049	\$391	\$658	63%
Orange, NSW	medium	\$1,370	\$949	\$421	31%
South NSW	small	\$599	\$415	\$184	31%
Adelaide, SA	small	\$180	\$124	\$56	31%
This table lists only five of the 156 region/zone and dwelling-type combinations examined by the ATA.					



With respect to current space-heating practices in eastern Australia, MEI have identified that there may be between 500,000 and 1,000,000 homes (particularly in Victoria) where RCACs have already been installed, but the householder is not aware that using the RCAC in winter can be the cheapest way to heat their home (i.e. instead of using their gas heating).

Were the householder to be informed of the possibility of savings, he/she might opt to switch off their gas heating, switch on their RCAC, and start saving money immediately.

Although Saddler reports signs that fuel-switching for space-heating is possibly already underway in NSW and the ACT (30), for many householders in Victoria, the ATA's findings will be news. This is because gas heating has traditionally been seen as the cheaper option in Victoria. As described by the ATA (20), homeowners lack the knowledge that the economics of space-heating have changed. Gas appliance marketing can often mislead consumers. The ATA recommends that it is necessary to:

“... strengthen the regulatory oversight of the marketing of gas as cheaper and more efficient than electricity.”

The amount of money that a householder can save is a function of the size of the home, their regional climate, and the gas and electricity prices<sup>13</sup> that prevail in each region/zone. The ATA made assumptions about the efficiency of gas and RCAC heating systems which will vary from home-to-home, as is described in the following sections of this report. In the author's personal in-home experience, heating costs were reduced by 70% when recently-purchased RCACs were used instead of a 20-year-old ducted-gas heating system (37) (40).<sup>14</sup>

Across eastern Australia, the amount of money that householders can save by using RCACs for heating instead of gas may be very large. For example, were 500,000 Victorian households able to save \$500 per year, this adds up to a savings of \$250 million dollars per year.

The following report sections describe in more detail how these new space-heating economics have come about because of:

- rising gas prices,
- falling electricity prices (energy-only costs, excluding fixed supply charges), especially for householders with access to rooftop-solar PV
- the emergence of efficient RCACs,
- the recognition of the poor performance of, in particular, ducted-gas heating.

<sup>13</sup> In these comparisons, it is appropriate to use energy-only prices, excluding fixed supply charges.

<sup>14</sup> As discussed later in this report, heating-cost savings achieved by using an RCAC instead of gas will depend on the effectiveness of the gas and electrical appliances being compared in delivering heat to where it is needed, the electricity and gas prices that consumers are able to negotiate with their suppliers, and well as comfort and convenience preferences.



### *Residential gas and electricity prices are converging*

The Victorian Government organisation Sustainability Victoria (SV) offers Victorians a comparison of gas-versus-electric heating running costs (41). In their comparison calculations, SV uses only a single electricity price of \$0.277/kWh to cover all parts of Victoria and all retail offers.

Unfortunately this is an unreasonably high price to select for space-heating comparisons. For example, current available offers include off-peak electricity (energy-only, excluding fixed supply charges) of \$0.10/kWh (incl. GST), shoulder-period prices as low as \$0.14/kWh (incl. GST), and flat-tariff rates as low as \$0.17/kWh.

The gas price of \$16.6/gigajoule used by Sustainability Victoria aligns with current residential gas prices (energy-only component). This price converts to \$0.06/kWh which is not far less than the off-peak price for electricity and is about the same as recent tariffs paid to rooftop-solar PV owners for electricity exported to the grid.<sup>15</sup> The significance of this comparison is that formerly electricity was viewed as an expensive form of energy while gas was seen as cheap. In reality, today the energy-only component of gas and electricity prices is converging.

Even with such a high electricity price, Sustainability Victoria's results still show RCACs to be the lowest cost option in most cases. SV and other consumer-information-oriented organisations need to offer more sophisticated comparison tools that allow users to vary inputs such as energy prices and device efficiencies.

---

<sup>15</sup> A rooftop solar PV feed-in tariff of \$0.062/kWh applies in Victoria as at 1 January 2015.



### *Rampant penetration of RCACs, for space-cooling and heating*

Already nearly 3.9 million eastern-Australian homes (approximately half of all homes) have at least one RCAC. This is an increase of 30% from 3.0 million in 2008 (2014 ABS survey data (42)). Figure 9 shows that RCAC penetration is greatest in South Australia at nearly 60% and ranges from 53 to 47% in Queensland, New South Wales, Tasmania<sup>16</sup>, and the ACT.

As shown in Figure 9, RCAC penetration is lowest in Victoria with only 38% of homes having at least one RCAC (42). However, penetration of RCACs in Victoria has increased from just 29% in 2008 and is expected to continue to increase, possibly reaching levels similar to those presently seen in the other eastern-Australian states.

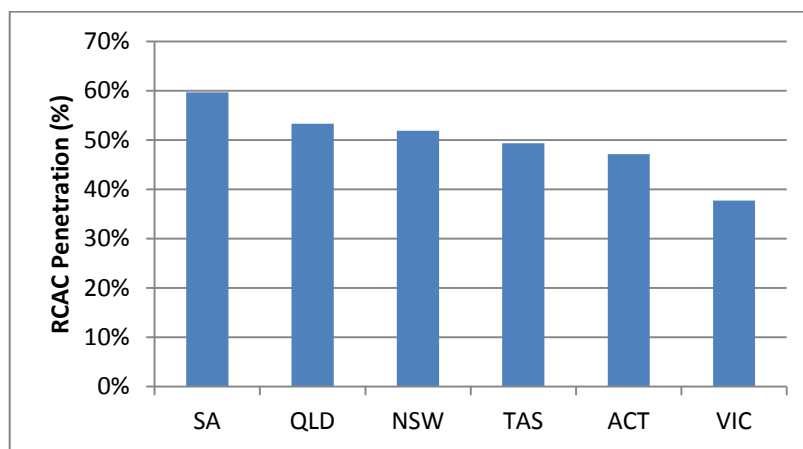


Figure 9: % of eastern-Australian homes with at least one RCAC - 2014 (42).

<sup>16</sup> For many years in Tasmania, RCACs have been widely used for space-heating. This is because of the historical availability of hydroelectricity and the non-availability of gas.



Relating to residential space-heating, the relevant questions are:

- In how many of these already-RCAC-equipped homes do residents use their existing RCAC(s) for space-heating?
- In homes where, to date, gas has been used for space-heating instead of an existing RCAC, how rapidly might a householder switch if they learned that their RCAC was their cheaper option?

ABS statistics do not address those questions directly. However, Figure 10 shows that electricity (RCAC and resistive) is the preferred method of space-heating, versus gas<sup>17</sup>, in Queensland, Tasmania, South Australia, and New South Wales. In the ACT, the use of gas and electricity for space-heating is evenly split, whereas Victoria stands alone with gas being clearly the preferred method of space-heating.



**Figure 10: Of homes using gas or electricity as main energy source for space-heating, % that use electricity (2014 data excluding wood, LPG, and other heating methods.) (MEI)**

In the MEI Scenario, Victoria's significant use of gas for space-heating is displaced by electricity as the following occurs:

- Victorians learn that RCACs are, in many cases, significantly cheaper to operate than gas heating,
- more RCACs are deployed in Victoria for both cooling and heating purposes.

The following sections describe the common circumstances where heating with RCACs is significantly cheaper than using gas.

<sup>17</sup> Wood, LPG, and other heating methods excluded.

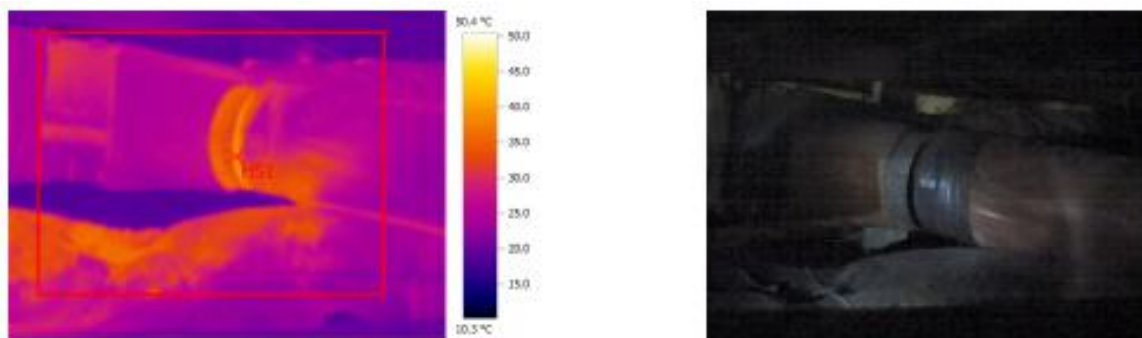


*Ducted-gas space-heating is often an ineffective way to warm a home*

Ducted-gas space-heating is the practice of using one central gas-combustion heater fitted with an air blower and a network of ducts (either under-floor or in the attic space) to carry warm air to the majority of rooms within a house. Around 40% of homes in Victoria and the ACT use ducted-gas space-heating, whereas in no other eastern Australia state does its prevalence exceed 4% (43).

Ageing ducted-gas systems can be inefficient at delivering heat to where it is needed (44). As with any gas heating system, some of the energy contained within the purchased gas is lost in the hot flue gases. Additional heat is lost from the ducts by the mechanisms of conduction, convection, radiation and air leakage. Under-floor ducts often go uninspected for decades and yet can suffer damage from animals, children, or under-floor maintenance or renovation activities. (See Figure 11.)

Blowing air around the house and through the ducting system can increase the leakage of warm air out of the house and the ingress of cold air. These losses can be exacerbated if internal doors block the flow of air back to the heater air intake. Lastly, ducted systems may direct heat to rooms where heat is not needed. The practice of closing a limited number of hot-air registers in unused rooms is often recommended, but this has the side-effect of over-pressuring the ducts upstream of the closed registers which then increases warm air leakage.



**Figure 11: Thermal and visual images of crushed and parted underfloor heating ducts.  
Damage was unrepaired for more than ten years.**



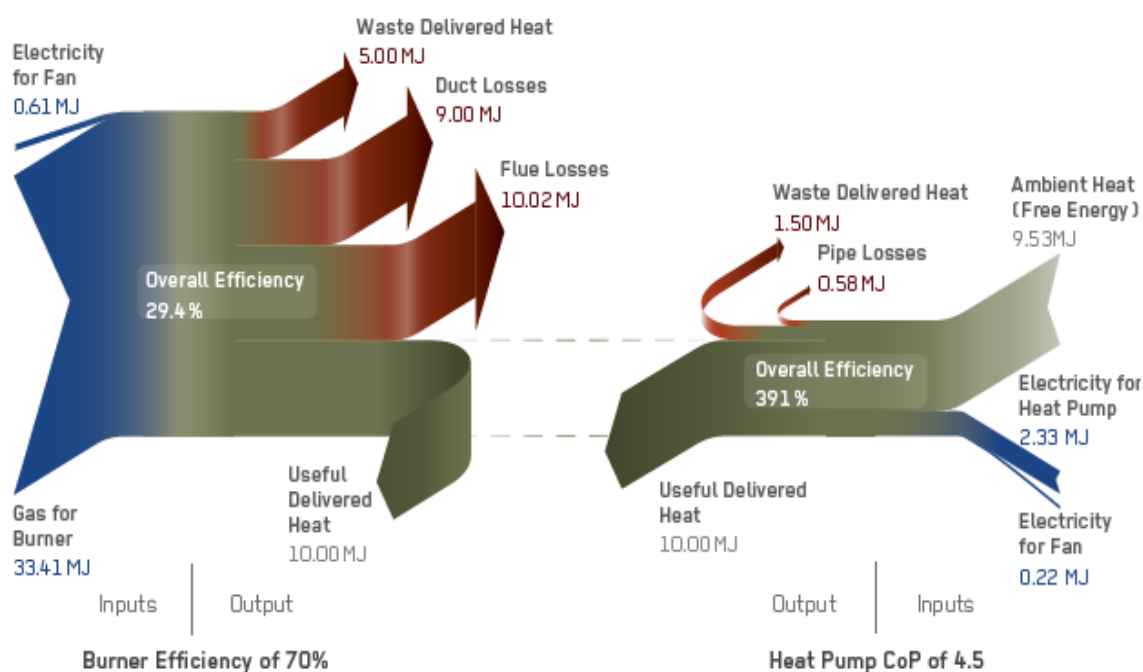


The performance of ducted-gas systems can be improved if:

- a highly efficient furnace is installed that uses condensing technology,
- robust and well-insulated ducts are installed and regularly maintained and inspected,
- the building is tightly sealed<sup>18</sup> to reduce over and under-pressuring the system.

The efficiency of ducted-gas space-heating systems in Australian homes can be as poor as 50% or less. In other words, in some homes half or more of the gas purchased for space-heating is, in a sense, immediately wasted and not used to effectively warm people in their homes.

Figure 12 compares an inefficient ducted-gas heating system with a non-ducted RCAC that is **13 times** more efficient (39).



**Figure 12: Comparing the effectiveness of delivering 10 megajoules (MJ) of useful heat from an ageing ducted-gas space-heating system (left-side) versus a modern wall-mounted (non-ducted) RCAC heat pump (right-side) (39).**

<sup>18</sup> Gas heating systems must be regularly inspected to ensure there is no build-up within the home of the poisonous gas carbon monoxide, especially in “tight” or well-sealed homes that have a low level of passive air leakage.



*Modern reverse-cycle air conditioners are efficient renewable-energy generators*

Contrasting with the potentially-poor performance of ducted-gas, some non-ducted RCACs (see Figures 13 and 14) achieve efficiencies of more than 500% when they capture up to 4.8 units of free, renewable-ambient heat from the outside air for every one unit of electricity applied (45). If the RCAC wall unit is located in the room directly where heat is needed, energy losses are minimal.

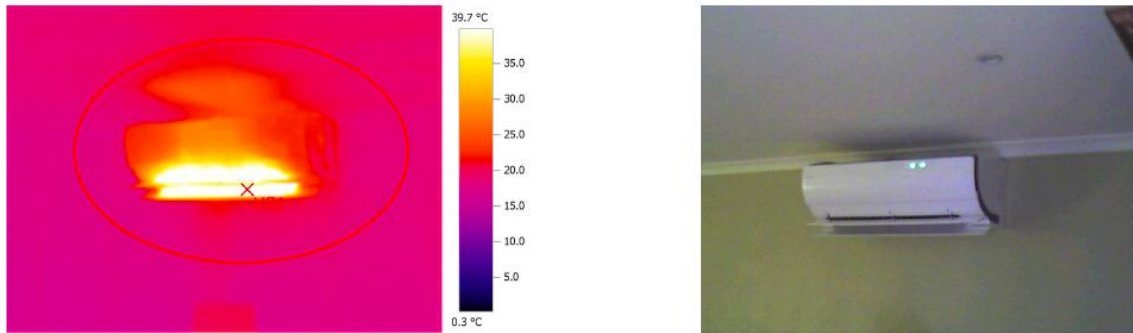


Figure 13: Thermal and visual images of an RCAC producing heat at 50°C.

**For every 1 unit of electrical energy used, up to 4.8 units of renewable-ambient heat goes in here.**

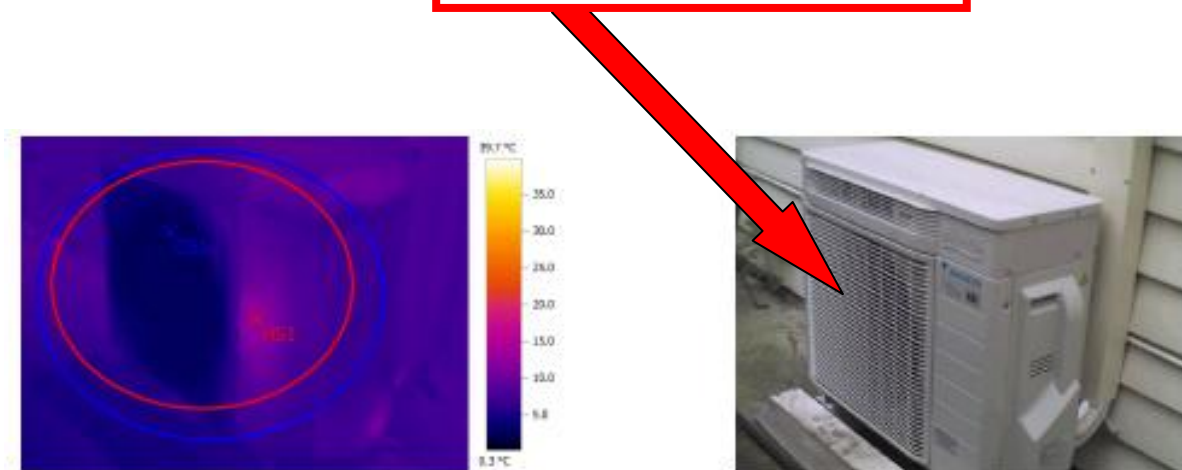
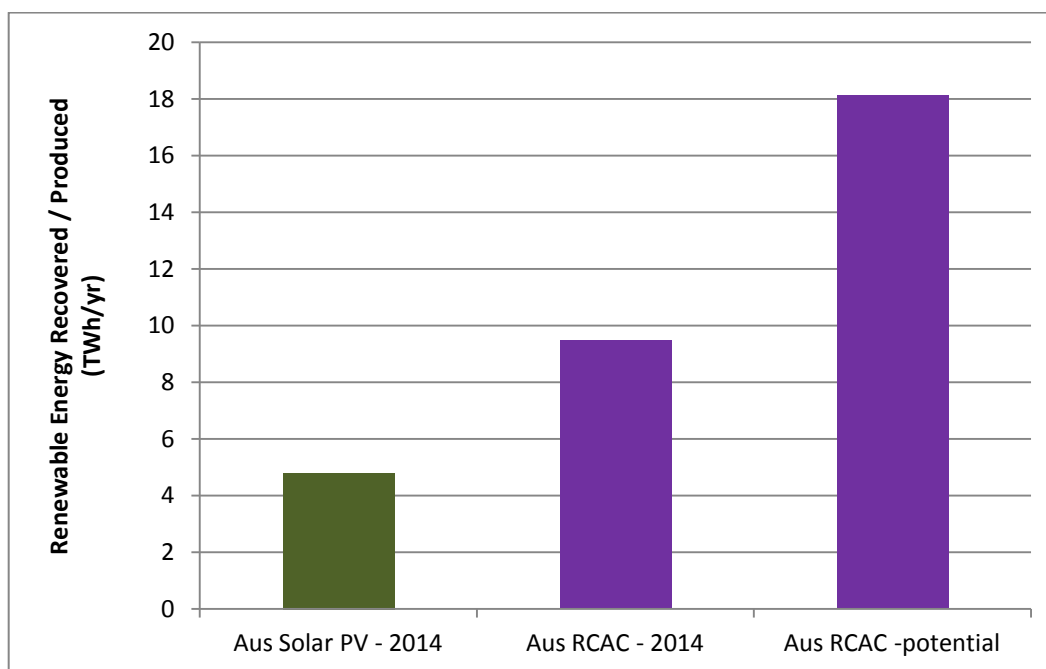


Figure 14: Thermal and visual images of exterior part of an RCAC collecting heat from 9°C ambient air, with heat exchanger operating at 2°C.



Unlike in the United Kingdom (46), RCACs are not eligible for renewable-energy credits in Australia. Nevertheless, RCACs are a disruptive technology and are already very significant harvesters of renewable energy in Australia, exceeding rooftop-solar photovoltaic (PV) panels in their energy recovery/production. Figure 15 illustrates that in 2014 the renewable energy recovered by RCACs exceeded that of rooftop-solar PV. In the coming years, RCAC-recovered renewable energy has the potential to double as more buildings in Australia (and in particular in Victoria, as described above) adopt this method of space-heating.



**Figure 15: Comparison of Australia-wide rooftop-solar-PV renewable energy recovery/production (47) versus the amount of renewable energy recovered / produced by RCACs. (MEI)**

### *Other aspects of space heating*

Individual comfort and convenience preferences also come in to play when deciding between gas and electric heating. If residents are accustomed and familiar with using gas, switching to electricity may mean a change in habits that can take time even if cost savings are large. Residents may be willing to “pay extra” for the quick heat up time of ducted-gas, whereas with an RCAC, a timer might need to be set to allow the RCAC to achieve the same early-morning warm outcome as gas.

The dryness of both gas and RCAC heating has been cited as a comfort and health concern (48). However now available in Australia are RCACs that use a desiccant wheel to humidify the heated air in order to eliminate this concern (49).



### *Householders can save by replacing all old gas appliances with new electric*

The ATA also identified the economic benefits of householders switching off gas as a householder's three key gas appliances (space heating, water-heating, and cooktops) near the end of their lives. For example, the Sydney-area owner of a "large home" presently heated by gas can save \$1,284 (net present value) by switching to an RCAC when their gas heater is in need of replacement (20).

### *Governments can now save on gas infrastructure costs*

The ATA found that there is no economic need for any new homes or suburbs anywhere in eastern Australia to connect to gas. Similar to recommendations made by the Grattan Institute (8), the ATA report called for an end to government subsidies for expanding gas supply networks, specifically recommending that

*"an urgent review of policy and programs that subsidise/support the expansion of gas networks is required."*

The Grattan Institute reported that a Sydney household that uses gas for cooking and hot water could save \$600/yr by disconnecting from the gas network and instead using electricity to supply these services. The Grattan analysis ignored the up-front costs of buying new appliances (8).

These studies call in to question the need for homes to be connected to both the electricity grid and the gas grid. Subsidies as high as of \$60,000 per home have been reported for Victoria's rural gas-grid extensions known as the "Energy for the Region's Program", should as few as 20% of homes take-up the gas option (50). According to the Grattan Institute:

*"People in regional Victoria may initially welcome the option of connecting to natural gas. With the predicted increase in gas prices, however, households in regional areas may well be better off from continuing to use other fuel sources, rather than connecting to the gas network. In some cases, regional consumers who commit to gas in good faith may find themselves financially disadvantaged" (8).*

Infrastructure costs can be reduced, if rather than expanding the gas grid, it can be rationalised. As consumers switch from gas to electricity, the existing electricity grid would become more productively used.



### *Hot water fuel-switching options*

Some homeowners can save hundreds of dollars per year by switching from gas hot water to a heat-pump water heater (HPWH, shown in Figure 16). Already more than 170,000 heat-pump water heaters have been installed in eastern Australia with most of them receiving renewable energy certificates (51). Rooftop-solar-thermal hot water generators, of which there are more than 700,000 in Australia, if electric-boosted, can also be another economically-attractive gas-free hot water option in regions that have a superior direct-solar resource (39). HPWHs can act as “energy-storage hot-water-batteries” if:

- charged at night when grid-supplied electricity is cheap, or
- charged at mid-day when a home’s solar PV panels would otherwise be exporting excess electricity (52).



Figure 16: Heat-pump water heater (HPWH).

For every 1  
unit of  
electrical  
energy used,  
up to 3.5 units  
of renewable-  
ambient heat  
goes in here.



### *Induction cooktops, gas-free homes, and the gas grid death-spiral*

The installation of RCACs, HPWHs (or solar-thermal hot water with electric boost), and efficient and controllable induction cooktops (see Figure 17) allows “all-electric” Australian homes to become gas free (39) (53). This “second electrification” of the Australian home is also being driven by the widespread deployment of rooftop-solar photovoltaic (PV) panels<sup>19</sup>. In future, electricity storage batteries and electric vehicles will also become widely used.



**Figure 17: Efficient, controllable electric-induction cooktop – where the pot or pan acts as the heating element.**

A utility market “death spiral” may occur when declining gas or electricity sales (due to factors such as customers switching fuels, implementing energy-efficiency measures, or making behavioural changes, etc.) require suppliers and distributors to further increase prices in order to maintain revenue. These ever-higher prices then further accelerate demand decline and result in a shrinking customer base. This phenomenon has been described regarding Australia’s electricity industry (54).

Eastern-Australian gas consumers who opt to completely disconnect from the gas network can eliminate the gas bill with its fixed charges of generally more than \$200 per year (20). With declining gas volumes, energy distributors and retailers may increase fixed supply charges in order to maintain revenue. Given that electricity offers a broader range of services than gas, and that gas services in most buildings can be provided by electric alternatives, the gas network may face a greater risk of a death spiral than does the eastern-Australian electricity grid (55) (56).

<sup>19</sup> According to the Clean Energy Council report “Clean Energy Australia 2014”, as at the end of 2014, 1,421,601 household rooftop-solar photovoltaic (PV) systems have been installed in Australia, or one installation for every six Australian homes.





### *AEMO have only begun to model fuel-switching*

As mentioned in Section 5, to date AEMO's official annual gas forecasts (5) do not indicate that the amount of gas used in buildings will change much over AEMO's 20-year outlook planning period. However AEMO's recently published "Emerging Technologies Information Paper" (26), does, for the first time, provide some quantitative analysis of fuel-switching in residential buildings.<sup>20</sup>

Unfortunately, AEMO's Emerging Technologies Information Paper examines only the economics of residents making future investments in new heating systems. AEMO ignores the potential for residents who already have both gas space-heating and RCAC(s), but who have traditionally used only gas for heating, to suddenly understand that using the existing RCAC is the cheaper option, and to then make a switch.

Nevertheless, AEMO's Emerging Technologies Information Paper indicates that electricity demand could, in around 2034, increase because of fuel-switching by 2,552 gigawatt-hours per year (GWh/yr). Curiously, AEMO have not published any figure for the corresponding decline in gas demand. Using a factor of five<sup>21</sup>, 2,552 GWh/yr converts to a decline in gas demand, due to residential fuel-switching, of 46 PJ/yr. This is a very significant reduction in gas demand (57). However, this potential gas demand decline is not as imminent nor as great as the 75 PJ/yr decline in residential gas demand (by 2025) projected by the MEI Scenario (due to fuel-switching and other drivers as described in Section 9). The gas savings to be made in the MEI Scenario are greater than AEMO's assessment in part because AEMO has not yet included the possibility of "immediate" fuel-switching.

### *New ATA modelling, done for MEI, confirms fuel-switching reduces gas demand*

The ATA has created a "bottom-up" residential fuel-switching time-series model that incorporates the data from the "Are We Still Cooking with Gas Report" (20). It also models residents with existing RCACs progressively learning that using that their RCAC can be the cheaper way to heat a home, and then making an immediate switch.

MEI contracted the ATA to model multiple future residential fuel-switching scenarios. The ATA's results confirm the fuel-switching outcomes included in the MEI Scenario. Of interest is the ATA's finding that a greater degree of fuel-switching occurs for space-heating as opposed to water-heating. This is because of the space-cooling side-benefits achievable with RCACs and the reflexive nature of "emergency" hot water service replacement decisions, among other factors.

---

<sup>20</sup> AEMO plans to extend this analysis to commercial and industrial consumers.

<sup>21</sup> See the last line of Table 7 where ratios of gas-replaced-by-electricity range from three to 18 in the chosen examples.





## 11. Energy efficiency and other factors reducing gas use in buildings

In the MEI Scenario, fuel-switching drives the greatest reduction of gas demand in buildings. However this section describes additional gas demand drivers including energy-efficiency measures, consumer behaviour and price responses, warmer winters, and energy-retailer marketing activities.<sup>22</sup>

### *Energy-efficiency measures: “exploring” for gas in your attic*

In eastern Australia, gas “exploration” and “mining” can economically take place in eastern-Australian attics and lounge rooms via the deployment of energy-efficiency measures such as insulation (see Figure 18), draught-proofing, and improved windows and window treatments (e.g. drapes and blinds) (58) (59) (60) (61). According to the Australian Bureau of Statistics, 30% of Australian homes still have no form of insulation (62). The Insulation Council of Australia and New Zealand (ICANZ) cite five-year economic payback for insulation upgrades (63). Sustainability Victoria reported that an energy efficient household can save about 40% on an average household’s energy costs (64).



**Figure 18: Uninsulated attic in Melbourne, Victoria.**

<sup>22</sup> In the MEI Scenario, double-counting of gas demand drivers has been avoided. For example, in the case where a switch from gas to electric space-heating occurs, subsequent energy-efficiency measures (e.g. insulation) will reduce electricity demand, not gas demand.



Hot water systems and piping are also often poorly insulated, if at all. (See Figure 19.)

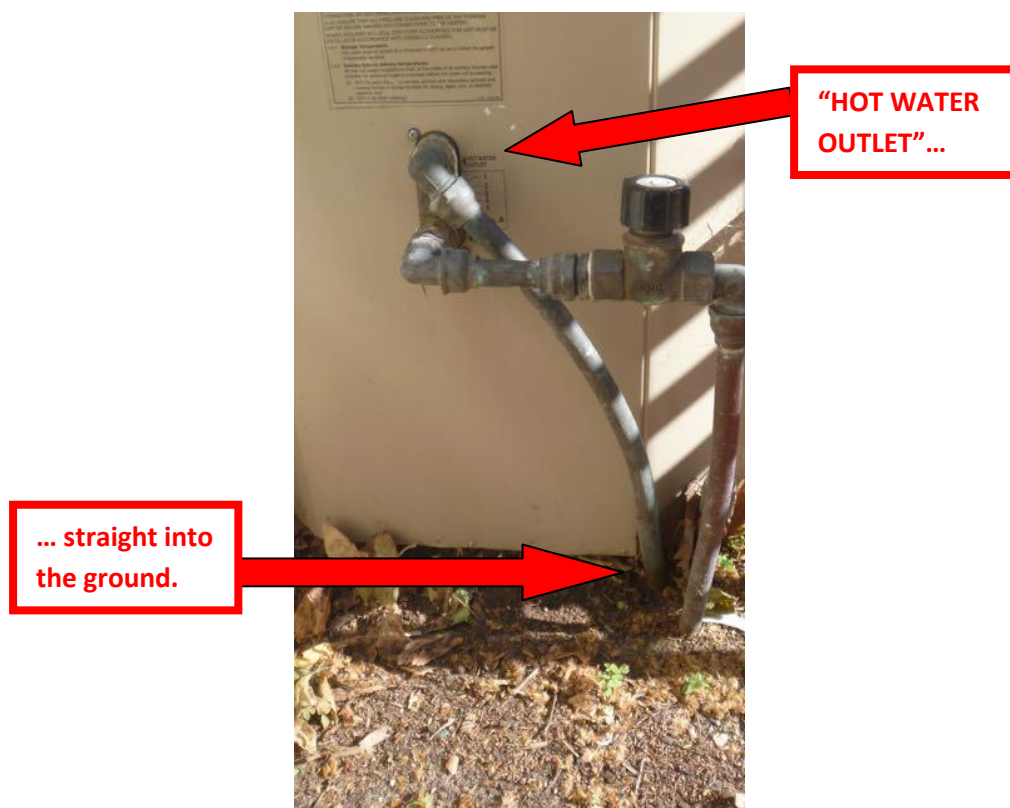


Figure 19: Uninsulated hot water outlet pipe running directly into the ground (Victoria).

Continuing deployment of efficient showerheads can reduce the amount of gas used for hot showers by over 40% compared with inefficient showerheads (65).

Saddler found that by 2030, an approximate 1 PJ/yr (10%) reduction in the amount of gas used in NSW commercial buildings may result from a range of Commonwealth building energy-efficiency measures in place in 2013 (66).

Providing warmer and cheaper-to-operate homes can lead to improved home health outcomes especially for the sick and elderly (67).

#### *Consumer behavioural and price responses*

Increasing gas prices will increase consumer bills as quantified in Section 4. Users of larger-than-average amounts of gas will, of course, see larger cost increases. Consumers may respond to larger bills by changing behaviours. Saddler describes how consumers responded to rising electricity prices being often in the news and a topic of political debate, by reducing their demand for electricity (66). If rising gas prices become a widespread news topic, gas consumers could respond in a way similar to that seen with electricity price rises.



### *Winters are getting warmer*

Core Energy describes the impact of warmer winter temperatures, caused by climate change and the urban-heat-island effect, on reducing gas demand (65). NIEIR quantifies this for the New South Wales buildings sector at 0.095 PJ/yr, year-on-year as winter temperatures rise each year (65). Over ten years, this amounts to a 1 PJ/yr reduction in gas demand in NSW.

In their August 2014 earnings report, AGL cited a “record mild winter” as a reason that gas sales were down 9.3% for the full financial year ending 30 June 2014 (68). Likewise, Energy Quest (69) reported that the warmest early-winter period *on record* in NSW contributed to non-electricity-generation related gas demand across eastern Australia being down 10% in the quarter ending 30 June 2014.

### *Electricity-only retailers actively promoting fuel-switching from gas*

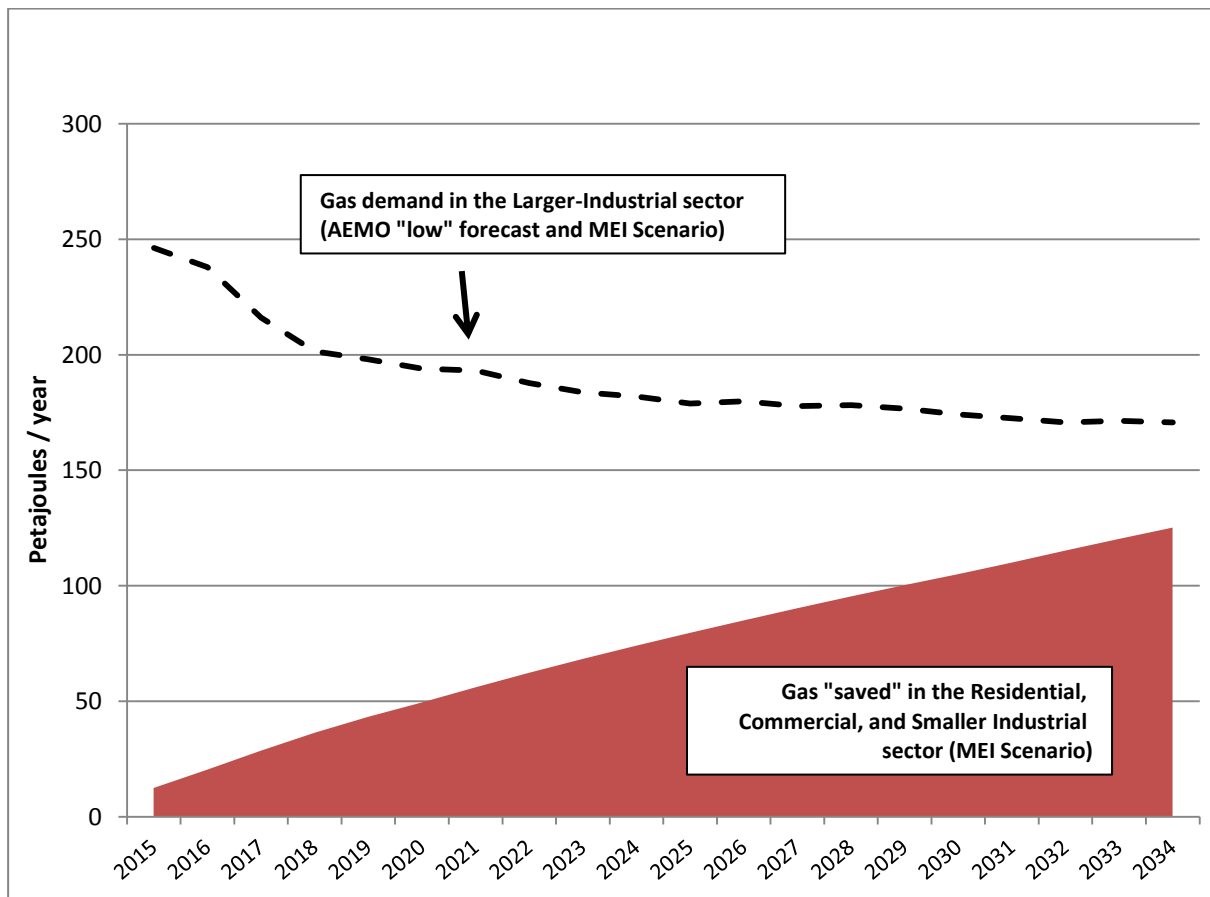
Some energy retailers sell mostly electricity and little or no gas. Especially while electricity demand remains at below historical levels (25), these retailers have an incentive to actively promote fuel-switching from gas to electricity. In Japan, this strategy allowed electricity retailers to nearly double the revenues gained from individual households (70).



## 12. Switching off gas in buildings frees up gas for industry

Ending gas waste, particularly in the buildings sector, will free up large volumes of gas that could have higher-value industrial uses. As shown in Figure 20, in twenty years time, approximately 70% of the gas used in the Larger-Industrial sector could be sourced from gas “saved” in the Residential, Commercial, and Smaller-Industrial sector.

In the MEI scenario, the fraction of gas used by larger industry increases from 44% (2015) to 58% (2030). This indicates the future movement of gas use away from sectors where economic gas substitutes are available, and toward the industrial sector where economic gas substitutes are less available and gas is valued more highly.



**Figure 20: Demand in the Larger-Industrial sector compared with gas “saved” in the Residential, Commercial, and Smaller-Industrial sector. (MEI Scenario)**



### 13. Switching off gas in buildings aids decarbonisation

Energy-efficiency measures and economic fuel-switching in buildings from gas to electricity can help Australia to economically decarbonise, especially as eastern Australia's electricity is increasingly produced with renewable energy. ClimateWorks identified that virtually no gas is used in buildings by 2050 in a Deep Decarbonisation scenario (34). The ATA's study of the greenhouse gas emissions impact of gas-to-electricity residential fuel-switching (71) found:

- *"Emissions were lower when switching all three traditionally gas-fueled (space-heating, water-heating and cooking) uses to efficient-electrical appliances. This was consistent across household scenarios and across all locations apart from in Mildura, Victoria, where there was a small increase as a result of the switch.*
- *Space-heating was consistently found to be less emissions-intensive when delivered by efficient-electrical appliances, as opposed to gas.*
- *The emissions impact of water-heating varied by location – with all Victorian and some NSW/ACT locations experiencing a modest increase in emissions with a switch to efficient-electric, while South Australia, Queensland and other parts of NSW experienced a reduction.*
- *Minor emissions increases from switching to efficient-electric are likely to be even smaller in coming years as Australia's electricity grid utilises more renewable generation."*



## 14. Declining gas demand decelerates gas reserves depletion

Figure 21 compares how gas reserves are consumed in AEMO's 2014 medium forecast versus the MEI Scenario. In the AEMO forecast, approximately 10,000 petajoules of gas are consumed over the period 2015 to 2032. In the MEI scenario, because gas demand declines in all sectors, 10,000 petajoules of gas is not consumed until a decade later. This illustrates the opportunity that declining gas demand presents for measured consideration of reserves depletion in concert with identification of gas supply and demand management options. (See Section 16.)

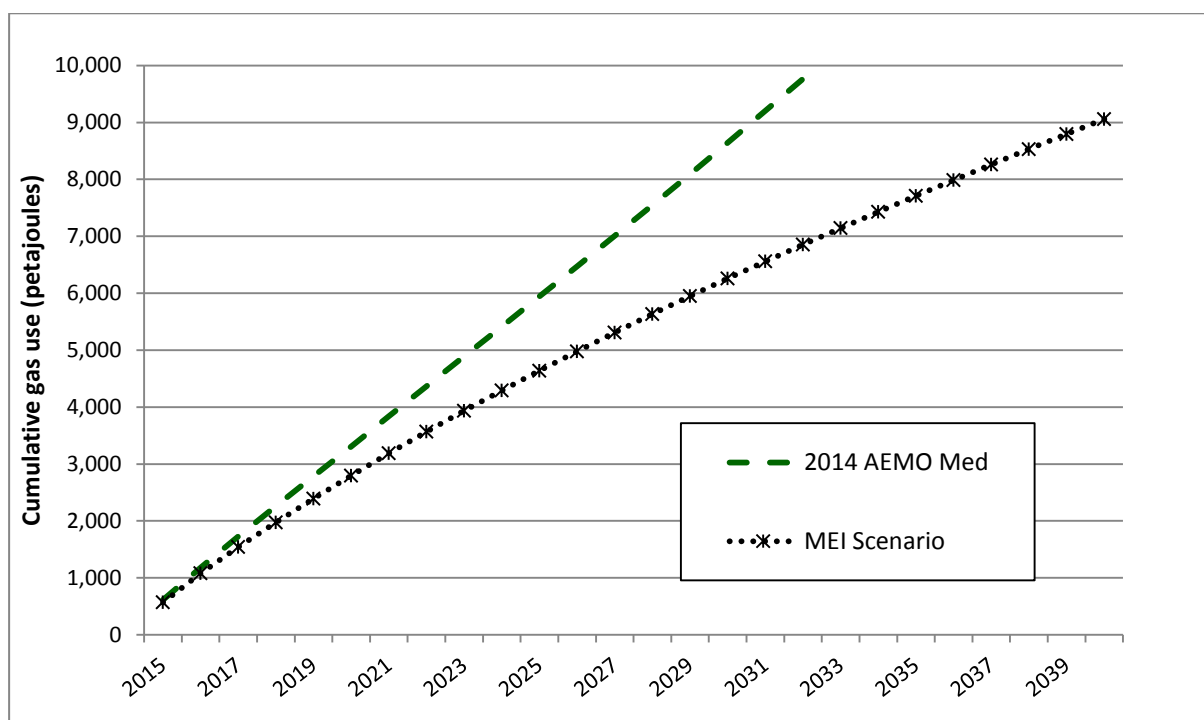


Figure 21: Eastern Australia cumulative “domestic gas” consumed / reserves depletion. (MEI)



## 15. New industries? Biogas and gas for transport

### *Biogas*

As fossil gas prices rise and the preference for lower-carbon energy and chemical feedstock sources increases, the distributed production of renewable biogas may become economic in eastern Australia. Renewable biogas is gas derived from biomass sources and municipal waste.

Bioenergy and gas from waste (72) is proving to be a significant resource in countries such as Denmark and Germany (73).

In 2013, the Sydney City identified that up to 50 PJ/yr of gas<sup>23</sup> could be produced from sources located around Sydney (74) (75). As an example, Sydney Water reports that up to 5 PJ/yr of gas could be created available from their own waste sources (76).

In 2012, the CSIRO's work for AEMO's "100% Renewable Energy Study" for eastern Australia identified a recoverable biogas resource of more than 200 PJ/yr (77). This can be compared with 2030 gas demand in the MEI Scenario of approximately 300 PJ/yr.

### *Gas for transport*

Neither AEMO's forecasts nor the MEI Scenario explicitly describe any significant or growing use of gas in the transport sector. Other analysts point to growing use of gas for powering heavy transport in Australia over the coming decades (34) (78).

---

<sup>23</sup> Note that the City of Sydney study does not utilise timber plantations or native forest timber. The study did include a small amount of bioenergy (~ 0.4 PJ/yr) from pine wood processing residues.





## 16. Needed: An Integrated Resource Plan that considers demand-side opportunities

Eastern Australia needs an Integrated Resource Plan (IRP) that considers both gas-supply and gas-demand management options such as economic fuel-switching and energy-efficiency measures. Furthermore, as fuel-switching from gas to electricity occurs, the demand for electricity will increase. Therefore consideration of electricity generation and distribution must also be part of the Integrated Resource Plan.

Examples of Integrated Resource Planning in use in the United States include the Arizona Public Service, the Public Service Company of Colorado, and PacifiCorp (79).

### *1990 Gas and Fuel least-cost supply planning never completed*

In the early 1990's, Victoria's Gas and Fuel Corporation started work on gas demand management and least-cost supply planning (80) (81). One objective was:

“...to provide an evaluation of the potential to enhance and/or supplement natural gas supplies in Victoria, over the next 20 years, through demand management.”

Identified measures included appliance development promotion, household thermal design, and consumer education.

The Gas and Fuel Corporation described “Integrated Analysis” ...

“...in which the cost-effective demand management programs are allowed to compete against supply alternatives in the long-term supply/demand balance in order to minimise the cost of end-use energy services to the community.”

However that Gas and Fuel Corporation program was terminated prior to completion.

### *AEMO focus has been on the supply side*

To date, AEMO has tended to focus on gas-supply options to the exclusion of demand-side opportunities. This is highlighted by the following statement from Section 2.4 of AEMO's April 2015 Gas Statement of Opportunities:

*“Analysis indicates that sufficient commercially viable reserves and resources are available to satisfy projected gas demand for at least the next 20 years. To ensure that gas consumption can be met, however, **new gas reserves need to be developed.**” (bold font added)*

Indeed, AEMO's April 2015 Gas Statement of Opportunities did not highlight any gas demand-side opportunities.



AEMO publishes the Gas Statement of Opportunities (GSOO) in accordance with Section 91DA of the National Gas Law. A stated aim of the GSOO is to:

“...provide industry participants, investors, and policy-makers with transparent information to support decision-making to ensure gas – a key resource – is managed in Australia’s long-term interests.”

Regarding that aim, our report suggests that the current often inefficient and wasteful use of gas, particularly in the buildings sector, is not in Australia’s long-term interests. AEMO and other relevant authorities should develop an Integrated Resource Plan that, in addition to supply-side opportunities, also identifies and recommends economic opportunities for fuel-switching from gas to electricity and economic energy-efficiency measures. Such a plan is likely to identify that large and economic gas “discoveries” can be found in industry and in the buildings of eastern Australia, as described in earlier sections of this report.

As an example, the 1,000 petajoules (PJ) of gas “savings” that accrues in the RCSI sector (see Section 9) is equivalent to a significantly-large gas field. This volume of gas can be compared with the Minerva field in the offshore Otway (Victoria) basin that was reported to initially contain 330 PJ of gas (82), or to the offshore Kipper field in Bass Strait (Victoria) that was reported to contain 680 PJ of gas (83).



## 17. Summary of ways to ease the transition to higher gas prices

The Australian federal government, eastern-Australian state governments, and local councils can pursue policies to ease the transition to higher gas prices, such as:

- informing gas consumers (individuals and businesses) of the economic and other advantages of switching to other energy sources and of applying energy-efficiency measures
- acting on recommendations such as those documented by the Alternative Technology Association and the Consumer Utilities Advocacy Centre (22) with respect to residential fuel-switching from gas to electricity (20)
- removing subsidies that encourage uneconomic use of gas, where other options exist such as using efficient-electrically-powered appliances
- removing subsidies that encourage uneconomic expansion of the gas grid
- strengthening the regulatory oversight of the marketing of gas and gas appliances, which are often claimed to be cheaper, more efficient, and more environmentally benign than all electrically-powered appliances
- facilitating the identification and financing of economic fuel-switching and energy efficiency projects
- reducing infrastructure costs by rationalising the gas grid where economic
- creating, maintaining, and implementing an Integrated Resource Plan.



## 18. References

1. **Forcey, T., and Sandiford, M.** *The dash from gas. Could demand in New South Wales fall to half?* s.l. : University of Melbourne Energy Institute, January 2015.
2. **Parliament of New South Wales, Legislative Council.** Final Report, Supply and cost of gas and liquid fuels in New South Wales. [Online]  
[http://www.parliament.nsw.gov.au/prod/parlament/committee.nsf/0/FE7E85037FC7378BCA257DF700040351?open&refnavid=CO4\\_1](http://www.parliament.nsw.gov.au/prod/parlament/committee.nsf/0/FE7E85037FC7378BCA257DF700040351?open&refnavid=CO4_1).
3. **Australian Energy Market Operator (AEMO).** *2011 Gas Statement of Opportunities for Eastern and South Eastern Australia.* December 2011.
4. First shipment of LNG to leave Gladstone in central Queensland bound for Asia. [Online] The Australian Broadcasting Corporation (ABC), 2 January 2015.  
<http://www.abc.net.au/news/2014-12-30/first-shipment-of-lng-to-leave-gladstone-bound-for-asia/5992840>.
5. **AEMO.** *National Gas Forecasting Report.* December 2014.
6. **ACIL Allen Consulting.** *Fuel and Technology Cost Review - report to the Australian Energy Market Operator.* 10 June 2014.
7. **Deloitte Access Economics .** *Gas market transformations - Economic consequences for the manufacturing sector .* July 2014 .
8. **Wood, T.** *Gas at the Crossroads, Australia's Hard Choice.* The Grattan Institute. October 2014.
9. **Haylen, A.** *A tightening gas market: supply, demand and price outlook for NSW.* Parliamentary Research Service, New South Wales Government. September 2014. Briefing Paper no. 4/2014.
10. **Bureau of Resources and Energy Economics (BREE).** *Eastern Australian Domestic Gas Market Study.* Austrlian Government. December 2013.
11. **Ledesma, D., Henderson, J., and Palmer N.** *The future of Australian energy exports: Will domestic challenges limit the development of future LNG export capacity?* The Oxford Institute for Energy Studies. September 2014.
12. **Grudnoff, M.** *Fracking the future - Busting industry myths about coal seam gas.* The Australia Institute. March 2014.
13. **Macdonald-Smith, A.** Household gas bills to jump 30pc: ANZ. *The Sydney Morning Herald - Business Day.* [Online] July 23, 2015. <http://www.smh.com.au/business/energy/household-gas-bills-to-jump-30pc-anz-20150723-giixxq.html>.
14. **St John, A.** The coal seam gas debate. *Parliament of Australia.* [Online]  
[http://www.aph.gov.au/About\\_Parliament/Parliamentary\\_Departments/Parliamentary\\_Library/pubs/BriefingBook44p/GasDebate](http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BriefingBook44p/GasDebate).
15. **Core Energy Group.** *Gas Production and Transmission Costs - Eastern and South Eastern Australia.* February 2015.
16. **Macdonald-Smith, A. and Ker, P.** Queensland LNG ventures deny gas shortfall. [Online] February 18, 2015. <http://www.smh.com.au/business/queensland-lng-ventures-deny-gas-shortfall-20150218-13i3p7.html>.
17. **Cook, P.** Parliament of Victoria. *Inquiry into Unconventional Gas in Victoria.* [Online] July 22, 2015. <http://www.parliament.vic.gov.au/epc/references-committee-inquiries/article/2637>.
18. **Manufacturing Australia.** *Reforming the East Coast Gas Market.* 13 April 2015.



19. **Australian Competition and Consumer Commission (ACCC).** East Coast Gas Inquiry 2015.  
[Online] <https://www.accc.gov.au/regulated-infrastructure/energy/east-coast-gas-inquiry-2015>.
20. **Alternative Technology Association (ATA).** *Are we still Cooking with Gas?* November 2014.
21. **Australian Energy Regulator.** The AER approves the 2015 Victorian gas network tariffs. *Australian Energy Regulator*. [Online] December 1, 2014. <https://www.aer.gov.au/node/29018>.
22. **Consumer Utilities Advocacy Centre.** *Our Gas Challenge - The Role of Gas in Victorian Households*. August 2014.
23. **Pitt and Sherry.** *Cedex Carbon Emissions Index*. June 2015.
24. **AEMO.** *Gas Statement of Opportunities for Eastern and South Eastern Australia*. 2010.
25. *Five Years of Declining Electricity Demand in Eastern Australia, Causes and Consequences.*  
**Sandiford, M., Forcey, T., Pears, A., McConnell, D.** s.l. : The Electricity Journal (accepted for publication), August 2015.
26. **AEMO.** *Emerging Technologies Information Paper*. June 2015.
27. —. *2013 Gas Statement of Opportunities for eastern and south-eastern Australia*. 29 November 2013.
28. —. *Gas Statement of Opportunities for eastern and south-eastern Australia (2015)*. April 2015.
29. **Lewis Grey Advisory.** *Projections of Gas and Electricity Used in LNG - prepared for the Australian Energy Market Operator*. 15 April 2015.
30. **Saddler, H.** Coal continues its post repeal recovery. *Climate Spectator*. [Online] August 4, 2015 .  
<http://www.businessspectator.com.au/article/2015/8/4/energy-markets/coal-continues-its-post-repeal-recovery>.
31. **AEMO.** *Generation Expansion Plan for the 2014 National Transmission Network Development Plan*. December 2014.
32. —. *Forecasting Methodology Information Paper*. December 2014.
33. **IT Power.** *Renewable Energy Alternatives for Australian Industrial Gas Users* . 13 October 2014 (draft).
34. **ClimateWorks Australia.** *Pathways to deep decarbonisation in 2050 – How Australia can prosper in a low carbon world*. September 2014.
35. —. *Industrial energy efficiency data analysis project*. May 2013.
36. Process heat, boilers and steam systems. *eex.gov.au - The bottom line on energy efficiency*.  
[Online] Australian Governments. <http://eex.gov.au/technologies/process-heating-and-steam-systems/>.
37. **Forcey, T.** It's cold in my house and the price of gas is going up – what can I do? *The Conversation*. [Online] July 20, 2015. <https://theconversation.com/its-cold-in-my-house-and-the-price-of-gas-is-going-up-what-can-i-do-44824>.
38. **Core Energy Group.** *Gas Demand Forecasts - Australian Gas Networks | SA Gas Access Arrangement 2017-21*. June 2015.
39. **Beyond Zero Emissions.** *Zero Carbon Australia Buildings Plan*. August 2013.
40. **Forcey, T.** Turn on your air conditioner - and knock hundreds of dollars off your heating bill (submitted). *Renew - Technology for a sustainable future*. 2015., 133.
41. Heating running costs. *Sustainability Victoria*. [Online] Victorian Government. [Cited: August 2, 2015.] <http://www.sustainability.vic.gov.au/services-and-advice/households/energy-efficiency/at-home/heating/heating-running-costs>.
42. **Australian Bureau of Statistics.** 4602.0.55.001 - *Environmental Issues: Energy use and Conservation*, Mar 2014. 3 December 2014.



43. —. 4602.0.55.001 - Environmental Issues: Energy Use and Conservation. [Online] November 28, 2008.  
<http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/4602.0.55.001Mar%202008?OpenDocument>.
44. **Nisson, Ned.** Surprising Field Observations on Forced Air Distribution Systems. *Energy Design Update*. Jan 1990., Vol. 9, 1.
45. Air Conditioners - AS/NZS 3823.2. *E3 Equipment Energy Efficiency*. [Online] Australian and New Zealand Governments.  
[http://reg.energyrating.gov.au/comparator/product\\_types/64/search/](http://reg.energyrating.gov.au/comparator/product_types/64/search/).
46. Domestic Renewable Heat Incentive (RHI). *UK Government*. [Online] November 12, 2014.  
<https://www.gov.uk/domestic-renewable-heat-incentive>.
47. **Clean Energy Council.** 2014 *Clean Energy Australia Report*.
48. Manage Dry Indoor Air This Winter. *WebMD*. [Online] <http://www.webmd.com/women/home-health-and-safety-9/dry-indoor-air?page=2>.
49. Ururu Sarara Discussion Group. *Facebook*. [Online]  
<https://www.facebook.com/groups/996387660405677/>.
50. **Wright, M.** The Massive Subsidies in Victoria's Gas Expansion Plans. *Renew Economy*. [Online] May 29, 2014. <http://reneweconomy.com.au/2014/hot-mess-victorias-gas-expansion-plans-really-costing-us-93988>.
51. **Clean Energy Regulator.** Postcode data for small-scale installations. [Online]  
<http://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/Postcode-data-for-small-scale-installations>.
52. **Forcey, T.** Get more out of your solar power system by using water as a battery. *The Conversation*. [Online] 2015 йил 24-February. <http://www.sustainability.vic.gov.au/services-and-advice/households/energy-efficiency/at-home/heating/heating-running-costs>.
53. Energy Freedom. [Online] Beyond Zero Emissions. <http://energyfreedom.com.au/>.
54. **Simshauser, P. and Nelson, T.** *The Energy Market Death Spiral – Rethinking Customer Hardship*. AGL Applied Economic and Policy Research . June 2012.
55. **Energy Networks Association.** *Reponse to the Energy White Paper – Issues Paper*. 7 February 2014.
56. **Sandiford, M.** Has the death spiral for Australia's electricity market begun? *The Conversation*. [Online] June 29, 2014. <https://theconversation.com/has-the-death-spiral-for-australias-electricity-market-begun-28581>.
57. **Wright, M.** AEMO analysis indicates disaster for residential gas market. *Climate Spectator*. [Online] <http://www.businessspectator.com.au/article/2015/7/2/energy-markets/aemo-analysis-indicates-disaster-residential-gas-market>.
58. Your Home - Australia's Guide to Environmentally Sustainable Homes. [Online] 2013 - 5th Edition.  
<http://www.yourhome.gov.au/>.
59. Green Home Heating ebook. [Online] Alternative Technology Association (ATA), 2015.  
<https://shop.ata.org.au/shop/green-home-heating-ebook>.
60. Energy efficiency at home. *Households*. [Online] Victorian Government.  
<http://www.sustainability.vic.gov.au/services-and-advice/households/energy-efficiency/at-home>.
61. Sustainability Advice. *Positive Charge*. [Online] Moreland Energy Foundation.  
<http://www.positivecharge.com.au/>.





62. **Australian Bureau of Statistics.** *Information Paper: Towards the Australian Environmental-Economic Accounts, Chapter 3, Energy.* 2013.
63. **Insulation Council of Australia and New Zealand (ICANZ).** *The value of ceiling insulation. Impacts of retrofitting ceiling insulation to residential dwellings in Australia .* September 2011.
64. **Sustainability Victoria.** *Victorian Households Energy Report.* Victorian Government. 2014.
65. **Core Energy Group .** *Core Energy Group. Gas Demand and Customers Forecasts, Jemena Gas Networks/ NSW Gas Access Arrangements 2015-2020.* 30 June 2014 .
66. **Saddler, H.** *Final Report: Quantitative Assessment of Energy Savings from Building Energy Efficiency Measures .* s.l. : Pitt and Sherry, 20 March 2013 .
67. **Barnett, A.** Cold weather is a bigger killer than extreme heat – here’s why. *The Conversation.* [Online] 2015 йил 22-May. <https://theconversation.com/cold-weather-is-a-bigger-killer-than-extreme-heat-heres-why-42252>.
68. **AGL.** FY14 Full Year Results. 20 August 2014 . [Online] [http://www.agl.com.au/~media/AGL/About%20AGL/Documents/Media%20Center/Investor%20Center/2014/2014Results\\_Pres\\_release.pdf](http://www.agl.com.au/~media/AGL/About%20AGL/Documents/Media%20Center/Investor%20Center/2014/2014Results_Pres_release.pdf).
69. **Energy Quest.** *Energy Quarterly.* August 2014.
70. **Wright, M.** Corporate cannibals: Electricity sector may have to kill gas to save itself. July 15, 2014.
71. **Carrazzo, N.** *Are we Cooking the Planet with Gas?* s.l. : The Alternative Technology Association, January 2015.
72. **International Energy Agency.** *Annual Report 2013 IEA Bioenergy .* 2014.
73. —. Task 37 Biogas Country Overviews. [Online] <http://www.iea-biogas.net/country-reports.html> .
74. **City of Sydney.** *Decentralised energy masterplan, renewable energy 2012-2030.* December 2013.
75. **Talent with Energy.** *Renewable gases supply infrastructure, prepared for the Council of the City of Sydney.* March 2013.
76. **Anders, Peter.** *New energy paradigm, better energy better business. Our energy future.* Sydney Water.
77. **James, G., and Hayward, J.** *AEMO 100% Renewable Energy Study - Energy Storage.* Energy Transformed Flagship, CSIRO. September 2012.
78. **Clark, R. and Thomson, M.** *Transport Fuels from Australia's Gas Resources.* s.l. : UNSW Press, 2014.
79. **Wilson, R. and Biewald, B.** *Best Practices in Electric Utility Integrated Resource Planning - Examples of State Regulations and Recent Utility Plans.* Synapse Energy Economics, Inc. June 2013.
80. **Gas and Fuel Corporation of Victoria.** *Gas Demand Management Discussion Paper No. 1, Least-Cost Planning and Demand Management in the GFCV.* Economic Policy and Research Department. July 1990.
81. —. *Gas Demand Management Discussion Paper No. 7, Avoided Costs of Supply.* June 1991.
82. **BHP Billiton.** BHP Billiton Approves Minerva Gas Development in Victoria. *BHP Billiton.* [Online] May 17, 2002. <http://www.bhpbilliton.com/investors/news/bhp-billiton-approves-minerva-gas-development-in-victoria>.
83. **Oil and Gas Journal.** Gas production starts at ExxonMobil's Kipper-Tuna-Turrum project. *Oil and Gas Journal.* [Online] April 11, 2013. <http://www.ogj.com/articles/print/volume-111/issue-11/general-interest/gas-production-starts-at-exxonmobil-s.html>.