The Energy Trilemma: A cost curve for emissions reductions & energy storage in the Australian electricity sector

SUMMARY REPORT

Marginal Abatement Cost (MAC) curve & Storage technology costs
2016-17
Australian electricity sector
BACKGROUND

A quantitative study of emissions reductions in the Australian electricity sector, and the full cost of ‘reliable’ energy supply, including energy storage technologies.

To meet its current and future emissions targets under the Paris Agreement, Australia will need to begin transforming its economy, with the electricity sector viewed as a critical pillar to achieve large-scale emissions reductions through to 2030, and beyond, as Australia transitions to net-zero emissions by 2050.

As policymakers and businesses begin to consult on policy design, RepuTex’s market study, “The Energy Trilemma: A cost curve for emissions reductions & energy storage in the Australian electricity sector”, provides the market with a quantitative basis for identifying emissions reductions opportunities in the Australian electricity sector, along with a more detailed understanding of the cost of “reliable” energy supply, including energy storage technologies.

The study identifies emissions reduction activities in the power sector - such as retrofitting existing coal-fired plants, developing new wind, solar, gas and ‘clean coal’ generation - with analysis mapping the size and cost of abatement through in 2020 and 2030, in the form of a marginal abatement cost (MAC) curve.

In light of scrutiny over the reliability and affordability of energy supply, we also present detailed analysis of the costs of energy storage technologies in the Australian market. The study compares the cost of individual technologies in multiple applications, such as load-following and peaking. Technology costs are then applied to analyse the levelised cost of ‘firm’ energy (LCOFe) in Australia - or the “full cost” for renewables to supply reliable power - including the cost of batteries, pumped hydro, or thermal storage - ensuring like-for-like comparison of each technology true value to the electricity system.

The market study therefore aims to provide policymakers and businesses with an in-depth dataset of emissions reductions and energy storage technology costs to serve as an updated reference point for the design of a “technology-neutral” roadmap to meet Australia’s 2030 target, while ensuring low-cost, reliable energy supply - referred to as the energy trilemma.
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WHAT IS A MARGINAL ABATEMENT COST CURVE?

A Marginal Abatement Cost (MAC) curve is used to analyse greenhouse gas (GHG) emissions reduction opportunities of a specific activity, industry or economy - and the cost of action - enabling comparison of the relative abatement potential and cost of emissions reductions to be derived from different sectors under a wide range of costs.

Abatement is presented as the emissions reduction potential (the width of the bar) that an individual opportunity can deliver in the specified year compared to the baseline forecast. The height of each bar reflects the net cost of reducing one tonne of carbon dioxide equivalent emissions for that activity.

Unlike a societal cost curve, which uses lower discount rates and excludes taxes and subsidies, analysis in this report adopts an ‘investor approach’, taking account of the net costs as the market sees them when determining whether to implement a specific opportunity. Analysis also considers market barriers such as availability of capital and financing, energy security requirements, learning curves and the maturity of new technologies.

This study builds on our earlier MAC curve for the Australian market, released in 2015, which developed a GHG abatement database of the size and cost of 90 emissions reduction activities across 10 sectors, for both 2020 and 2030. Current analysis considers updated assumptions for accounting for changes in Australia’s greenhouse gas emissions trajectory, the commercial viability of low-carbon technologies, and updated energy and technology costs.
ANALYSING THE ‘FULL COST’ OF ENERGY SUPPLY, INCLUDING STORAGE

MAC analysis above does not try to capture the full complexity of power markets, nor does it reveal how the power generation mix will develop over time. To complement our MAC analysis, we also analyse the economic attractiveness of electricity supply by calculating the levelised cost of energy (LCOE), representing the average price that a generating facility would need to receive for investors to recover capital and operating costs, along with a return on their investment.

However, there are inherent limitations in LCOE analysis, most notably the inability to distinguish between intermittent and dispatchable technologies. Given the need for electricity demand and supply to always be balanced, dispatchable technologies that can vary output in a flexible way are of more value to an energy system than less flexible units or intermittent technologies, whose generation is dependent on forces outside of the operator’s control.

To consider the full cost of intermittent versus dispatchable power on a like-for-like basis, we therefore analyse the cost of individual storage technologies to the supply of electricity generation. We refer to this as the levelised cost of “firm” energy (LCOFE). This considers the “full cost” for renewable energy to supply dispatchable power, such as following daily energy demand swings or being available to immediately provide additional power for short periods.

The study also includes the cost of energy storage technologies in Australia compared to the cost of competing baseload, peaking, and load-following technologies, critical to determining which technologies can be characterised as least cost, in which applications, while delivering system reliability.

IN SHORT

There are several pathways to transition to zero emissions.

Complex inter-dependent relationships characterise the electricity sector more than any other. Thus, the abatement potential of our marginal abatement cost (MAC) curve, 484 million tonnes (Mt), is more than the entire emissions of the electricity sector (186 Mt in 2030). This is because many activities could supply the majority of emissions reductions by 2030 by themselves. For example, a shift to a gas dominated system would result in a large emissions reduction by 2030, while a shift to distributed solar PV could also result in a similar scale of abatement. The latter, however, would decrease the need (and market) for gas-fired generation, reducing the abatement potential of a coal to gas shift.
Rather than assume abatement is derived entirely from the activity with the lowest marginal cost first (solar PV), analysis applies a policy based approach to model a range of scenarios for the generation mix in 2030. The abatement potential of each activity in the marginal abatement cost (MAC) curve reflects the maximum abatement potential of each activity that occurred across the entire range of scenarios. The result is that the sum of these maximum potential in the MAC curve is larger than the maximum potential of any given scenario. By and large this does not indicate a potential for negative emissions, e.g. sequestration, for the electricity sector.

Figure 1: RepuTex marginal abatement cost curve - Electricity sector (2030).

The cost curve shows a range of abatement options at various price points, with four key groups of abatement measures underpinning the decarbonisation of the sector: increased renewable generation, demand reduction via the take-up of solar PV, the phase out of coal generation, and energy storage.

Among abatement activities, demand reduction via the take-up of solar PV has the lowest marginal cost of emissions reduction, with capital costs anticipated to continue to drop, while abundant financing is expected to persist. Among energy generation technologies, wind and solar generation represent the cheapest source of abatement from centralised facilities. Building renewable energy can take many forms, eventually including large-scale energy storage, with the zero emissions electricity displacing emissions intensive coal-fired generation, leading to potentially the full decarbonisation of the sector by 2030.
How will electricity policy impact Australia’s 2030 emissions target?

The RepuTex 2030 Energy & Climate Policy (ECP) Tool is an interactive web tool, designed to provide quantitative analysis of how policy may be set to meet Australia’s 2030 target, and the distribution of the abatement task across economic sectors.

Users are able to customise the strength of policy assumptions for state and federal energy and climate policy, including Renewable Energy Target (RET) schemes (state and federal), the National Energy Productivity Plan (NEPP), Emissions Reduction Fund (ERF) and Safeguard Mechanism, and the electricity sector (clean energy scale up, coal fired retirement, electricity demand, solar PV penetration).

To request a free trial of the RepuTex 2030 Energy & Climate Policy Tool, please click here >>

“Clean coal” not viable at scale before 2030 - will not support Australia’s 2030 target under Paris Agreement

While analysis shows, there are many opportunities for emissions reductions in the sector, “clean coal” technology is not among the cheapest. While carbon capture and storage (CCS) has potential to make a significant emissions impact by allowing for the continued use of coal for power generation, at low emissions, projected costs indicate that CCS will not be commercially mature at the GW scale until at least the middle of the next decade.

We see costs for CCS falling as low as $100/MWh by 2030, at which point large-scale projects may be feasible if there is appetite for baseload-only generation. On that timeline, however, the contribution of abatement from CCS in support of Australia’s 2030 emissions reduction target is limited.

This is also the case for “high efficiency, low emission” coal technologies, with Integrated Gasification Combined Cycle and ultra-super critical coal constituting some of the highest cost abatement activities with very little emissions reduction potential relative to government projections for the electricity sector.

Levelised costs of energy (LCOE) analysis confirms renewables are the cheapest source of new supply in Australia

While MAC analysis identifies the potential to reduce emissions in the power sector, and the marginal cost of action, a MAC curve does not try to capture the full complexity of power markets, nor does it try to forecast how the power generation mix will develop over time.

Instead, analysis of the Levelised Cost of Energy (LCOE) can be calculated as a measure of the overall competitiveness of different electricity generating technologies, representing the annualised cost per megawatt-hour that must be met to achieve a financial return from a project.
Findings indicate that renewable energy technologies constitute the cheapest form of investment in new energy in Australia, with Wind and Solar cheaper than new conventional fossil fuel generation sources such as Gas and Coal.

This reflects that the capital cost of intermittent renewable technologies is now lower than building new coal-fired facilities and has much lower fuel costs than a gas-fired facility. Given wind generation has the lowest LCOE, large amounts of low-cost wind generation are displacing existing generation, causing such facilities to generate less energy, recover revenue less frequency, and increasingly exit the market.

In parallel, the forecast rising price of gas means that existing gas-powered electricity generators will become more expensive, while baseload-only coal fired plants face a diminishing market and must consider expensive carbon capture options in order to justify such long-term investments.
System reliability: “flexible energy supply” of greatest value to the modernised NEM

As older coal and gas-fired generators leave the market, system reliability has become an issue in states with high levels of intermittent generation. This is because intermittent generation does not necessarily coincide with peak demand (timing) and cannot be easily ramped up to follow a load forecast (controllability).

To alleviate pressure on system reliability, we view “flexible generation” as a critical addition to the system to better adjust to annual and daily peaks, in parallel to investment in low-cost generation. This may be in the form of load-following generation to adjust as demand changes throughout the day, as well as peaking generation to provide reserve capacity that is available to ease critical situations.

With the market’s preference for cheaper intermittent technologies necessitating flexible generation that can ramp up or down, we see “baseload-only” generation as being increasingly unable to compete in Australia’s future electricity system. This suggests that low emissions baseload-only technologies such as nuclear and “clean coal” are likely to be ill-suited to Australia’s future electricity market, with more flexible generation technologies favoured from an economic and policy standpoint.

In this way, LCOE is limited by its inability to differentiate between baseload, intermittent, load-following, and peaking technologies, which each have a different value to the reliability of the energy system.

Analysing the ‘full cost’ of power supply - including energy storage for renewable energy

To consider the full cost of intermittent versus dispatchable power on a like-for-like basis, we calculate the levelised cost of firm power (LCOFP), taking account of the cost of supplying flexible, instantaneous power across all technologies. To do this, we adapt traditional LCOE analysis by building in the cost of individual storage technologies to the supply of electricity generation under a range of applications. For example when comparing the new build of peaking power facilities, as depicted in Figure 3, the levelised costs of technologies are markedly different.
Traditionally, gas-fired generators have been the least cost technology that could provide energy security, such as load-following and peaking services. Analysis indicates, however, that new renewables with energy storage are now competitive with new gas in providing flexible generation services. This is because of recent declines in capital costs of both wind and solar, coupled with rises in electricity and gas prices, resulting in a rebalancing of the least-cost technologies.

New investment in specific renewable energy or storage projects is constrained by geographic, infrastructure, and resource availability, however, these factors may also apply to fossil fuel facilities. For example, while a combined cycle gas facility can be built in a wider range of locations, it is constrained by the availability of existing transmission infrastructure and low-cost gas resources, while being exposed to higher risk of fuel price variability.

Analysis indicates that new coal-fired facilities remain the cheapest source of baseload-only generation, however, findings point to a diminishing role for baseload generation, with new baseload-only generation facing considerable commercial barriers - irrespective of how clean or dirty it is - given its lack of flexibility to compete in Australia’s future electricity system.
The Energy Trilemma: A cost curve for emissions reductions & energy storage in the Australian electricity sector, provides the market with a quantitative basis for identifying emissions reductions opportunities in the Australian electricity sector, along with a more detailed understanding of the cost of new energy storage technologies, and the levelised cost of energy supply in Australia. Analysis includes:

- **Our marginal abatement cost (MAC) curve for the Australian electricity sector**, showing the size and cost of each activity to reduce emissions in 2020 and 2030, and impact on Australia’s 2030 emissions target.

- **Levelised cost of energy (LCOE) supply** in Australia for each generation source, represented as the present value of the total cost of building and operating a generating plant over its financial life in Australian dollars per megawatt hour ($/MWh).

- **Costs of individual energy storage technologies** in the Australian market in multiple energy security applications, such as integration of intermittent generators, peaking power replacements, and electricity grid-stabilisation and support. Costs are annualised to include total cost of building and operating a generating plant over its financial life in Australian dollars per megawatt hour ($/MWh).

- **Levelised cost of ‘firm’ energy (LCOFE) supply**, calculating the ‘full cost’ to supply reliable power, including storage costs for renewables. Costs are annualised to include total cost of building and operating a generating plant over its financial life in Australian dollars per megawatt hour ($/MWh).

- **Access underlying data in Excel form**, including a breakdown of marginal abatement cost (MAC) and abatement volume of activities in 2020 and 2030, our LCOE cost estimates by technology, our database of energy storage technology costs by application, and our LCOFE estimates by technology.

- **Access the full series** - This study is the first in a series of publications and datasets exploring the cost and opportunity for emissions reductions across the Australian economy to 2020 and 2030. The full series will consist of analysis of the power sector, the industrial and transport (safeguard) sectors, the land-use sector and the Australia economy as a whole.

**ACCESS UNDERLYING DATA**

Our Marginal Abatement Cost (MAC) analysis, along with our LCOE, LCOFE and energy storage technology databases are available to our subscribers, including breakdowns of abatement activities in 2020 and 2030.

To learn more, please register your interest >>
With customers across over 150 firms, RepuTex is Australia’s largest provider of energy and emissions market analysis. We work with a wide range of public and private sector customers in Australia and Asia-Pacific, with subscribers across high emitting Power, Energy, Metals & Mining and Industrial companies, Aggregators & Project Developers, Professional Services, Financials and Government.

RepuTex has offices in Melbourne and Hong Kong, supported by a team of analysts with backgrounds in economics, commodities, policy and energy markets.

The company was the 2012 winner of the China Light and Power-Australia China Business Award for excellence across Australia-Pacific.

RepuTex has a depth of expertise in energy & climate policy and market analysis, utilising our proprietary models to help opinion leaders understand the economic and market impacts of policy design, while assisting businesses to analyse the impact of policy on cost and supply dynamics.

We cover key energy and emissions markets in Australia, including the National Electricity Market (NEM) and the Renewable Energy Target (RET), and the Emissions Reduction Fund (ERF) and Safeguard Mechanism. Our coverage also extends to complimentary state and federal policies including the National Energy Productivity Plan (NEPP) and state-based initiatives such as state renewable energy targets and state based land-clearing regulation.