energetics

An assessment of emissions reduction technologies

Maturity, cost-effectiveness and potential impact

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Executive summary

Prior to the COVID-19 pandemic, the Prime Minister flagged the potential for deeper cuts in Australia's emissions that would deliver a net zero economy by 2050, a doubling of renewable energy in the National Electricity Market (NEM) and "more than 100 new technologies" to reduce emissions[1]. Earlier, the Energy Minister, Angus Taylor on two occasions both questioned "aggressive top-down targets" with no "clear pathways to deliver" [2] and yet noted that there is "enormous potential in established and emerging technologies such as hydrogen, carbon capture and storage, biofuels, lithium production and waste-to-energy".

Following Energetics' previous analysis[3,4] of the government's 2019 emissions projections for the nation, we now assess the technologies available to meet our targets. What we saw in the 2019 emissions projections is that the government was only really considering one new technology – electric vehicles, and one not so new technology – renewable electricity generation coupled with pumped-hydro and battery storage. Other improvements in emissions performance simply reflected the business-as-usual evolution in technology.

In this report, Energetics examines other potential technologies. We show where substantial investment to accelerate their take up could be made and identify those technologies that are simply not feasible within the Australian context.

[1] Taylor, A: "***Renewables key to carbon emission cuts***", The Australian, 2019.
[2] The Australian: "***We do our climate share: Australia is meeting and beating emission-reduction targets, and we'll improve yet***" January 2020.
[3] Commonwealth of Australia: "***Australia's emissions projections, 2019***", 2019.
[4] Weiss, G: ***An examination of the 2019 emissions projection***, 12.2.2020.

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1. Our approach to assessing the feasibility of emissions reduction technologies

In our assessment we use the following factors to determine the ability of different technologies to achieve meaningful emissions reductions. Most important of these are:

- **Maturity:** A technology that is still in the laboratory will have a limited impact over the next decade, no matter how good it is.
- **Cost-effectiveness:** If it is not competitive with alternatives, uptake will be limited.
- **Potential impact:** The maximum extent to which the application of the technology can have on Australia's emissions. For example, a new technology that eliminates emissions from the biological treatment of solid waste will have very little impact on national emissions as biological treatment of solid waste is responsible for 0.05% of Australia's emissions.

Given these factors, it is not surprising that renewable electricity generation and electric vehicles are driving emissions reductions now and are projected to continue to do so until 2030. The underpinning technologies are very well understood (solar cells, wind generation, electrically driven vehicles, batteries), as they tackle two of the largest sources of global emissions (power generation, emissions from light vehicles) and have proven to be cost effective.

2. The big emitter

As detailed in Energetics' ***first article on Australia's 2019 emissions projections***, the headline result from the report is a projected shortfall in the Nationally Determined Contribution under the Paris Agreement.

Australia's target under Paris is for emissions of 452Mt CO_2-e and 440Mt CO_2-e in 2030, which equates to 26% to 28% reductions compared to 2005 levels. Instead, the 2019 Projection report shows Australia is on track for emissions of 511Mt CO_2-e in 2030.

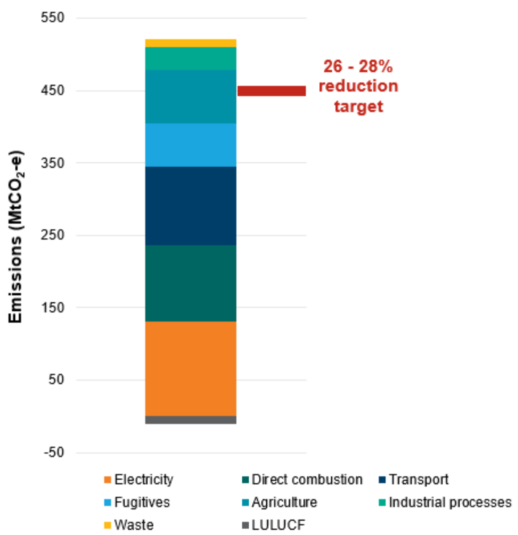

Figure 1: Australia's emissions in 2030[5]

[5] Commonwealth of Australia: "***Australia's emissions projections, 2019***", 2019.

Figure 1 from the 2019 projections shows the sources of Australia's emissions in 2030 spread across eight major categories. It also shows where a 26-28% reduction sits in comparison; the gap to be closed is 59Mt CO_2-e to 71Mt CO_2-e.

From Figure 1, achieving the target may be as simple on paper as eliminating emissions from one of the four larger sources (electricity, direct combustion, transport, or agriculture). However, achieving the necessary emissions reductions from the selected source would be incredibly disruptive to the sector and the broader economy.

Figure 2 breaks emission sources down into 45 sources across the seven major categories to provide another view of Australia's emissions to aid in targeting reductions. The major categories are highlighted in the figure.

The largest single source of greenhouse gas emissions in Australia is the burning of coal for electricity generation, followed by fuel combustion in cars. This highlights the emissions reduction opportunity already observed in the increase of electricity from renewable fuels and from transitioning to electric vehicles. The third largest source is enteric emissions from cattle, demonstrating the significance of agriculture as a source of emissions. Other important sources are direct combustion of fuel in energy industries (predominately fuel for motive power - to drive machinery - and power generation in LNG trains, and direct combustion of fuel in manufacturing, primarily for process heating).

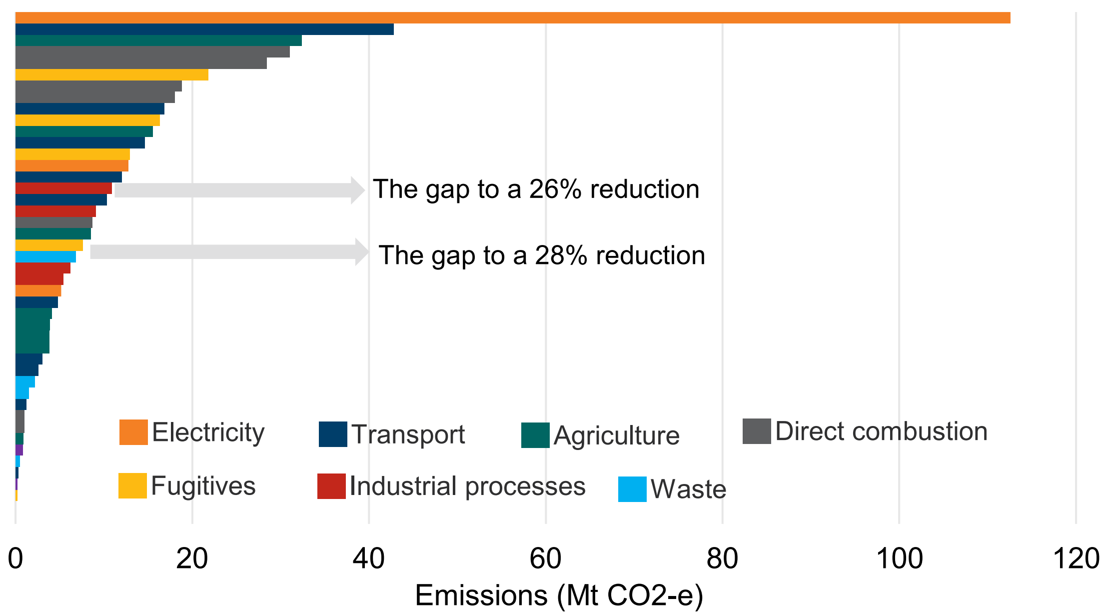

Figure 2: Emissions broken down into sources within broad categories

Table 1 shows the top 12 emission sources, which are cumulatively responsible for 70% of Australia's emissions. With the exception of coal-fired generators, no single source contributes more than the 59 Mt CO_2-e to 71 Mt CO_2-e towards closing the gap to the achievement of the 2030 target. Therefore, reductions must come from actions or technologies that can be applied across multiple sources of emissions. It is this latter option, technologies that can be applied, that is of most interest.

Table 1: Top 12 sources of Australia's emissions

Category and source	Emissions ($Mt\ CO_2$-e)
Electricity: Coal	113
Transport: Cars	43
Agriculture: Enteric emissions from grazing beef	32
Direct combustion: Manufacturing	31
Direct combustion: Energy	28
Fugitives: Underground coal mines	22
Direct combustion: Mining	19
Direct combustion: Buildings	18
Transport: Light commercial vehicles	17
Fugitives: Domestic natural gas (gas other than LNG)	16
Agriculture: Enteric emissions from sheep	16
Transport: Articulated trucks	15

Energetics' modelling suggests that closing all coal-fired power stations that were opened prior to 1995 and replacing them with a mixture of utility scale renewable generators, gas peaking plants and storage would see Australia meet its reduction 2030 target without compromising the stability of the grid (in line with AEMO's recommended target of 50% dispatchable generation).

Yet the indications are that this solution is not currently an option for the government.

Given that, what are some of the other technological solutions? Are there any 'silver bullets'?

3. What about energy efficiency?

Before considering some low emissions technologies available, it is worth reviewing the option of energy efficiency as an abatement measure.

The emissions associated with electricity, direct combustion and transport form two-thirds of Australia's emissions and all are due to the combustion of a fossil fuel to ultimately deliver an energy service – heat, light and/or motive power.

Lowering the emissions intensity of energy services offers emissions reductions as well as other benefits such as reducing energy bills and improving energy security[6]. The value of energy in the

[6] Energy Efficiency Council: "***The world's first fuel: how energy efficiency is reshaping global energy systems***", June 2019.

economy can be measured using energy productivity, which is the ratio between GDP and primary energy use. The 2019 projections of emissions assume that energy productivity will increase by 40% between 2015 and 2030, which is the target in the National Energy Productivity Plan. By increasing this target to 70% improvement in energy productivity between 2015 and 2030, an additional 65 Mt CO_2-e reduction in annual emissions could be secured by 2030, allowing Australia to achieve the 26% reduction target[7].

The major challenge with energy efficiency or energy productivity improvements is (with the exception of LED lights) the lack of single actions or technologies that can be readily applied across multiple sectors and applications.

With no such single actions in sight, achieving significant uplifts in energy productivity will require actions and investments across all sectors of the economy. While these will deliver benefits beyond emissions reductions, particularly cost savings, they may not be as effective as other approaches in reducing emissions nor as easy to implement at scale across sectors given the often customised nature of solutions.

As an example, let's consider the options for reducing the emissions associated with motive power and transport. In most cases, this involves an electric motor and the emissions come from the burning of fuels to generate the electricity. A range of measures such as high efficiency motors, more efficient pumps, redesigning pipe networks, scheduling of operations use of electric motors in industry, could be implemented. All require separate decisions or actions by businesses and governments, and all make small contributions to the task of reducing emissions associated with the electricity consumed by the task.

Alternatively, transportation could be powered by zero-emissions electricity sources. For the asset owners, this solution is far simpler and probably cheaper, and has the advantage of the emissions remaining zero, irrespective of how efficiently or inefficiently it is used.

While energy efficiency makes good sense and offers other benefits such as reduction in energy expenditure, it must compete against renewable energy as a path to zero emissions. This is a tough contest!

[7] Energetics' own modelling

What about carbon capture and storage (CCS)?

The Prime Minister and Energy Minister both recently mentioned carbon capture and storage (CCS) as a technology option and that successful deployment of CCS would allow for a reduction in emissions from coal-fired generation without requiring the closure of the power stations.

However, Energetics does not believe that CCS can rescue coal-fired generation. There are very specific reasons why it is not a solution for Australia.

The supporters of coal for power generation see CCS as underpinning coal in a carbon constrained world. Certainly it is seen as a viable option in regions or counties that have a high demand for electricity per unit of land (or roof) area, in which renewable generators such as wind and solar may not be able to meet the region's or the nation's needs. In these countries, coal-fired generators with effective CCS offer a potential solution. But in a large country like Australia with bountiful renewable energy resources, the business case does not stack up.

If we look at the economics, the levelised cost of renewable generation is less than the levelised (and in some areas, the marginal) cost of coal-fired generation. While the addition of energy storage and some expansion of the grid is needed to make renewable generation dispatchable as it is for coal-fired generators, the high cost of CCS in terms of equipment and parasitic power demand significantly adds to the cost of "zero emissions" coal-fired generation.

Also, while the net cost of solar+batteries is comparable to coal+CCS , CCS must be applied to every coal fired power station, whereas batteries need only be deployed if there is a requirement for additional storage across the entire power system.

Another obstacle to CCS is that no new coal-fired power stations will be built in Australia. Retrofitting CCS to existing and especially older coal-fired generators will have technical challenges and the lifespan of the CCS unit will be limited by the remaining lifespan of the power station. With most of Australia's large coal-fired power stations likely to close within the next 20 years, the opportunities to implement a cost-effective CCS retrofit are limited.

4. Are there any 'silver bullets'?

Excluding emissions from coal-fired generation, the major sources of emissions in Table 1 can be grouped into several categories:

- **Transport:** Cars, light vehicles, heavy vehicles and mining. The latter is included as most of the emissions are due to the operation of the mining fleets – dump trucks and excavators.
- **Heating:** For buildings, this will be low temperature heating associated with space conditioning. Heating in industry is more complex, with requirements ranging from hot water to high temperature furnaces in foundries and smelters.
- **Motive power:** Much of the direct combustion linked with the energy sector and some linked to mining is from fuel burnt to drive compressors and other machines (including power generators).
- **Enteric fermentation in livestock.**

- **Fugitive emissions:** Occurring from the production and the consumption of energy.

From this we can see that while there are still multiple sources, the requirement remains to find low emission technologies that address several sources. Two technologies stand out.

The first is electrification –of transport via electric vehicles and of heating using heat pumps (in both cases using renewable electricity). The second option is the deployment of zero emissions fuels – hydrogen and biofuels. Table 1Table 2below shows how it could work.

Table 2: Electrification and renewable gas

Emissions source	The place for electrification	The place for zero emissions fuels
Transport	The electrification of light vehicles has a clear, cost-effective technology trajectory, driven by the falling cost of batteries and the deployment of charging infrastructure.	Challenges still exist with respect to the electrification of heavy vehicles and other transport modes. However, existing engines can be fuelled using renewable fuels[8].
Heating	Heat pumps in the form of reverse cycle air conditioners already provide space heating for buildings. Industrial heat pumps can deliver heat up to 150°C or more if a waste heat stream is available. The cost effectiveness of higher temperature heat pumps is still marginal[9].	Heating to temperatures above 200°C needs a flame or concentrated sunlight. Existing heating equipment such as furnaces, kilns and boilers can be fired using renewable gas.
Motive power	Electric motors could drive the large compressors and pumps in facilities such as LNG trains.	Renewable gas could fuel the gas turbine engines that are typically used to drive large rotating machines in remote locations.

We see two themes emerging. First, electrification can (and already does) provide cost effective options for decarbonising certain applications such as light vehicles and low temperature heating. However, it is not yet cost effective, or feasible in some cases, to use electrification for other applications such as heavy vehicles and high temperature heating.

Secondly, renewable fuels provide a route to zero emissions where electrification is not feasible and can substitute for electrification even when it is feasible and cost effective. For instance, fuel cell electric vehicles are already available in several markets.

Renewable hydrogen is the interesting one. As well as being a substitute for fossil fuels in significant sources such as engines and furnaces, it can also reduce certain industrial emissions such as those associated with the reduction of metal ores. Renewable hydrogen could therefore

[8] Hydrogen offers a route to electric vehicles by using fuel cells rather batteries to provide the electricity for the motors. In this case, the hydrogen is powering the fuel cell rather than an internal combustion engine. This offers the advantages of EVs in terms of a simpler drive train without the weight and range disadvantages of batteries.
[9] Australian Alliance for Energy Productivity: "***High temperature heat pumps for the Australian food industry: opportunities assessment***", 2017.

be the next silver bullet, a technology that offers emissions reduction across a range of sources without causing significant disruption to the fuel using systems.

Hydrogen has already been flagged as one of the new technologies by the Prime Minister, and that all governments in Australia are supporting the early stage development of the “hydrogen economy”. However, while the pathway to renewable hydrogen is well known, considerable advances in technology are required if renewable hydrogen is to be cost effective and deployed on a national or global scale.

5. Tackling the rest - should it be technology or trees?

We have explained how the decarbonisation of energy can be achieved through a combination of electrification and switching to zero emissions fuels – renewable electricity, hydrogen and biofuels. Decarbonising energy can reduce Australia’s emissions by two thirds by 2030.

Low and zero emissions technologies have been identified for non-energy related emissions but are not yet available for commercial or even pre-commercial deployment. Some emissions may never be eliminated at source and land-based sequestration can be used to offset these emissions.

The remaining emissions to be reduced come from fugitive emissions associated with energy production and use, agriculture, industrial processes, waste and land use. The most material of these remaining emissions are from the sources outlined in Table 3.

Table 3: Seven important non-energy related sources

Category and source	Emissions (Mt CO_2-e)
Agriculture: Grazing beef	32
Fugitives: Underground coal mines	22
Fugitives: Domestic natural gas (gas other than LNG)	16
Agriculture: Sheep	16
Fugitives: LNG	13
Industrial processes: Metal industry	11
Industrial processes: Products used as substitutes for ozone depleting substances	9

We see that three of these sources are associated with the extraction and use of energy (fugitives from coal mines, LNG and other domestic natural gas), two are due to enteric fermentation in livestock and two are due to industrial processes. All require their own solutions to reduce emissions (such as feed changes as a way to reduce enteric emissions) or changes in the markets (such as falling demand for fossil fuels or policies to eliminate products used as substitutes for ozone depleting substances).

The technologies to eliminate many of the non-energy related emissions are less well defined than the available or potential technologies that address energy related emissions. As a result, we have greater uncertainty about the magnitude and the timing of abatement that can be realised using these technologies.

Therefore, Australia needs a Plan B to deal with emissions that cannot be eliminated in either a cost-effective manner or in time to meet national emissions reduction targets.

Land-based sequestration is Australia's Plan B.

In 2015, the CSIRO assessed the significant potential for land-based sequestration in Australia[10]. It found that carbon and environmental plantings have the technical potential to provide average annual abatement of up to 513Mt CO_2-e over the period 2031–2050. The analysis demonstrated the value of land-based sequestration as a measure available to close any gap that cannot be addressed by a new zero-emissions technology to tackle the emissions at their source.

However, Energetics argues that given its effectiveness for addressing emission gaps, there is a risk that land-based sequestration is seen as the 'easy' option for dealing with short term demands for abatement. Land-based sequestration should not become Australia's Plan A! Such a short-sighted solution would do little to transform Australia's economy and would leave our nation vulnerable in the midst of the global transition to decarbonisation. In short, we would miss the opportunity to link our emissions reduction task to a new vision for the Australian economy.

That new vision could include the continuation of uptake in renewable generation and electric vehicles, followed by electrification and zero emissions fuels, supported by land-based sequestration for sources where no other emissions reduction technology is available.

Pending technology maturity, cost-effectiveness and potential impact, we could already have the silver bullets we need.

[10] Bryan BA, Hatfield-Dodds S, Nolan M, McKellar L, Grundy MJ, McCallum R: "***Potential for Australian land-sector carbon sequestration and implications for land use, food, water, and biodiversity***": Report for the Australian National Outlook 2015. CSIRO, Australia.

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Our services include:

- Strategy, policy and financing
- Climate risk and adaptation
- Renewables and energy efficiency
- Energy accounting and data management
- Energy and carbon markets
- Reporting, compliance and program audit

We're more than carbon neutral.

Sustainability is core to Energetics' business.

In June 2008, Energetics became one of Australia's first consulting firms to achieve carbon neutrality through the Australian Government's Greenhouse Friendly Program.

Since the FY19 reporting year, our carbon neutrality has been certified under the Climate Active Carbon Neutral Standard (formerly the National Carbon Offset Standard – NCOS) for Organisations. Climate Active is a partnership between the Australian Government and Australian businesses to drive voluntary climate action. www.climateactive.org.au

This approach aligns with Energetics' commitment to best practice calculation of our complete emissions profile and with how we have assisted some of our clients with becoming carbon neutral. We offset 100% of the greenhouse gas emissions associated with the complete lifecycle of our organisation. Our offsets are sourced from projects that are Verified Carbon Standard (VCS) or Gold Standard accredited and contribute to Sustainable Development Goals 7 (Affordable and Clean Energy), 9 (Industry, Innovation and Infrastructure) and 13 (Climate Change).

In keeping with our Sustainability Policy, we drive continuous improvement by identifying and implementing internal carbon mitigation, sustainable procurement and behavioural change projects. Being a sustainability role model is one of our core business values. Every employee is given two days personal development time to volunteer in environmental or social sustainability activities within their communities.

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We have been creating value for ASX200 firms for more than 30 years	We procure more than $2b in energy annually for our clients	We are energy managers or advisors to more than 200 of Australia's largest energy users
We employ over 60 specialists with technical, commercial and regulatory insights	Our experts support more than 30 companies with NGER and NPI compliance	We have six Certified Energy Managers (CEM) and two Energy Managers In Training (EMITs)
We have ten Certified Measurement and Verification Professionals (CMVP) and two awaiting final certification	As a trusted advisor to Government, we understand regulations, compliance and grant funding programs	More than 12 million line items, across 5,000 sites and 17,000 accounts from various reporting platforms have been migrated
Our data management processes undergo annual reviews by external auditors	Our energy accountants support 27 businesses, 6500 sites, 18500 utility accounts, $910 million annual utility spend	2.8 is the average number of tertiary qualifications per employee

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