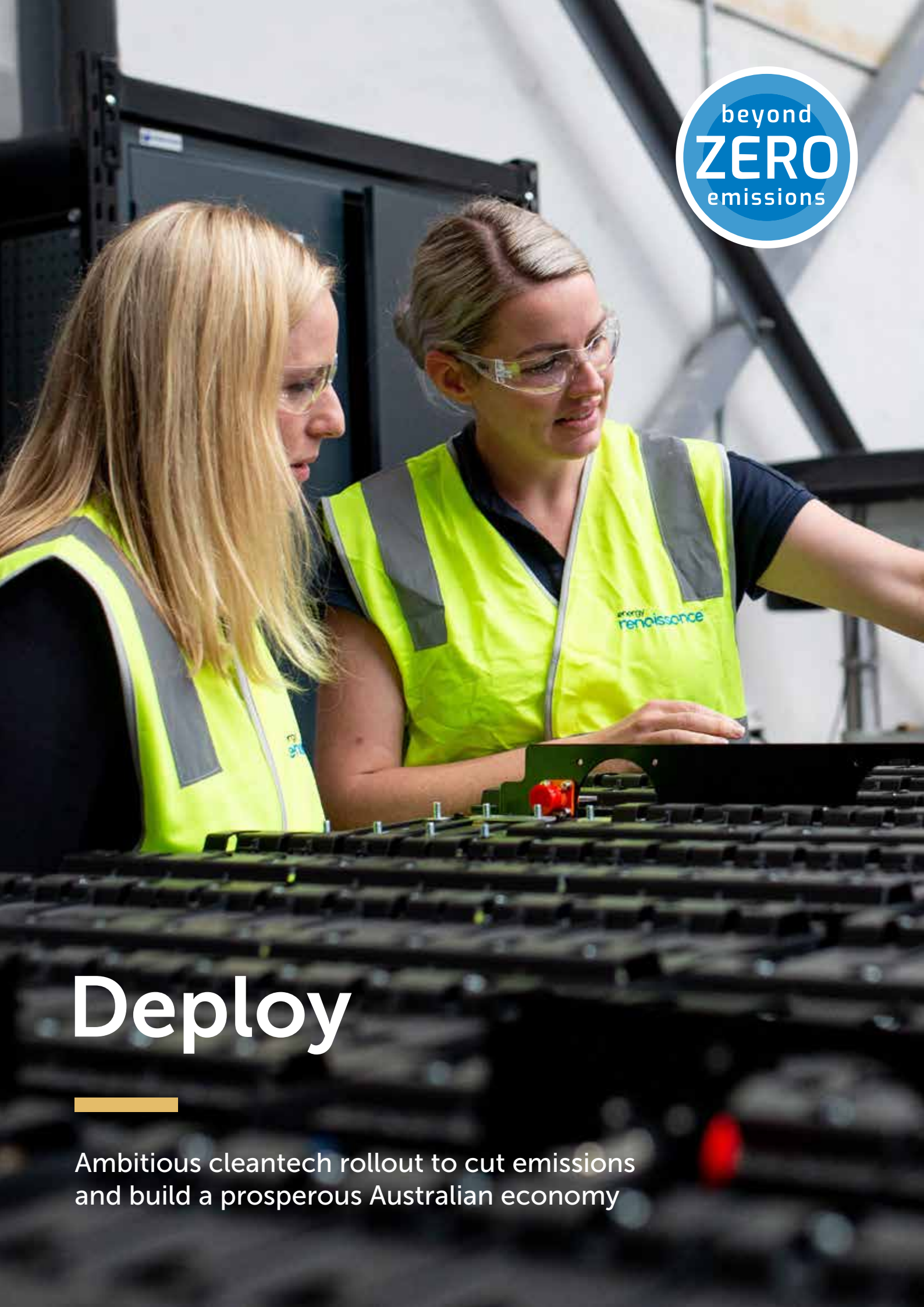

Deploy

Ambitious cleantech rollout to cut emissions and build a prosperous Australian economy

Recognition of traditional custodians

We recognise that Aboriginal people's sovereignty over their land was never ceded and the impact of this ongoing dispossession continues to this day. Beyond Zero Emissions stands in solidarity with First Nations people in calling for the establishment of a First Nations Voice in the Constitution, as described in the Uluru Statement from the Heart. We further support calls for the establishment of a Makarrata Commission on agreement-making and truth-telling between Aboriginal and Torres Strait Islander peoples and governments.

Beyond Zero Emissions maintains an office on the traditional lands of the Wurundjeri-willam people of the Kulin Nation, and in Newcastle on the lands of the Awabakal, Worimi and Wonnarua peoples. We pay our respects to all First Nations Elders past, present and those emerging.

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Letter from the Chair

Beyond Zero Emissions vision is for a prosperous zero-emissions Australia and this year we celebrated a 43% legislated emissions cut passing into law with the Australian Climate Bill. 'Deploy' is BZE's first research publication since the passing of this federal legislation and in this report, we make the case for a more ambitious 81% reduction by 2030.

Economic and technological transformations have often happened at a speed far greater than pundits predict. Three factors drive these transformations: cost curves and economies of scale (solar PV is now the cheapest source of energy); transformative applications from technology convergence (wind, solar, storage, grids); and the 'S' curve of adoption (slow to start then rapid to saturation). These three elements are now in play in Australia and globally. We are at the dawn of an economic and industrial transformation on a scale that will only be fully appreciated in hindsight from the 2030's, when we look back at this decade.

As with all economic transformations there will be massive winners and those who didn't see the seismic shifts that are occurring. Australia has the elements and natural attributes to once again be the lucky country at this point of inflection and global economic transformation. Our challenge is one of ambition and urgency, where time is of the essence.

This report addresses this ambition and sets aside the misconception that emissions cutting technologies are still in the development stage, or worse do not yet exist. With six technologies that are developed and in-market today, we outline how we can achieve outsized emissions reduction, create future-proof jobs, and lay the economic foundations for modern and competitive export industries. Deploy sets out how, wind turbines, solar, energy storage, heat pumps, electrolysers and EV's, can transform electricity generation, buildings, vehicles, and industry, supported by carbon drawdown, to combine to deliver an 81% reduction.

Australia is already a global leader in technological transformation with rooftop solar. In other areas we detail the need to rapidly scale to create the foundations for a prosperous zero-emissions Australia. I hope you find our research ambitious. It has been supported by a wide range of influential stakeholders and it is communicated in a compelling manner. The Board and leadership of BZE commends 'Deploy' as a roadmap for a Zero Emissions future.

Geoff Summerhayes
Chair
Beyond Zero Emissions

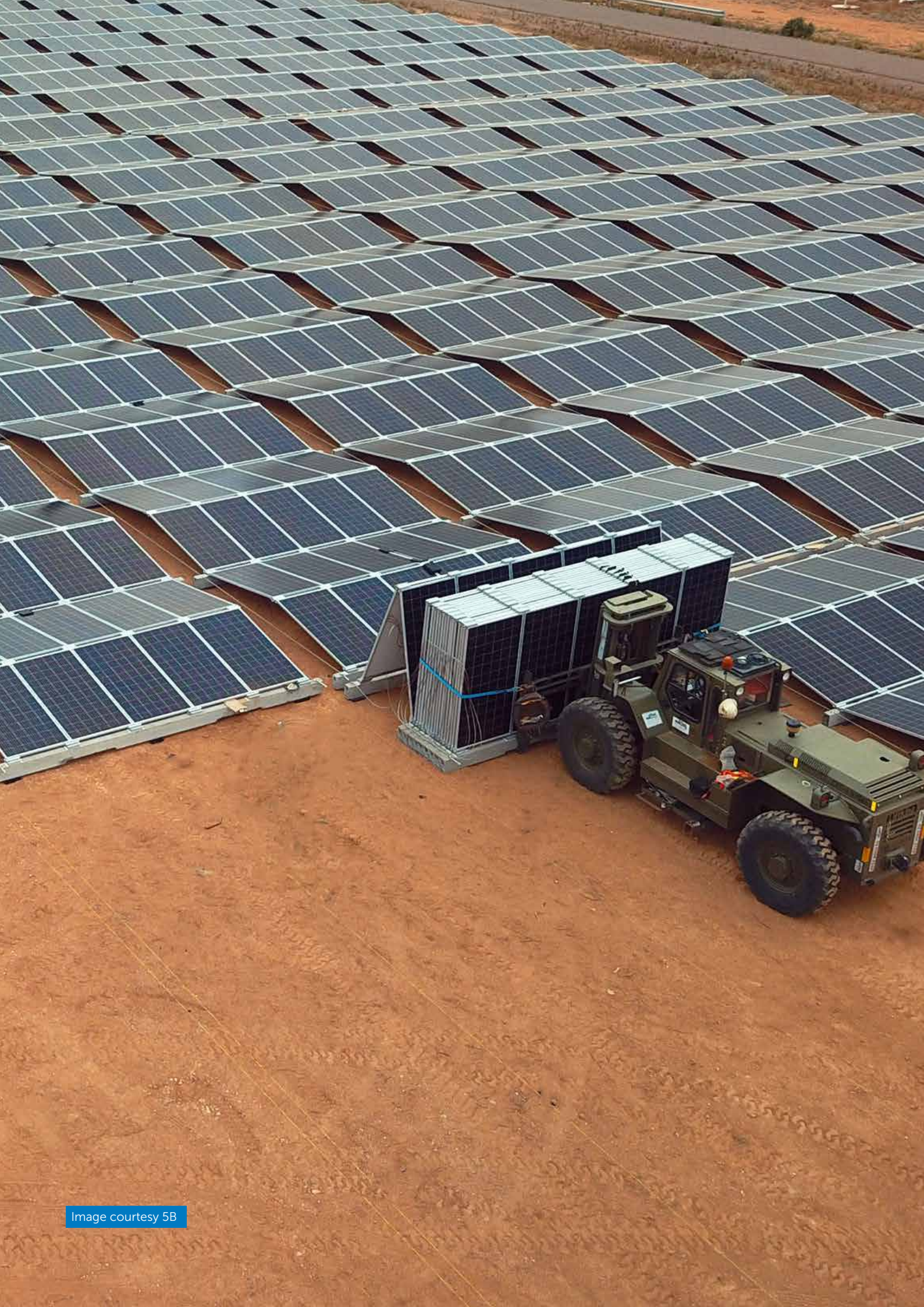

Image courtesy 5B

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1. Executive summary

A national cleantech rollout can cut Australia's emissions 81% by 2030

Australia has the opportunity to make ambitious cuts in greenhouse gas emissions and build a prosperous modern economy using the clean technologies that exist today. The Australian Government's legislated target of 43% emissions reduction by 2030 is just the start of what is possible.

This report demonstrates that an **81% emissions reduction is achievable by 2030** with an ambitious rollout of clean technology over the next five years, supported by targeted carbon drawdown initiatives. This can only be achieved with immediate and large-scale actions, prioritising short-term ambitious targets for already-available technologies.

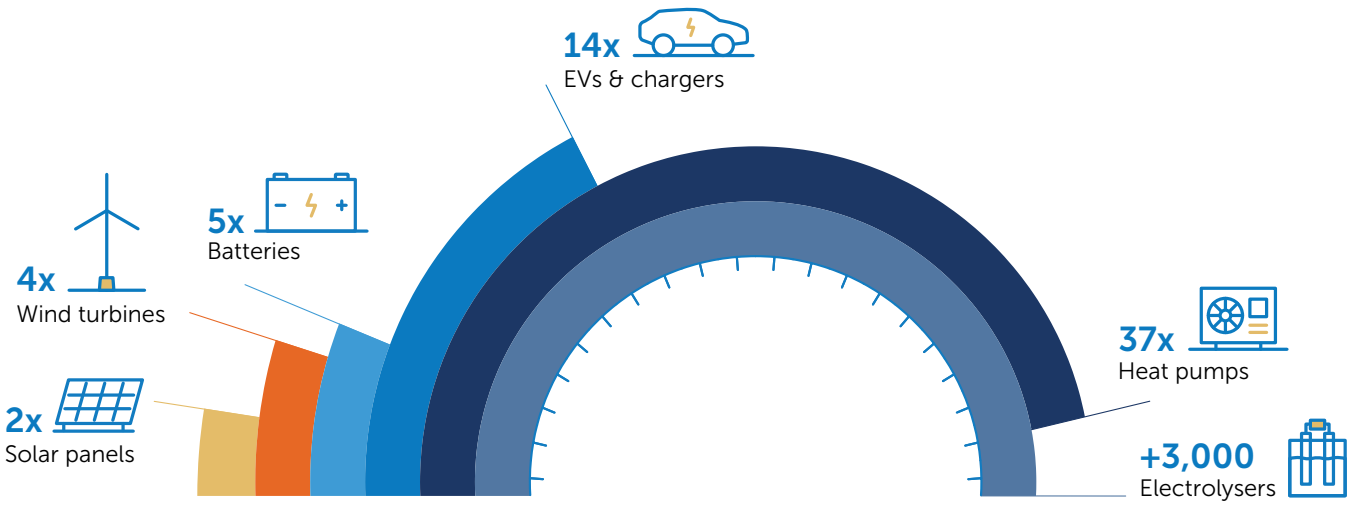
In this report Beyond Zero Emissions outlines a five-year deployment plan, identifying the most impactful technologies, the number of units of each technology we need to deploy, and what it means for rollout rates over the next five years.

The deployment plan will create jobs: we found a technology rollout at scale, plus carbon drawdown for targeted activities, can put Australia on the path towards the IPCC scenario SSP1-1.9 (for 1.5 degrees of average global warming)[1] and create 195,000 jobs that are not susceptible to the boom and bust of the fossil fuel markets.

Six technologies – all available today – will do the heavy lifting: solar panels, wind turbines, batteries, electric vehicles, heat pumps and electrolysers.

Figure 1: Increase in rollout rates for six key technologies to achieve the five-year plan

	Deployed in 2021	Annual deployment plan	5-year deployment plan total	5-year technology deployment plan
Solar panels (utility scale)	1.9M	3.5M	17.7M	66.7M Solar panels, inc. utility scale and domestic
Wind turbines (utility scale)	300	1,200	6,000	6,000 Wind turbines
Batteries	270,000	1.3M	6.4M	67 GWh inc. utility scale and domestic batteries
EVs (passenger vehicles)	21,000	281,000	1.4M	3.8M Passenger electric vehicles & chargers
Hot water heat pumps	26,000	950,000	4.8M	9M Hot water and split-system heat pumps
Electrolysers	1	600	3,000	3,000 Electrolysers for green H2 for industry



The Five-Year Deploy Plan

This report shows where commercially available technologies can be rolled out to reduce emissions and create jobs. We consider deployment of all-electric clean technology across three sectors of the economy: buildings, transport and industry. A mass build-out of new renewable electricity generation and storage is the underpinning enabler for powering zero-emissions homes, vehicles and industries. Carbon drawdown in the land use sector is allocated only to the hardest-to-abate activities that are central to our economy.

Impact is considered in terms of the emissions reductions achievable and the number of jobs that can be created.

To succeed, our five-year Deploy plan requires investment and coordination, skilled people and reliable supply chains. Each sector needs an ambitious, individualised roadmap to achieve its emission reduction contributions rapidly and deeply, removing inertia and allowing momentum to build.

This plan sets the ambition, establishes the job potential and demonstrates the opportunity of acting without delay for industry and manufacturing, business and households.

Electric bus. Image courtesy of Custom Denning.

Renewable generation and storage are the foundation

Our five-year Deploy plan is ambitious and achievable. One-hundred percent renewable generation and storage is the foundation for success.

By deploying 64 GW of renewable capacity and 13 GW (67 GWh) of energy storage capacity Australia can reach 84% renewable energy generation within five years. This equates to about 6,000 wind turbines and 66 million solar panels. With this foundation, a target of 100% renewable energy generation by 2030 is feasible.

This ambitious undertaking means installing more generation capacity and far more storage than the total of all types of generation capacity and storage in Australia today. It is doable: in 2021 alone Australia added 6.2 GW of renewable generation.[2] Doubling the 2021 rollout rate of renewable generation will realise the ambitions identified in this plan.

Six technologies for households, industry and transport

In the next five years, we need to install clean technology in our homes, vehicles and industries at a rate of about two units or appliances per household. We cannot afford to wait for new research and inventions, and we don't need to. We already know how to make the key technologies that are needed for a zero-emissions economy – we just need to make more of them and put them to work. Over five years, this looks like:

- 10.6 million units of clean technology in three million residential buildings, such as hot water and air conditioning heat pumps
- 2.9 million units of building efficiency technologies (including thermal upgrades and induction cooktops)
- 7,000 units of technology in industrial settings, largely industrial-scale heat pumps and electrolysers
- 3.8 million units for transport (made up of electric vehicles and chargers).

Australia has set a renewable energy record with more than a quarter of households now generating power on their roofs.[3] Australia's roll-out of residential air-conditioning heat pumps is already faster than the pace needed in this plan, and the rollout of domestic solar panels needs to increase by less than double. Installations of heat pump water heaters, however, need to ramp up significantly.

For certain clean technologies accelerated rollout is from a standing start. The uptake of electric passenger cars, for example, will need to be almost 14 times today's rate. Fleet sales, a third of Australia's new car market, can do the heavy lifting here. This level of ambition is not unprecedented. Sweden increased its new car sales from 10% EVs in December 2019 to 60% by December 2021.[4]

Benefits can be multiplied for regional Australia

This ambitious technology rollout is a once-in-a-generation opportunity to upgrade Australia's building stock to increase comfort and reduce energy bills, electrify our vehicles for quieter, cleaner roads, and build modern, competitive industrial capability.

Mass technology deployment, in combination with strong local procurement mandates, can revitalise our manufacturing industries with onshore assembly and manufacture of clean technology. In our regional industrial heartlands, where so much of the necessary innovation and manufacturing is already underway, we can leverage traditional manufacturing strengths and create economic opportunities for areas that will be most impacted by a drop in demand for fossil fuels.

Wind turbines, lithium-ion batteries, thermal storage and electric vehicles are among the renewable technologies already manufactured onshore today, and highlighted in this report. In the Hunter Valley, NSW, the region could soon be manufacturing a wide range of green technologies, including batteries and low carbon building materials such as green steel, in clusters of manufacturing plants powered by 100% renewable energy.[5] In Central Queensland, this model of Renewable Energy Industrial Precincts[6] could be producing wind turbines, high purity alumina, renewable hydrogen and ammonia for domestic and export customers.[7]

The precinct approach to manufacturing capitalises on existing skills and trades in mining regions, with more than half of the new jobs needed being equivalent to current ones, including technicians, trades, machinery operators, drivers and labourers.[8]

Establishing Renewable Energy Industrial Precincts in just two of 14 identified first-mover regions – Central Queensland[9] and the Hunter[10] – could attract $36 billion in investment, support 45,000 new ongoing jobs by 2032 and earn $13 billion in annual revenue. As the world shifts to a zero emissions we can capitalise on Australia's abundance of competitive renewable resources, rich mineral wealth, and skilled industrial base and workforce. We can use these ingredients to leverage our manufacturing capability and build new export industries worth up to $333 billion – more than three times our fossil fuel revenue.[11]

Coordination and community support are essential

The five-year deployment plan will require careful coordination and integration. New renewable energy generation, storage and transmission to replace the fossil fuel-driven electricity grid must be at a pace that supports the mass rollout of clean electric technologies. The goal is to become zero-emissions without spiking emissions from our current fossil-fuel energy generators. To achieve this, we must drive uptake of energy efficiency measures in buildings and industries, where more than half of current energy use can be saved.[12] [13]

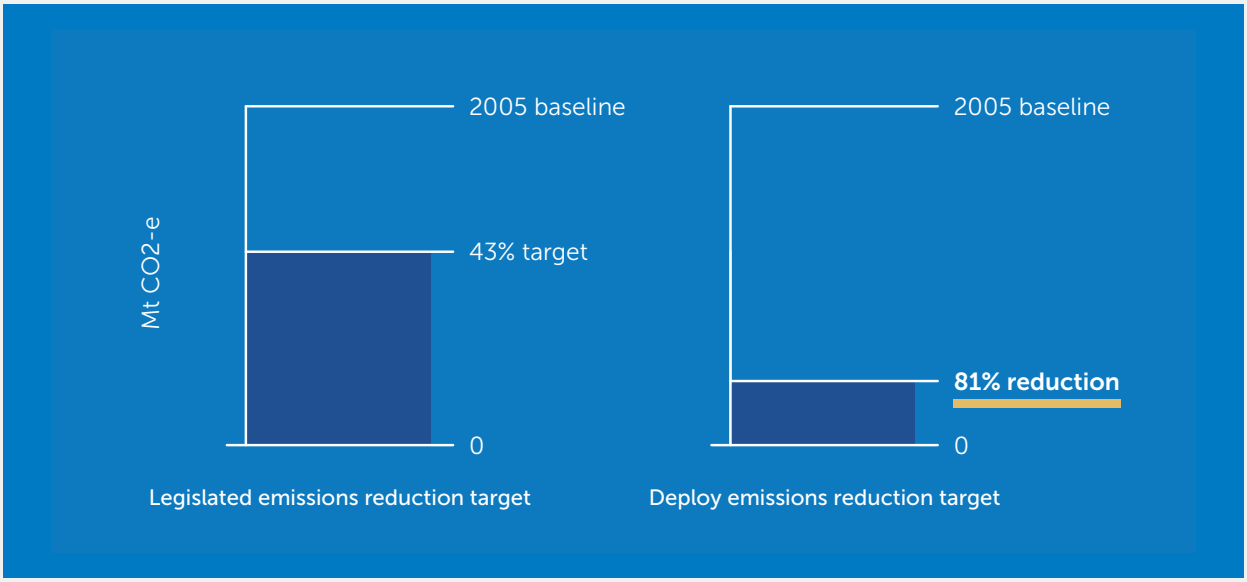
To be a just transition with opportunities realised for all, local communities must be at the forefront. First Nations' participation regarding environmental, social and economic impacts needs to be integral to planning, execution and management. Pilbara Solar is an example of a 50%-Aboriginal-owned renewable development company with a mission to develop utility-scale, renewable energy solutions.[14] Its 10 MW Junja Solar Farm project is under development and has equity ownership with the Jinparinya Aboriginal Corporation.[15] The solar farm is proposed to be built on Aboriginal land with the agreement of the Traditional Owners, who will receive significant benefits from the project.

More ambitious than Australia's 43% emissions reduction target

For this report we use 2019 as the emission baseline to capture the actions Australia needs to take right now with confidence.

When we compare our total reduction figures to 2005 emission levels (used by national and state governments) we reach a 70% emissions cut by 2030. This is 81% when carbon drawdown is taken into account. The potential for emissions reduction is far greater than the Australian Government's legislated target of a 43% reduction in emissions by 2030 compared to 2005 levels.

Figure 2: Emission reductions by 2030 with the Deploy Five-Year Plan compared to current legislated target



The Intergovernmental Panel on Climate Change (IPCC) says it is essential that carbon emissions are brought to net zero as rapidly as possible to stay in line with 1.5 degrees of planetary warming, and avoid "an environmental disaster,"[16] but we need to go further, beyond net zero, to bring atmospheric concentrations of carbon dioxide to safer levels. That must be our long-term aim.

ReThinkX calculates that 90% reduction in global emissions is possible by 2035 using just eight existing technologies.[17] The International Energy Agency supports this position in its 2021 report: "All the technologies needed to achieve the necessary deep cuts in global emissions by 2030 already exist."[18]

Climateworks' Decarbonising Futures report shows that by reducing our emissions by 74% by 2030 (from 2005 levels), we can reach net zero by 2035.[19] Our Deploy plan will cut 81% of emissions by 2030 (from 2005 levels) and, if achieved, could reach net zero before 2035. In 2030, some of the technologies that are emerging now will be commonplace and deployable. It will be cheaper, more efficient, faster and, with an upskilled workforce, easier to roll out. The opportunity to drive down to zero emissions will be very real indeed.

SEA-Drive® 100 power-system rear pod install at factory in Dandenong (Melbourne, Australia). Image courtesy SEA Electric

2. Overview

The technology is ready

Action to reduce global greenhouse gas emissions must accelerate dramatically to stay on track to reach the goals of the 2015 Paris Agreement.[20]

The world has a wealth of mature, proven clean technologies that can cut greenhouse emissions. These technologies have completed their 'technology readiness journey' and are available, affordable and ready to deploy across all sectors of the economy.[21] They each have the potential to cut emissions across multiple sectors of economic and daily activity.

These technologies generate and store renewable energy, or will need to operate using renewable energy to replace outdated fossil fuel-powered technologies.

Many are modular, relatively small units of equipment that can be assembled or manufactured onshore. In this report, a unit of technology can be large (such as a wind turbine or electrolyser), or small (such as a Tesla Powerwall battery). A unit is not being used here as a technical term, but as a means to collate existing, diverse, clean technologies that can be rolled out.

In addition, our plan also takes other efficient technologies into account, including induction cooktops, home insulation, revegetation and pyrolysis machines to produce biochar on farms.

The cost of such technologies will likely fall dramatically as demand grows. The cost of solar, wind and batteries continues to drop because of efficiency gains, economies of scale, wider public acceptance, more product variety and increasing capacity. This is demonstrated by the rapid uptake and price decrease of solar panels, with uptake growing 18 fold from 2010 to 2020 as cost dropped 80%.[22]

In contrast, old energy systems are experiencing less demand and reverse economies of scale, higher costs, lower revenues, less investment and government support, and decreasing social licence.[23]

Other jurisdictions are investing billions of dollars to drive renewable technology rollouts. The United States' recent Inflation Reduction Act commits more than US$300 billion towards climate action[24] and the European Union has quadrupled its hydrogen target to 20 million tonnes by 2030.[25]

These significant actions will drive international momentum in the deployment of renewable technologies such as solar, wind, batteries, electric vehicles and electrolysers in turn driving the growth of clean technology companies. The US Inflation Reduction Act offers significant opportunities for Australia, as a free-trade partner to grow our green supply chain exports.

The Five-Year Deploy Plan

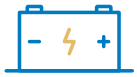
Accelerating the deployment of technological solutions that are available now at scale and speed is critical to Australia's capacity to build a zero-emissions economy this decade and to ensure we play our role in global decarbonisation. It will also allow Australia to seize an enormous economic opportunity.

The plan has three areas of activity: generation, use and drawdown:

- Generate 64 GW of renewable energy and 13 GW of storage capacity
- Install clean tech to reduce energy use and wastage across all sectors
- Remove carbon from the atmosphere with drawdown initiatives

Australia could reach 84% renewable energy generation within five years by deploying 64 GW of renewable capacity and 13 GW (67 GWh) of energy storage capacity (in line with the Strong Electrification Sensitivity Scenario in Australian Energy Market Operator's *2022 Integrated System Plan*).[26] This will replace fossil fuel power stations and ensure there is enough renewable energy to meet usage in an increasingly electrified world (see Table 1).

Table 1: Deployment of clean tech in renewable energy generation over five years

Technologies to deploy	Amount to deploy	Jobs	Benefits
Generation  • wind turbines • solar panels (utility scale and buildings)	64 GW of generating capacity: • 6,000 wind turbines • 66 million solar panels	46,000	• Create a stable, cheap energy supply • Create demand for Australian-made / Australian-assembled renewable energy technologies
Storage  • Batteries (utility scale and buildings)	13 GW/67 GWh of storage (6 million units)		

At the same time, we need to install and operate 13.5 million units of technology in our buildings (in homes, offices and retail settings), 7,000 (very large) units in our factories and bring online 3.8 million units for transport (made up of electric vehicles and chargers). Table 2 shows how these technologies can be deployed across energy use sectors, and the jobs and other benefits that deploying at this scale can create.

Natural emission 'removal' is also an important opportunity to reduce atmospheric carbon. This includes approaches such as habitat restoration, ecosystem protection, tree planting and soil improvement to draw down carbon from the atmosphere. We have calculated that in five years time we can sequester 35 million tonnes CO2 (MtCO2) per year.

Table 2: Deployment of clean tech by energy use sector over five years

	Technologies to deploy	Units to deploy	Jobs	Emission reduction and other benefits
Buildings 	Domestic heat pumps (hot water and air conditioners), 10.5 million units Commercial heat pumps (hot water and ducted air conditioners), 8,000 units Additional efficiency tech incl. insulation and induction cooking, 3 million homes *(domestic and commercial PV and batteries included under RE generation)*	13.5 million	87,500	Annual building emissions reduction from 2019 baseline (107.48 MtCO2-e) at year 5 = -75% (-80.46 MtCO2-e) • Cut household fuel bills by $1160 per year[27] • Improve air quality in homes
Vehicles 	Electric vehicles including: • E-passenger cars, 1.4 million • E-buses, 34,500 • E-utes and e-vans, 850,000 • E-trucks, 115,000 • E-tractors, 36,000 Public and residential charging units, 1.4 million	3.8 million	31,500	Annual transport emissions reduction from 2019 baseline (99 MtCO2-e) at year 5 = -15% (-14.15 MtCO2-e) • Cut transport costs for households, businesses, industry • Lower transport costs for manufacturing (domestic & export) • Reduce reliance on imported fuel • Improve air quality in major transport hubs
Industry 	Electrolysers (1 MW), 3,000 units Industrial heat pumps (100 kW), 1,500 units Electrifying mining equipment (1,000 kW), 2,500 mining vehicles	7,000	8,500	Annual industry emissions reduction from 2019 baseline (154.9 MtCO2-e, not including fossil fuel extraction) at year 5 = -48% (-74.51 MtCO2-e) • Support existing industrial manufacturing strength • Unlock export powerhouse $333 million green commodities export opportunity

Table 3: Carbon drawdown over the next five years

Action		Drawdown potential	Jobs	Benefits
	• 11 Mha of revegetation • Deploy 2,500 pyrolysis machines • Protect existing ecosystems and carbon stock	Annual emissions drawdown 35 MtCO2	21,000	• Expanded habitat and biodiversity corridors • Agricultural productivity • Additional farm income

The five-year plan is ambitious and achievable

To succeed in rapidly reducing emissions, the clean technologies must be deployed systematically and be the preferred technology for new leases, purchases, fitouts and builds across all sectors.

Table 4 shows the increase in deployment rates for sample technologies. Australia's deployment of domestic split-system heat pumps (air conditioners) is already faster than the pace needed in this plan, and the deployment of domestic solar panels needs to increase just 1.2 fold.

Table 4: Increase in rollout rates necessary for sample technologies

Technology	Baseline deployment rate (2021)	Annual deployment required (units)*	Fold increase in annual deployment rate required (1 = no change)
Residential split systems	943,420	792,470	0.8
Residential solar panels	6,445,950	7,653,001	1.2
Building batteries	40,415	85,553	2.1
Wind turbines	309	1,185	3.8
Utility batteries	230,827	1,107,000	4.8
Electric passenger cars	20,665	281,031	13.6
Hot water heat pumps	25,704	949,619	36.9

*BZE calculated

In total, the plan would require deployment of 10.6 million units of clean technology in residential buildings over five years, such as hot water and air conditioning heat pumps, as well as a further 2.9 million units of building efficiency technologies (including insulation and induction cooktops). Broadly, this works out at almost two units/appliances per existing household.

We would need to increase the uptake of electric passenger cars almost 14 times, but much of the heavy lifting can be led by fleet sales, which account for half of Australia's new-car market.

This level of ambition is not unprecedented. For example, Sweden has increased its new car sales from 10% EVs in December 2019 to 60% in December 2021.[28] In addition, Shenzhen, a city of 17 million in China, electrified its entire fleet of 17,000 buses in one year after a number of small pilots were carried out between 2012 and 2015. The rollout also included installation and operation of 1,707 charging terminals across 104 stations.[29]

We are already getting faster at deploying clean technology. In May 2022, for example, Australian solar technology innovator 5B claimed a global speed record for deploying utility-scale solar more than five times faster than the industry standard for a client in the Atacama Desert, Chile.[30] We are likely to see ongoing innovation in approaches to technology deployment as demand increases.

Technology and skills

Deploying new technologies at the rates proposed will create job opportunities across manufacturing, construction, installation and maintenance. The necessary uplift in skills presents an opportunity to train Australian workers in the skills of the future.

Skilled personnel may be sought through greater provision of training courses and targeted migration. Pathways to attract and integrate skilled migrants, including recognising international qualifications, will boost the skills base rapidly. At the same time, retraining courses can encourage trades and skills to transition from fossil fuel jobs to the new green manufacturing economy. Transitioning these workers into stable, secure and future proof-industries will also benefit the communities in which they live and work.

Technology and behaviour change

We cannot rely on technology alone to address greenhouse emissions. Behavioural change must occur alongside the technology transition and has the potential to add further significant emission reductions, in line with findings of the IPCC[31] and many others.

The International Energy Agency's Net Zero by 2050 report found 4% of emissions reductions can be achieved through behaviour change such as transport modal shifts and heating set points in buildings.[32] Lifestyle changes that shift and reduce 'demand' need to occur systematically across the whole of society and require motivation, as well as capacity by individuals. Driving change to human behaviour is slow, and establishing change as a new societal norm is challenging. This essential activity is outside the scope of this report.

The role of carbon drawdown

Forests, grassy woodlands and natural regeneration of soils and plantations can make a major contribution by removing past emissions. This natural removal or carbon drawdown can also be effective on agricultural crop, grazing and forestry land with a range of co-benefits.

Carbon drawdown should be used to counter hard-to-abate emissions and the small number of activities for which there are currently no known zero-emissions solutions. It's critical we do not allow drawdown to be squandered on emissions that can be cut through technology and instead use it as an opportunity for Australia to meet and even go beyond net-zero emissions.[33]

A successful program of carbon drawdown will require strong environmental laws, policy settings, regulations and abatement incentives. Genuine community engagement will be critical to ensure co-benefits are delivered over the long term for farmers, regional communities and precious biodiversity. It should be noted that drawdown methods carry risk from future climate impacts such as droughts and fires.

Australia's natural carbon drawdown potential

Australia's vast natural resources have significant potential for carbon drawdown. Unlocking this potential requires long lead times. New seedlings take time to establish before their carbon capture ability rapidly increases to plateau at maturity. It is important to establish these seedlings as quickly as possible alongside strategic land management to maximise drawdown capabilities and deliver co-benefits to farming and biodiversity.[34]

Australia's native forest and ecosystems already sequester significant amounts of carbon per year – 25 MtCO2 per annum. We can maintain this drawdown potential by protecting our existing carbon stock of ecosystems and retaining their sequestration capabilities.

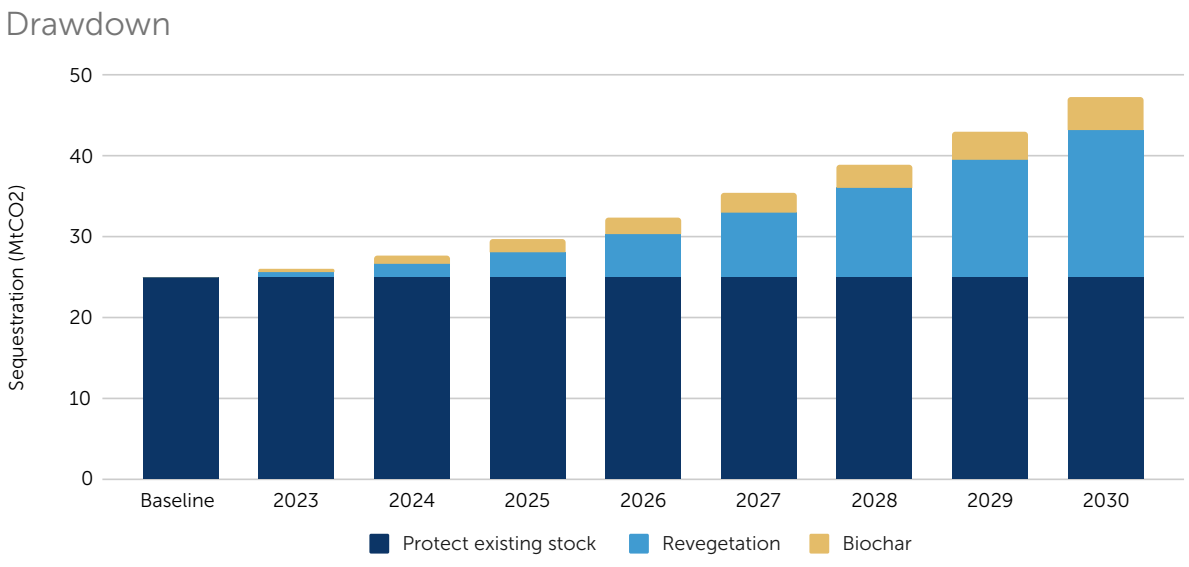
Revegetating 11 million hectares in the next five years by planting trees, bush regeneration and strategic revegetation on farmland (shelterbelts, riparian corridors, agroforestry) would expand Australia's natural sequestration advantage and add to Australia's ability to draw down carbon.[35] [36] This would be slow initially, drawing down 1 MtCO2 in its first year but rapidly increasing to 8 MtCO2 per annum by year five. As the vegetation matures, this amount grows steadily to 18 MtCO2 per annum by 2030 while creating over 20,000 jobs.[37]

Another potential drawdown technology is biochar, which is a fine-grained, biologically unavailable charcoal made from plant material and agricultural waste through a process called pyrolysis. Biochar can fix carbon in the soil for centuries to millennia whilst enriching soil health and productivity.[38] Deploying 500 pyrolysis machines (mobile units the size of shipping containers) each year into cropping districts can help draw down 2.5 MtCO2 by year five and create 500 jobs.[39]

Combining revegetation, protection of existing stock and integrated farming methods such as biochar, we have calculated that Australia's ecosystems and agriculture have the potential to draw down a combined 35 MtCO2 in year five, growing to 47 MtCO2 in 2030 (see figure 3).

Carbon removal in the land sector has immense benefits for farmers beyond emissions removal. Carefully planned and implemented drawdown initiatives allow farmers to diversify their income streams, build resilience to droughts and floods, and contribute to productive and healthy agricultural lands.[40]

Figure 3: Annual drawdown potential for Australia through protecting our existing ecosystems (existing stock) and the deployment of biochar and revegetation programs.



Emissions and agriculture

Switching fuel use and electrifying 60% of farm vehicles (including tractors noted in vehicles section) and equipment by 2030 would cut 5.66 MtCO2-e emissions (just 7% reduction from 2019). This would need to occur in tandem with solar panel and battery storage roll out to ensure rural networks are not overloaded.

The livestock industry uses more than 300 million hectares of land in Australia, making it our largest land user. Livestock production is also Australia's most valuable agricultural commodity, making up more than half of our agriculture sector's economic output. The industry association, Meat & Livestock Australia, has a goal to be carbon neutral by 2030.[41]

Research and innovation has come up with some promising solutions to reduce emissions from livestock, including red seaweed addition to feedstock and improved herd management. Scalable cultured meat production and plant-based meat substitutes provide alternatives to livestock, helping to indirectly reduce emissions and also enable more land for carbon removal. These new technologies have the potential to offer mass manufacturing and job opportunities.

Cropping is also a major economic agricultural activity that uses five million tonnes of fertilisers each year, 85% of which comes from overseas.[42] Aiming to reduce fertiliser use would be beneficial to global emission reduction and needs could be met with construction of biofertiliser plants in Australian agricultural centres to increase domestic supply and ensure stable fertiliser prices for primary producers.[43]

Coordination and collaboration

Coordination and integration of technology deployment will be essential. New renewable energy generation, storage and transmission need to come on line at scale and speed to replace the existing fossil fuel-driven electricity grid. Clean electric technologies will need to be deployed at a pace that broadly aligns with the increasing availability of renewable energy so that we are zero-carbon ready without increasing electricity demand too sharply. In parallel, we must drive uptake of energy efficiency measures in homes, commercial spaces and factories to minimise energy waste and unnecessary electricity use, ensuring we maximise use of clean electricity when it is available (e.g. running heat pumps and charging EVs during the day).

To derive optimal economic benefits, deeper analysis of supply and value chains will be needed to ensure Australian suppliers capture the full value of this technology roll out.

Benefits to business, industry and regional communities

Mass deployment of emission reducing technologies will create demand that Australia's manufacturers can meet with a growing proportion of onshore technology assembly and manufacture. Wind turbines, lithium-ion batteries, thermal storage and electric vehicles are among the renewable technologies manufactured onshore today. Mass rapid deployment of technology will generate significant demand, increase industry confidence to invest, and create opportunities for quality on-going jobs particularly in Australia's industrial heartlands.

This deployment will develop the demand for new industries and support the emergence of diverse local manufacturing opportunities that can drive the new era of prosperity for our manufacturing regions and their communities. Australia now has the opportunity to build a cohesive industry strategy to match key trading partners and stay ahead of competitors in this space. The groundwork is already in place with great work already being done by Australian companies such as Tritium, Tindo Solar and MGA Thermal.

Deploying this technology over five years will:

- **Create 175,000 jobs** in the next five years in manufacturing, construction, installation and maintenance by rapidly deploying existing technology. Additional indirect jobs created are not included in these figures.
- **Reduce energy costs** for manufacturers and **reliance on volatile fossil fuel prices**, making Australian-made products more competitive on the global market and increase sovereign security. Households will also benefit from lower energy bills.
- **Help stimulate a green export industry worth $333 billion** including green steel and aluminium, green hydrogen and chemicals, batteries and critical minerals. Modelling shows potential revenue growth from green exports from $21 billion in 2020 to $333 billion by 2050, almost triple fossil fuel exports of $128 billion in 2021.[44]
- **Revitalise manufacturing in the regions and urban centres:** Australia's industrial heartlands are primed to benefit from a large-scale, rapid uptake of renewable energy technologies that boost demand for Australian-made technology and their supply chains - increasing sovereign security.

3. Electricity generation

Additional renewable energy generation underpins the five-year plan

Renewable energy generation to produce electricity already meets one third of Australia's electricity needs and has the potential to replace all fossil fuel generation.

Exceptional solar and wind resources mean Australia has the potential to become the world's first renewable energy superpower. Australia could reach 84% renewable energy generation within five years by deploying 64 GW of renewable capacity and 13 GW (67 GWh) of energy storage capacity – and 100% renewable energy generation by 2030. We share this ambition with others, including AEMO's Strong Electrification Sensitivity scenarios model of 97% renewables by 2030[45] and the University of Technology, Sydney 2016.[46]

Australia is also a global leader in energy storage, an early adopter of 'big batteries' and is developing a new generation of pumped hydro assets.

It is essential that all new electric technology is powered by renewable energy, and this study considers electricity an 'enabler'. To rapidly progress towards a 100% renewable energy powered and firmed economy, we must accelerate the deployment of renewable energy generators to replace fossil fuel power stations and build in energy storage at the utility scale and through distributed systems (households and commercial buildings). Over the next five years this would include:

- 63.9 GW of generation (12.8 GW per year)
  - » 32.6 GW of new large scale wind farms
  - » 31.3 GW of new solar capacity (10.6 GW utility scale, 5.4 GW commercial and 15.3 GW residential buildings)
- 13 GW/67 GWh of new energy storage = 2.6 GW/13.5 GWh per year (8.5 GW/56 GWh utility scale, and 4.7 GW/11 GWh building batteries)

Transition to 100% renewable electricity will cut Australia's total annual emissions (across all sectors) by 35%, deliver 46,000 jobs and eliminate the price setting influence of gas and coal power.[47]

A national supergrid

For Australia to run entirely on renewable energy and embrace the economic opportunities it presents, we need to substantially upgrade the electricity network to one that is fit for the task: a 'supergrid'.

Where we once had a small number of power plants that sent electricity one way into the network, renewable energy will come from many varied sources – solar and wind farms, hydro power plants, rooftop solar units and batteries.

The 'supergrid' will have the scale to harness our best renewable resources, send electricity in many directions to where it's necessary and access the energy storage (firming) capacity needed to provide low cost, reliable power. It will be able to power industries, homes and cars as well as enable advanced features such as vehicle-to-grid (V2G) integrations and making homes Virtual Power Plants (VPPs).

Over the next five years, a 'supergrid' will allow Australia to plug in the 64 GW of renewable capacity and 13 GW/67 GWh of storage technology to power buildings, vehicles and industry.

Utility-scale renewable energy and storage

In the next five years, we can increase utility-scale wind and solar generating capacity from 15 GW[48] today to 43 GW, which will deliver 17,600 ongoing maintenance and operations jobs. Utility-scale storage needs to increase from 0.5 GW/0.77 GWh[49] to 8.5 GW/56 GWh, delivering 4,043 jobs.

Utility solar is already deploying at a tremendous speed that will enable us to reach these targets, while wind needs to increase threefold and utility battery storage needs to double to ensure adequate firming.

Distributed renewable energy and storage

Australia can capitalise on existing technology supply chains to deploy 20.6 GW of solar panel capacity and 4.7 GW/11GWh of storage primarily in the form of building batteries to cut emissions in the building sector over the next five years.

To achieve this we need to increase the rate of rooftop solar deployment by about 30%, from 3.2 GW[50] to 4.1 GW per year. That's the equivalent of installing about 7.7 million solar panels on residential buildings and 2.2 million solar panels on commercial buildings per year for the next five years). In addition, we need to install 0.9GW/2.2GWh of battery storage in buildings each year for the next five years, double current rates. This will create 24,400 ongoing jobs in tech installation and maintenance.

Figure 4: Increase in renewable power capcity by technology type in 2021 and in five years time with deployment rates as described.

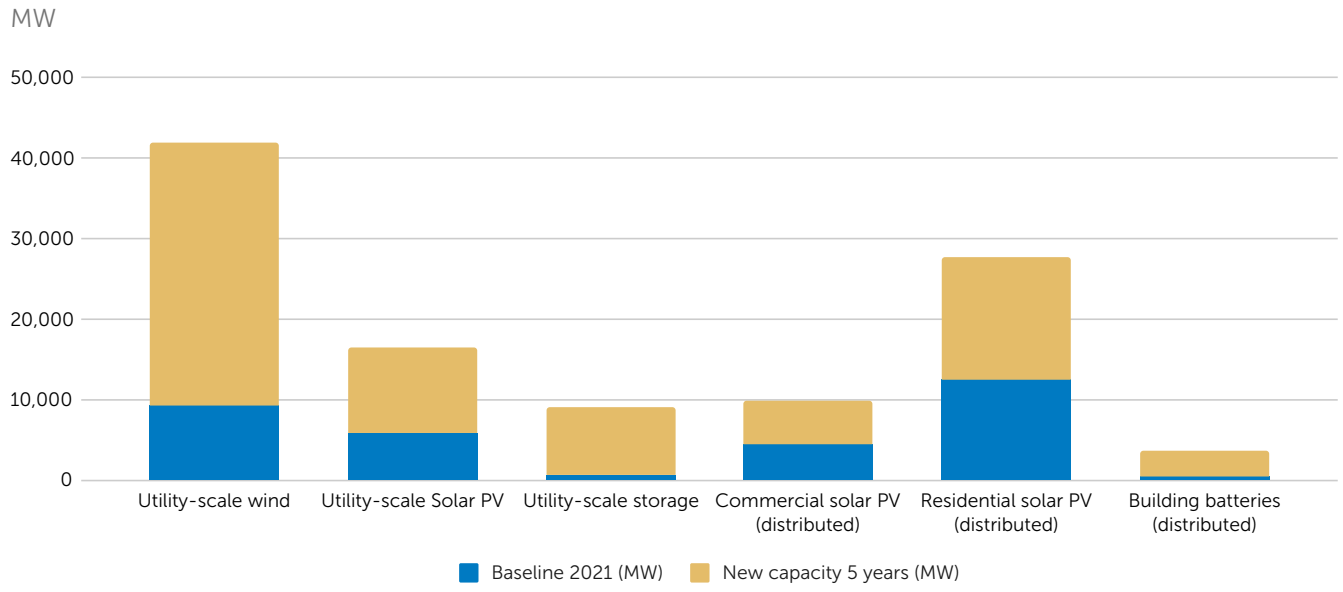


Figure 5: Mass deployment of renewable energy generation and storage will create jobs in construction, engineering, installation and maintenance.

13,361 jobs
Wind turbines

15,536 jobs
Solar PV
(residential)

2,047 jobs
Solar PV
(commercial)

4,217 jobs
Solar PV
(utility-scale)

6,726 jobs
Batteries
(buildings)

4,043 jobs
Batteries
(utility-scale)

Homes are the energy infrastructure of the future

Rooftop solar, home batteries, smart appliances and electric vehicles are already evolving how homes participate in the electricity market. Transition to a clean-energy future has the potential to reposition households as important 'energy infrastructure' assets.

AEMO's 2022 Integrated System Plan predicts that rooftop solar coupled with battery storage (home and EVs) will become a major energy asset for Australia's electricity network.[51] Forecasts predict that by 2027-28 rooftop solar will generate close to 34,000 GWh, equal to as much energy as Australia's remaining brown-fired coal generators combined.[52]

In November 2021 South Australia delivered a world first, meeting 100% of electricity demand for a short period through rooftop solar and only a small amount of utility solar.

Rooftop solar: Over the past four years, installation has grown 30% each year, setting new records in 2021.[53] About 370,000 systems were installed on Australian homes and businesses; a rate of about 3 GW per year.

At current installation rates residential rooftop solar will provide more than 30 GW by 2030. Increasing deployment to 4 GW/year, Australia could reach 50 GW by 2030 on homes alone, delivering 100% of household net-electricity demand including all electric upgrades of heating and transport.[54] [55]

Batteries: Australian homes have installed more than 100,000 home batteries with a combined storage size of more than 500 MW/1,099 MWh. This is equivalent to almost double the size of Australia's largest utility battery, Victoria's Big Battery.[56] Battery installations are simpler and quicker than rooftop solar and can be deployed at two to three times the rate.

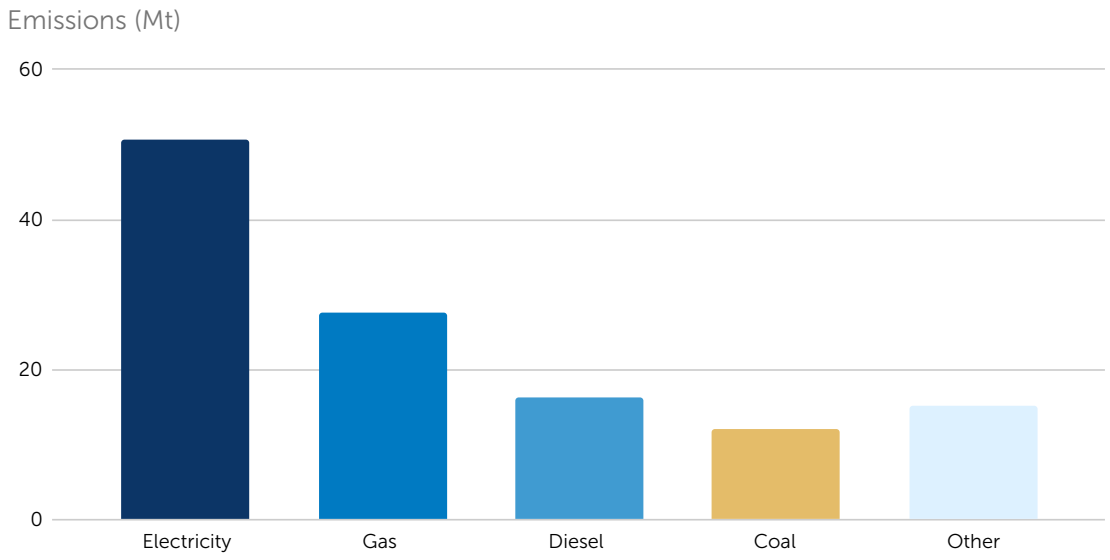
Powering industry with renewable generation and storage

Powering industry with 100% renewable electricity can dramatically reduce emissions. The industry sector is the largest single emitter of greenhouse gases in Australia, responsible for 46% of annual emissions,[57] of which electricity usage is responsible for 41%.[58]

This will need ample renewable generation as well as sufficient storage (such as grid scale batteries or other long duration energy storage) to ensure critical industry equipment stays powered 24/7. This requirement for both renewables and storage is an opportunity to avoid the 'chicken and egg' problem by pairing supply with demand. Collaboration and careful coordination can support industry decarbonisation as well as underpin investment through offtake agreements.

Switching energy contracts to a 100% renewable basis is one of the most competitive decisions industry can take. Repowering Australia's industrial sector with renewable energy will give industry access to the most competitive and stable priced energy available today, reduce exporters' exposure to international carbon tariffs (e.g. carbon border adjustment mechanisms) and unlock zero-emissions export opportunities.[59]

Figure 6: Industry emissions by fuel source (2019)



Renewable Energy Industrial Precincts

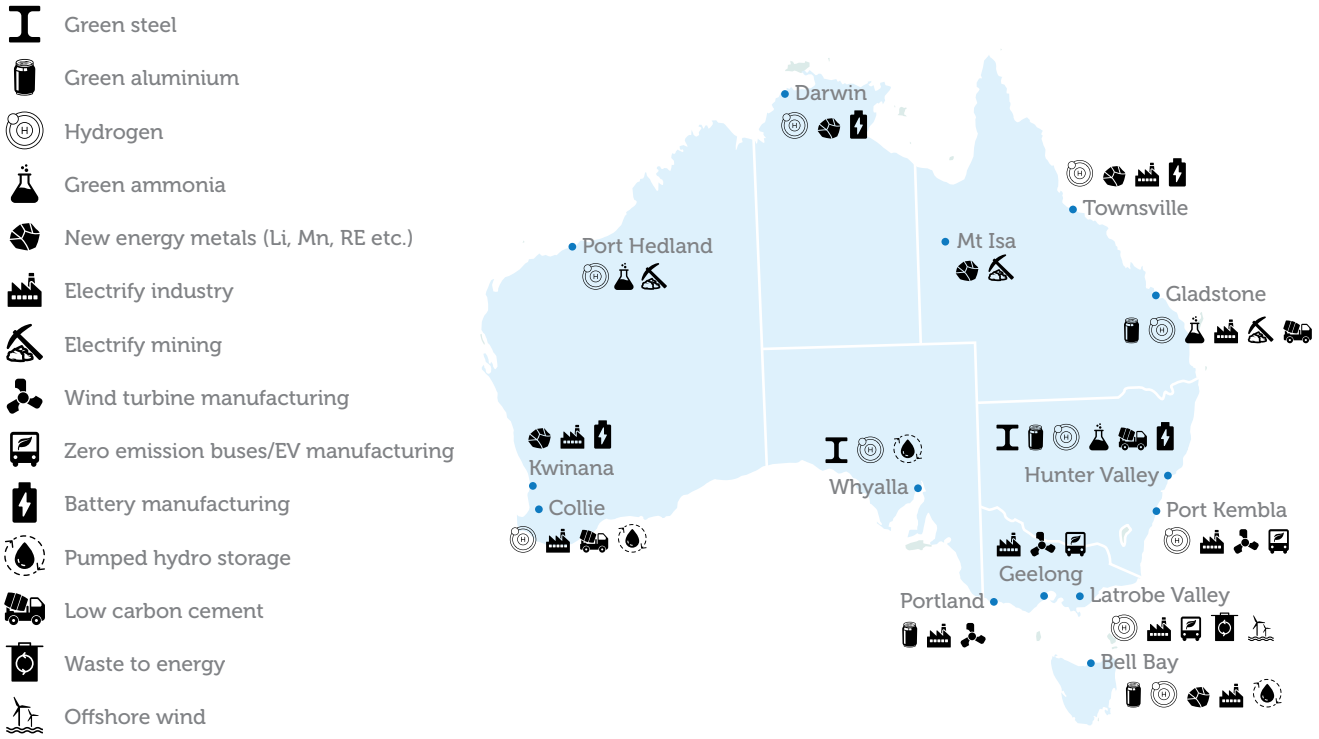
Renewable Energy Industrial Precincts (REIPs) are an efficient way to revitalise our industrial centres with low-cost renewable energy to power the industries of the future. They are clusters of industries powered by 100% renewable energy, minimising the cost of shared infrastructure and benefitting from its economies of scale and efficiencies.

Ideally REIPs should be located in existing industrial centres to benefit from the skilled workforces, ports and road, rail and energy infrastructure. REIPs need good renewable energy resources and access to green hydrogen production and clean heat.

REIPS will produce the low-carbon goods the new economy needs. They can support energy-intensive businesses such as green aluminium and steel, hydrogen, ammonia and chemicals production, recycling and battery manufacturing, which means a REIP model would work best in our regional manufacturing heartlands.

REIPs can also provide a home for manufacturers of the large amounts of clean technologies we need to deploy, such as wind turbines, electric vehicle chargers, batteries, electrolysers, electric buses and mining equipment, boosting manufacturing in Australia.

Figure 7: Priority locations for establishing Renewable Energy Industrial Precincts



Economic modelling by ACIL Allen commissioned by Beyond Zero Emissions and WWF-Australia showed the impact a REIP could have on the Hunter and Gladstone regions included[60]:

- creation of 45,000 new ongoing jobs
- an extra $13 billion in annual revenue in the Hunter and Gladstone regions alone
- attraction of new industries and tens of billions of investment dollars into regional areas
- high-quality jobs brought back onshore

Our recent briefing papers for the Hunter[61] and Gladstone[62] further explore energy and storage requirements as well as the opportunities in more detail. There are at least 14 regions across Australia that can be activated through a REIP and associated, coordinated deployment of renewable technologies. This is a once-in-a-generation opportunity to transform our regional industry heartlands into thriving renewable industry centres.

Technology to deploy in electricity sector

Solar photovoltaic (PV) panels

PV panels use photovoltaic technology to convert sunlight into electricity. Multiple panels combined with an inverter are called a solar system; the inverter is needed to convert the direct current (DC) generated by the panels to alternating current (AC) for use in standard electricity circuits. Systems can be installed on the ground, wall or rooftop, and may be fixed or use a solar tracker to follow the sun across the sky. They are scalable to the power needs of a home, business, factory or powerplant.

Solar panels: Made in Australia

Tindo Solar, Mawson Lakes, South Australia

Tindo Solar's new 150 MW state-of-the-art factory at Mawson Lakes in South Australia employs 80 people, creating panels for households, commercial buildings, and solar farms. Their 'Tindo Karra' series is a range of high-efficiency rooftop panels designed for residential and commercial use. All panels are built using the new global M10 cell technology.

Tindo Solar's Karra panels have a 25-year product warranty and an end-of-life recycling guarantee through a partnership with Reclaim PV. Tindo Solar is Australia's only solar panel manufacturing facility, founded in 2011.

Image courtesy Tindo Solar.

Wind turbines

Wind turbines use wind to turn their propeller-like blades around a rotor, which spins a generator to produce electricity. They can be located onshore or offshore.

Once installed, solar and wind both offer cost-effective electricity generation, require minimal maintenance and do not create pollution or greenhouse gas emissions.

Energy storage

Batteries store energy in a chemical form and convert it into electricity to provide power when needed. The underlying function of a battery is similar regardless of its scale, whether a home battery, community scale battery or a 'big' power plant battery.

When renewable energy generation is coupled with battery storage, energy is stored during times of high production and/or low demand and

released when demand is high. A combination of generation and storage creates the flexibility that underpins a reliable energy supply from variable, intermittent power sources such as wind or solar. Batteries also provide important backup electricity for telecommunications, public transportation and medical procedures.

Other technologies that store energy include pumped hydro, compressed air, thermal energy storage and kinetic energy systems, but they have not been modelled in this report. Nonetheless it is a growing market with homegrown innovators such as MGA Thermal and Raygen getting international attention,[63] [64] while Graphite Energy has launched its graphite battery at a Mars Petcare facility in Wodonga.[65]

Australian-made high-performance lithium-ion batteries

Energy Renaissance, Hunter Valley, New South Wales

Energy Renaissance builds batteries for vehicles, homes, business and the grid. The company is committed to building a 100% local supply chain and currently sources 92% of components used in its batteries from Australian suppliers. Sixty percent of the batteries that Energy Renaissance produces will be exported to Southeast Asia.

Energy Renaissance is building Australia's first Gigafactory battery and cell manufacturing facility in Tomago, in New South Wales' Hunter Region. The new facility will create 720 direct jobs and when it is fully operational, Energy Renaissance estimates it will support approximately 475 direct and 245 indirect jobs with skilled workers and technical staff comprising the bulk of direct positions created in the Hunter region.[66]

Kristal Bartlett, Industrial Electrician, works hands-on designing & manufacturing the batteries. Image courtesy Energy Renaissance

Image courtesy Tindo Solar

4. Buildings

Building upgrade opportunities

Technologies (Domestic and commercial PV, and domestic/ commercial batteries included under renewable energy)	• Domestic heat pumps (hot water and air conditioners) • Commercial heat pumps (hot water and ducted air conditioning) • Efficiency tech including induction cooktops and insulation
Target units (over 5 years)	• 13.5 million
Total jobs ongoing (over 5 years)	• 87,500
Annual buildings emissions reduction from 2019 baseline (107.48 MtCO2-e) at 5 years	• -75% (-80.46 MtCO2-e)

There are no technological barriers to achieving a 100% emissions reduction in Australia's buildings sector.[67] We can cut building emissions by 75% over the next five years by deploying clean technology. Buildings (commercial and households) currently account for 20% of Australia's emissions, primarily from electricity use and burning gas for heating, hot water and cooking. Of these:

- Commercial buildings (e.g. offices, schools and supermarkets) represent 9% of national emissions.
- Residential buildings, already taking a strong lead in rapid deployment of emission reducing technology, contribute 11% of national emissions, using one quarter of the total electricity supply and almost one fifth of gas.

Deployment

To achieve rapid emissions reduction in the building sector over the next five years we need to:

1. **Deploy 10.56 million units of clean technology in residential buildings (about 2.1 million each year).** This includes heat pumps for hot water and space heating/cooling, as well as efficient technologies such as induction cooktops. In turn this will lead to replacement of 2.1 million residential gas appliances, reducing household gas bills and reducing energy costs, as well as removing gas emissions, which has additional health benefits such as reducing the burden of childhood asthma.[68]
2. **Upgrade 3 million homes** to minimise energy waste and ensure lowest possible energy costs to homeowners. Better insulated homes cost less to heat and cool, while staying more comfortable all year round. Most Australian homes were built before the introduction of insulation standards in 2003.[69] These measures will assist with closing the gap between new more efficient homes and older inefficient homes.
3. **Upgrade 1,600 commercial buildings with clean technology each year – 8,000 in total.** Technology solutions for commercial buildings include installing heat pump water heaters and air conditioners, and switching energy supply to renewable sources. These reflect solutions for residential buildings but are more complex in terms of size and customisations required.

We need to increase distributed electricity generation and storage, specifically:

- Increase residential and commercial solar panel installation rate from 3.2 GW to 4.1 GW per year. As a result, 3 million homes will become energy positive and provide surplus energy for other sectors. 1,600 commercial buildings (with many more businesses) will benefit greatly from cheaper energy and lowered grid demand in business hours.
- Increase energy storage installation rates in homes and businesses from 300 MW/500 MWh per year to 900 MW/2200 MWh. Energy storage will deliver major benefits to both buildings and the grid. For example, energy storage helps to smooth grid demand by reducing peak demand. Homes and businesses will also benefit from blackout protection to ensure essential appliances continue to operate.

Strong support will be required from government to achieve required rates of deployment. Both residential and commercial split-system heat pumps are already being installed at the rates needed to reach the suggested targets. The rate of deployment of hot water heat pumps in residential settings will need to increase 37 fold. While this sounds incredibly ambitious, this type of heat pump has only recently reached price parity with gas options and rollout is starting from a low base. The rate required is only double the rate at which Norway recently rolled out heat pumps in residential settings.[70] Heat pumps also provide thermal storage in hot water tanks, a simple way for home owners to use excess solar during the day. This, along with programs such as the Victorian Gas Substitution Roadmap,[71] will rapidly increase deployment.

Policies to encourage deployment must ensure all households and businesses are able to benefit from efficiency upgrades and take advantage of Australia's energy transition and its benefits, regardless of income and energy literacy. There are big gains if older inefficient homes are converted first.

Benefits

Deploying clean technologies at scale in buildings and households can cut sector emissions by 75% in five years and will:

- **Create 87,500** jobs in retrofitting alone.
- **Help revitalise manufacturing** in the regions and in urban centres by creating a market for locally manufactured renewable technologies, such as Earthworker heat pumps in the LaTrobe Valley or Energy Renaissance batteries in the Hunter Valley.
- **Cut energy costs to households by more than 70%.** Victorian State Government economic analysis in 2022 estimated an all-electric home with solar and battery will save $1,700 per year on energy bills compared with homes with gas.[72]
- **Improve living and working environments** with comfortable home climate control that performs in extreme temperature and weather events. All-electric homes create lower levels of home air pollution and associated health risks, such as childhood asthma.

Technology to deploy in buildings

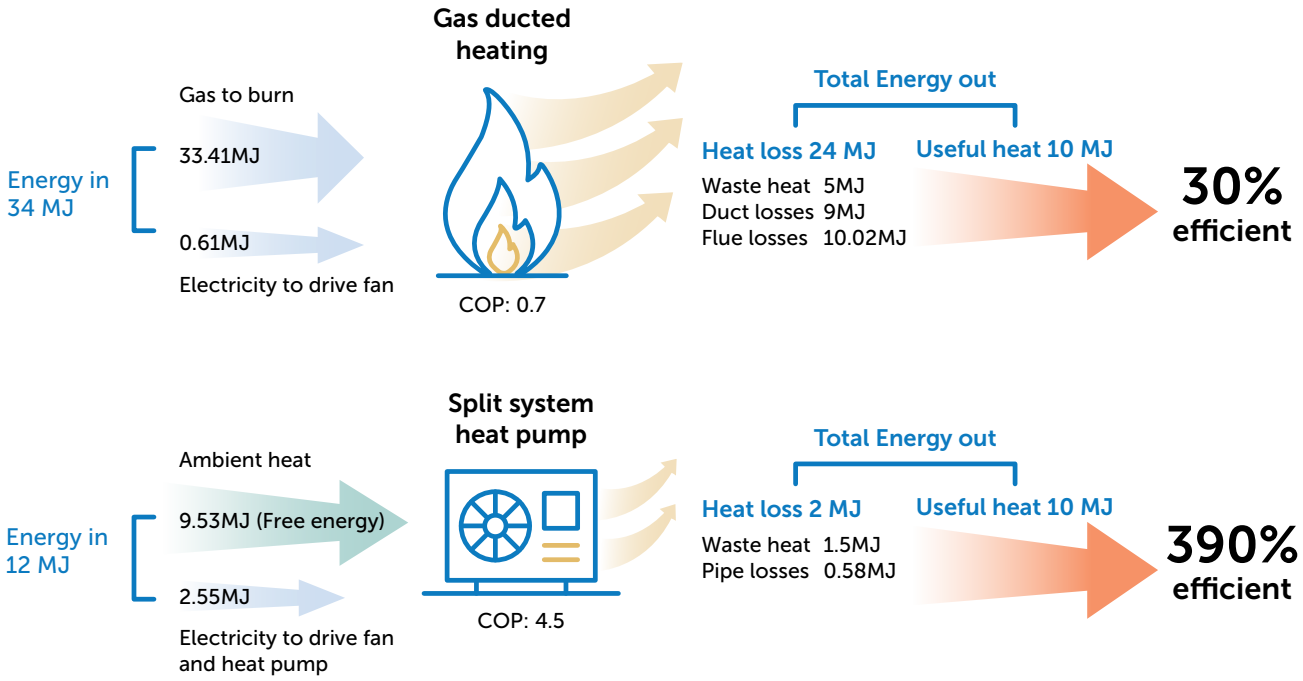
In addition to the headline technologies outlined in this report, we have also considered technologies that add to efficiency. Modern electric appliances are smarter and more efficient than gas alternatives and deliver large cost savings for households, especially relevant now with international gas price volatility. Split system heat pumps, for example, can reduce energy use, and smart appliances can shift energy usage to times when demand and price is low, or when rooftop solar is generating. Thermal upgrades including insulation, double glazing and draught proofing reduce energy needed for heating and cooling homes. Insulated homes are better able to maintain comfortable indoor temperatures and require less energy and ongoing costs.

Heat pumps

Heat pumps are efficient, flexible technologies that are used in a broad range of settings.[73] Every home in Australia has at least one in a refrigerator or air conditioner. The latest wave of heat pump application is in domestic hot water heating, proving heat pumps are mature and have multiple applications.

Heat pumps use electricity to pull heat from the air and thus generate more energy than they use; every unit of energy used will generate between three and six units of heating and cooling energy. In contrast, gas heaters generate less than one unit of energy for each unit of gas energy burnt, while traditional electric heaters can deliver at best one unit of heat per unit of electricity. This efficiency makes heat pumps the obvious choice for heating and cooling our buildings, and increasingly for heating water in both domestic and industrial settings to replace gas boilers. Using less energy, means cheaper energy bills without compromising on essential services.

Figure 8: Space heating relative efficacy – gas ducted heating vs split system heat pump



Award-winning Australian heat pumps

Reclaim Energy, Byron Bay, New South Wales

Reclaim Energy is an Australian-owned engineering company supplying heat pump hot water systems for Australian homes and businesses. Reclaim Energy's hot water heat pump systems have been developed in collaboration with a Japanese manufacturer and include a patented controller system developed by Reclaim, and a unique tank operating design that allows for maximum efficiency. At the time of writing, Reclaim Energy's hot water heat pump is considered the most efficient in the Australian market, consuming almost 80% less energy than a standard electric hot water system.

Reclaim Energy employ around 12 people, with products available Australia-wide. Reclaim Energy won the Future Energy - Industry Leader prize at the Victorian Premier's Sustainability Awards in 2022.

Image courtesy Reclaim Energy

5. Vehicles

Electric vehicle opportunities

Technologies	Electric vehicles, batteries, public and residential charging units
Target units (over 5 years)	3.8 million (100% EV Sales at year 5)
Ongoing jobs (over 5 years)	31,500
Annual transport emissions reduction from 2019 baseline (99 MtCO2-e) at 5 years	-15% (-14.15 MtCO2-e)

The transport sector is responsible for 19% of Australia's annual emissions,[74] the majority of which come from vehicles on the road, moving people, goods and services over large distances. We can cut transport emissions by 15% over the next five years by deploying electric vehicles (EVs) to replace those running on fossil fuels, and ensuring there is adequate charging infrastructure to support them. This can be a win-win as midday charging can utilise and store surplus solar PV.

Road transport represents 84% of transport emissions (2019). These have steadily increased over the last 30 years. Of the road transport emissions:

- Passenger vehicles contribute 45% of the sector's emissions, driven by sheer weight of numbers.
- Trucks (articulated and rigid) contribute 21% of sector emissions. These large, high-use vehicles have a disproportionately high emissions impact, producing greater amounts of emissions per unit than passenger vehicles
- Light commercial vehicles (utes and vans) contribute 17%
- Buses contribute approximately 2%
- Motorcycles contribute approximately 1%

Deployment

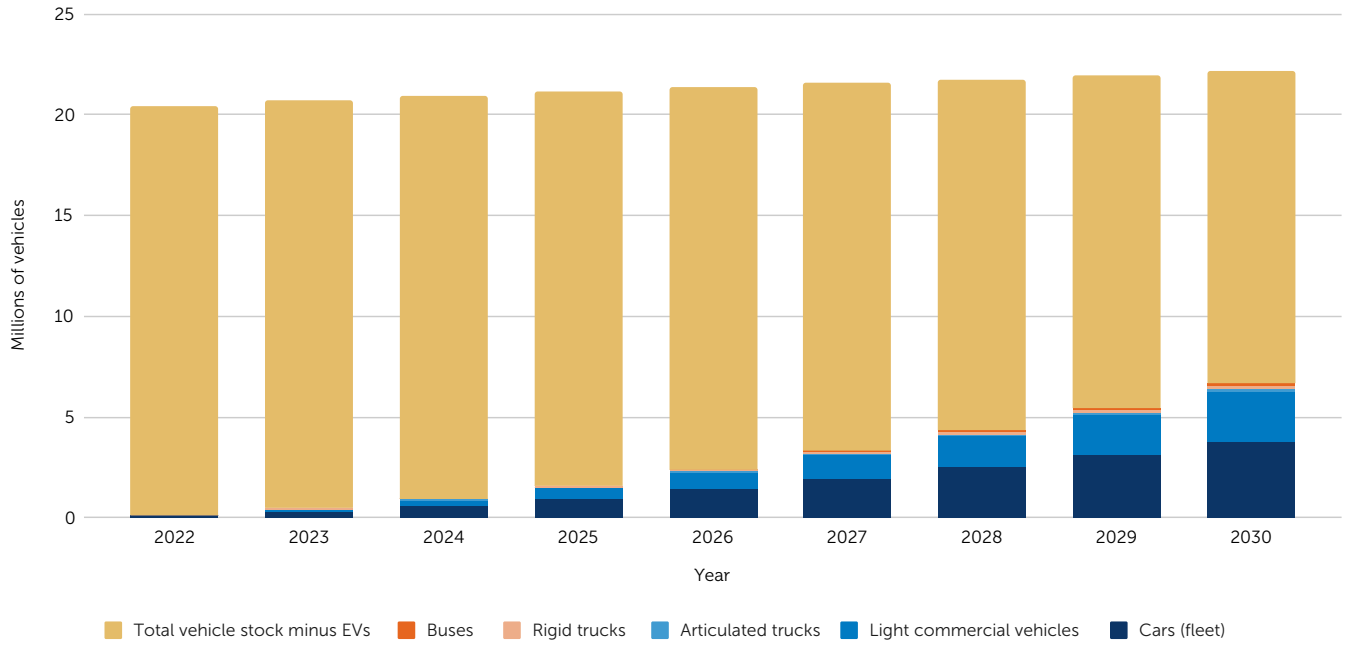
An ambitious EV deployment plan is critical to reduce emissions, reduce freight and supply chain costs, and eliminate bowser bills for households and industry reducing our dependence on imported oil. Australia requires a nationwide plan to deploy EVs across all vehicle types, with success in countries such as Norway offering a playbook to emulate.

To achieve rapid emissions reduction in the transport sector through electrification of vehicles in the next five years, we need to:

1. **Encourage purchase of 1.4 million electric passenger fleet vehicles** to kick start electrification of Australia's 20 million passenger vehicles. Fleet operators purchase almost 50% of all new vehicles, so electrifying fleet vehicles as a priority will increase EV sales and make second-hand electric vehicles available in the market sooner. In turn this will improve overall affordability of EVs by making 2 million second-hand electric vehicles available by 2030.
2. **Increase production of locally manufactured electric buses and rigid trucks** to replace 30% of Australia's national bus fleet (34,500 vehicles) and 70,000 rigid trucks.
3. **Electrify 850,500 light commercial vehicles (utes and vans), as well as 43,350 articulated trucks.** Electrifying transport in supply chains offers a huge emissions cutting opportunity, making light commercial vehicles and trucks ideal targets for a rapid switch.

4. **Deploy 36,000 electric farm vehicles:** small to medium tractors ranging up to 60 kW.
5. **Install 1.4 million chargers: 1.12 million residential and 236,000 public.** It will be essential to supercharge EV infrastructure, ensuring chargers are visible (to address range anxiety) and easy to access. Chargers will need to be available both in homes (to enable smart charging, vehicle-to-grid and vehicle-to-home capabilities) and publicly, in places where cars are parked during the day (in supermarkets and shopping centres).

Figure 9: EV deployment rate proportional to the total national vehicle stock.



The demand for electric vehicles in Australia is strong.[75] Currently, one of the greatest challenges for the uptake of electric vehicles for Australia is supply, and government support will be essential to address this. Introduction of strong fuel efficiency standards will be a great first step to ensure Australia receives lower-emitting vehicles.

Fleets and commercial vehicle operators can act as a high-impact funnel for driving electric vehicle uptake, and policies to support these groups will increase wider accessibility. Charging infrastructure, at home, in public places and also within depots also requires rapid rollout and government support.

Benefits

Deploying electric vehicles and chargers at scale can cut transport emissions by 15% in five years and will:

- **Create 31,500 new, ongoing jobs** in the next five years (12,800 in vehicle manufacture and 18,700 in installation and maintenance).
- **Increase investment in onshore EV supply chain and manufacturing,** particularly in buses and rigid trucks. Gold Coast company BusTech boasts a 95% Australian supply chain and builds electric buses at factories in South Australia, Queensland and Tasmania. It is investing in a fourth plant in New South Wales in response to an increased state government uptake of electric buses.
- **Reduce Australia's reliance on imported fuel** (91% in 2021), creating energy sovereignty, minimising exposure to fuel price spikes, lowering the national fuel bill and reducing inflationary pressure that fuel costs have across the economy, from big business to householders and farmers.

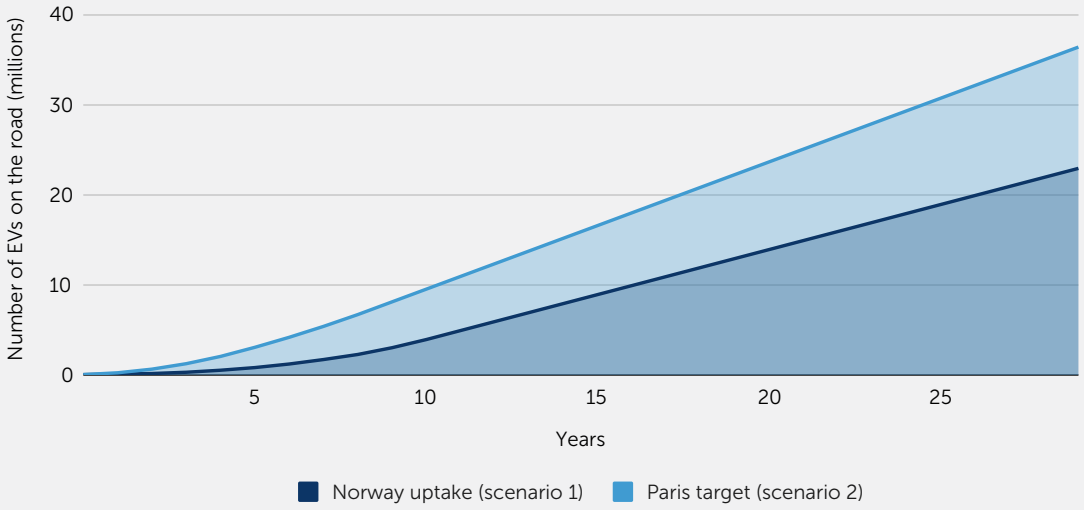
- **Create safer, more livable environments** especially around major transport routes. EVs produce far lower particulate matter and could significantly reduce the death toll associated with internal combustion engine vehicle pollution, currently over 1,750 deaths each year.[76] In addition, EVs, particularly trucks and vans, are quieter to run so their deployment reduces noise pollution.

Converting Australia's vehicle stock

Annual new car sales represent 5% of Australia's 20 million passenger car stock, so a switch to 100% electric vehicle (EV) sales today would take 20 years to electrify all the cars on the road. This will take even longer with the expected growth in total vehicle numbers.

What might this look like? Norway has one of the fastest uptakes of EVs around the world. If Australia follows Norway's sales trajectory, from a similar percentage of new EVs that were sold in Australia in 2021, it would take 27 years to replace our current 20 million internal combustion engine vehicles with 20 million EVs (see scenario 1 in figure 10). The Deploy plan (scenario 2) is a fast-track deployment model, which reaches 100% of new car sales as EVs by 2028 and keeps transport emission reductions in line with the Paris target.

Figure 10: On-road Electric Vehicles over 30 years, Norway rates compared to rates required by the Paris target



Internal combustion engines versus EVs

Electric vehicles currently have a higher upfront cost than internal combustion engine (ICE) vehicles, which can be a barrier to private ownership, even though over five years they have lower total cost of ownership, and even less in countries with subsidies.[77] EV prices are expected to be on parity with ICE vehicles somewhere between 2023 and 2025 due to increasing scale of economies matching ICE manufacturing.[78] They have lower servicing requirements and lower fuel costs, therefore cost less to run per kilometre, so people who drive EVs longer distances are likely to achieve cost equity more rapidly (e.g. taxis and couriers).

The monthly cost model operated by most fleet companies eliminates the upfront cost barrier for privately owned vehicles, and fleet operators benefit from the lower lifecycle cost of EVs.

Homes and businesses with rooftop solar can charge EVs at a low cost. Installation of two-way chargers enables EV batteries to be used as a home storage and power source, acting as a backup power supply for the home. This is a great benefit for people off grid or in areas with less stable supply or in bushfire/flood-prone areas. Tradies can also benefit from this feature, using e-Ute batteries as charging hubs for tools, removing the need for expensive temporary grid connections or generators. This will also cut the noise and emissions from petrol-powered generators.

Electric vehicles and charger technology

Electric vehicles

Electric vehicles (EVs) operate using one or more electric motors in place of a fossil fuel-dependent internal combustion engine. Electricity to run the motors may be obtained from external sources (e.g. trams), or can be powered directly from a battery. EVs include road and rail vehicles, surface and underwater vessels, electric aircraft and even electric spacecraft. Road EVs harness regenerative braking, where releasing the accelerator reverses the motor to act as a generator and charge the battery.

Australian-made electric trucks

SEA Electric, Dandenong, Victoria

SEA Electric launched its first proprietary electric power-system technology for urban delivery and distribution fleets in 2017, and has since released multiple medium and heavy-duty commercial EV platforms, with applications including delivery trucks, garbage trucks, tipper trucks, school and shuttle buses, plus cargo and passenger vans.

Founded in Australia in 2012, SEA Electric is now headquartered in Los Angeles serving markets in the US, Canada, Australia, New Zealand, Asia and the European Union, with numerous collaborations ongoing with leading OEMs and business fleets.

SEA Electric's Australian facility has commenced 100% Australian commercial production of electric trucks supported by a national SEA Electric dealer network.

SEA Electric assembly line in factory located in Dandenong (Melbourne, Australia). Image courtesy SEA Electric

Vehicle chargers

Chargers more efficiently connect electric vehicles to electrical sources. First generation chargers enabled an electric vehicle to draw electricity from the grid for storage as chemical energy in the vehicle's battery. New chargers enable bidirectional charging so that electric vehicles can provide electricity back to the grid when demand is high.

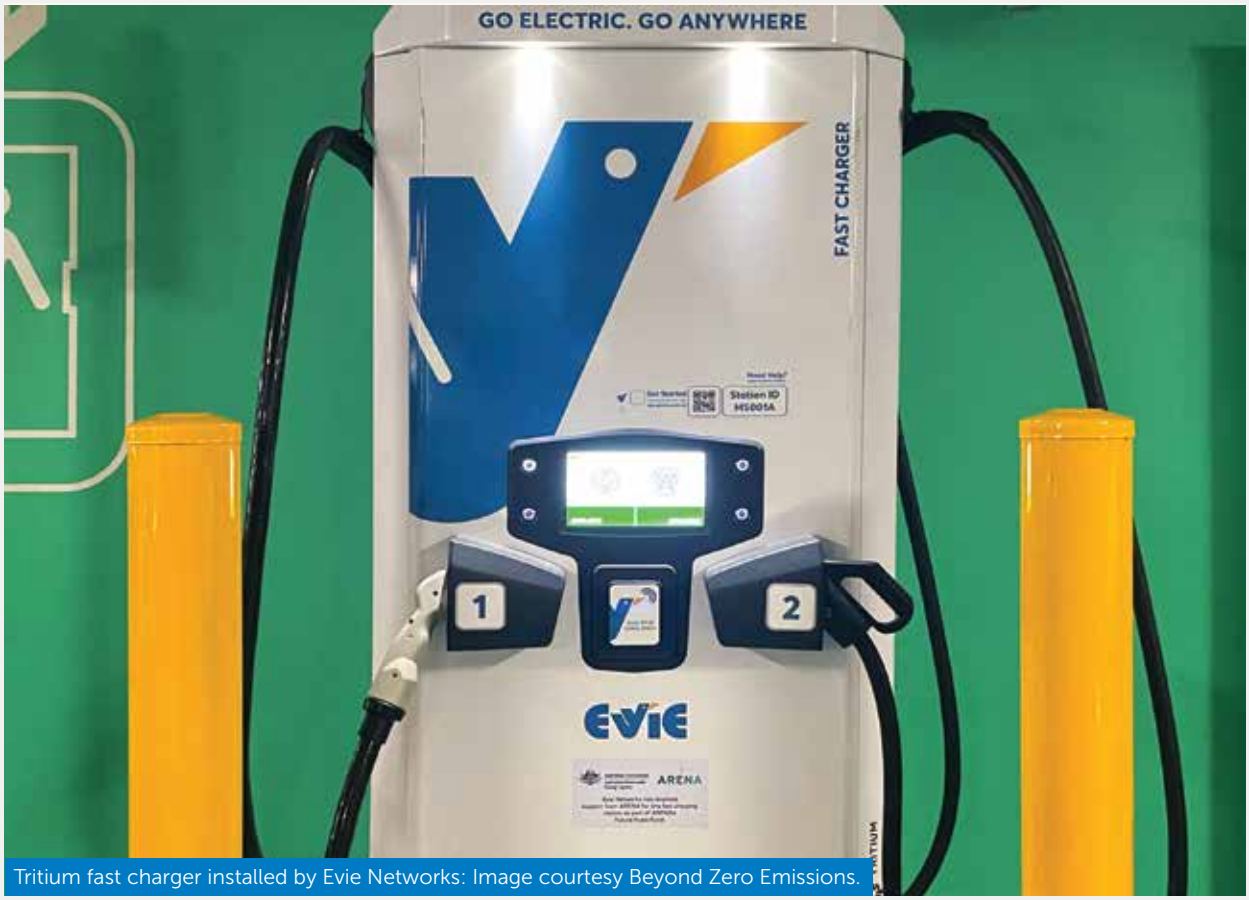
Ensuring many public chargers are available in places where people park during the day, such as supermarkets and carparks, will increase confidence that the growing national EV fleet can charge up on solar energy during the day. This will help balance supply and demand in the grid enabling more renewables at lower cost.

Brisbane start-up now world leading fast-charge company

Tritium Charging, Queensland

Tritium was founded by three engineering graduates in a shed in South Brisbane in 2001. The company designs and manufactures advanced direct current (DC) fast chargers for electric vehicles, and its chargers provide around 15,000 high-powered charging sessions per day. Over the years, the company has expanded and now employs more than 550 people around the world. In 2022, Tritium holds approximately 10% of the European charging market, 20% of the US, and more than 75% of Australia and New Zealand.

Tritium has recently moved some of its operations to the United States, where it's listed on the Nasdaq exchange.



Tritium fast charger installed by Evie Networks: Image courtesy Beyond Zero Emissions.

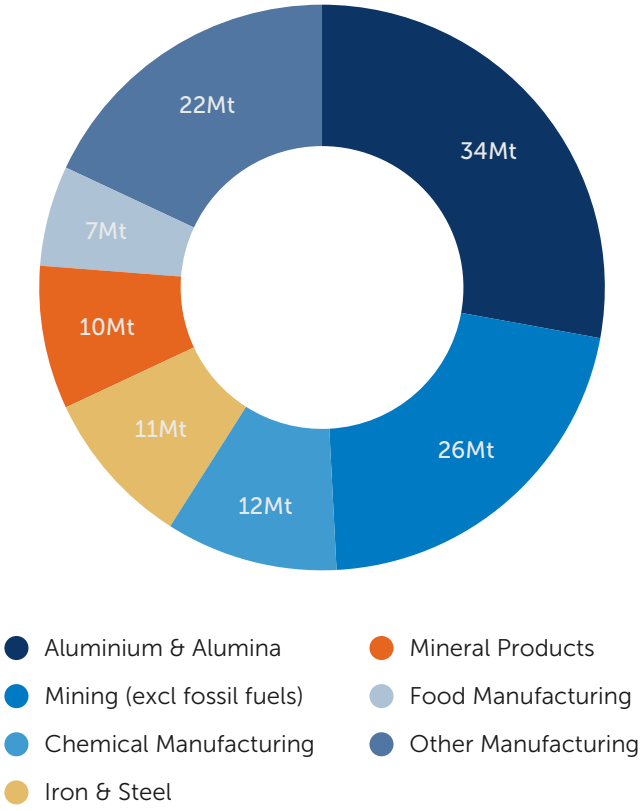
6. Industry

Industry upgrade opportunities

Technologies	Heat pump technology, electrolysers, electric (mining) vehicles
Target units (over 5 years)	7,000
Total jobs ongoing (over 5 years)	8,500
Annual industry emissions reduction from 2019 baseline (154.9 MtCO2-e, not including fossil fuel extraction) at 5 years	-48% (-74.51 MtCO2-e)

The industry sector produces the greatest proportion of Australia's emissions (46%), which have traditionally been considered difficult to abate due to the complexity and diversity of activities that fall into the category. However, advances in clean technology mean that industry emissions, largely focused around factories and processing plants, can be reduced by 48% in five years through the rapid deployment of proven clean technologies.[79] [80]

Figure 11: Industry greenhouse emissions by sector. Australia's four aluminium smelters and six alumina refineries generate one third of industry emissions.[81] [82] [83]



Deployment

The huge opportunity for rapid uptake of renewable electricity by industry is outlined above, cutting 41% of its emissions, supported by the deployment of solar, wind and energy storage. In parallel, to achieve even more rapid emissions reduction we need to electrify industrial processes:

- **Deploy 1,500 industrial heat pumps (100 kW equivalent)** to replace coal and gas boilers in industries such as food processing and paper/wood processing (additional applications are explored in our Electrifying Industry report[84]). Replacing end-of-life fossil fuel based assets with upgraded electrified alternatives is a simple initial step to take.
- **Introduce 3,000 electrolysers to industrial centres (~3 GW).** These will produce more than 300,000 tonnes of renewable hydrogen and replace expensive, fossil-gas feedstocks, provide high temperature heating for processes that cannot be electrified and help enable green steel production.[85] It is critical that the water used for the electrolysis process is sourced and managed sustainably, in line with best environmental practices and thorough consultation to maintain social licence.
- **Electrify mining by replacing 2,500 mining trucks with renewable alternatives** and shift towards zero-emissions mining equipment (for minerals/ores), reducing our reliance on imported diesel and forming the foundations of a green supply chain from mine to market.[86]

The deployment numbers in this section – 7,000 – may appear small but they pack a punch in emissions impact. For example, the installation of one industrial heat pump can be the equivalent of at least 20 typical household heat pump units, while the replacement of a mining truck can be the equivalent of replacing 460 passenger vehicles.

Policies that support capital upgrades for factories and processing plants will help accelerate the uptake of these key technologies and should be considered as a matter of urgency. These could be in the form of an industry decarbonisation fund that provides grants, low-interest loans, underwriting and other types of financial support. The use of local, low-emission procurement targets can also support investment by guaranteeing offtake of new industry products, such as green steel and zero-carbon cement in public infrastructure projects. Coordination of industry regions and supply chains through Renewable Energy Industrial Precincts can also assist with zero-emissions technology deployment, utilising the industrial ecosystem to leverage synergies and accelerate learnings.[87] [88]

Benefits

Deploying at scale to cut emissions in industry by 48% in five years will:

- **Create 8,500 jobs over five years** by manufacturing and maintaining heat pumps, electrolysers and mining trucks for the domestic market. Additional jobs will be created as manufacturing expands to meet export demand.
- **Ensure the ongoing competitiveness of Australia's mining and manufacturing sectors by:**
  - » Reducing fuel and energy costs for energy-intensive industrial processes, with less exposure to unstable prices as industry moves to 100% renewable power generation.
  - » Reducing maintenance costs
- **Revitalise manufacturing.** Producing green hydrogen onshore presents an opportunity to manufacture large-scale electrolysers onshore for domestic and export markets.
- **Help stimulate a green export industry worth $333 billion.** Transform our export supply chains to be zero emissions from mine to market, and tap into the growing global demand for green steel, green aluminium, renewable hydrogen and sustainably mined and processed zero-emissions critical minerals.[89]

Technology to deploy in industry

Industrial heat pumps

Industrial heat pumps operate in the same way as household heat pumps, but are much larger and often with higher operating temperatures to cater for industrial needs. They are at least four times as efficient as fossil fuel equivalents.[90]

Industrial heat pumps are already in use in the food manufacturing sector, offering an alternative to gas use for Australia's 4,000 food manufacturers.[91] Companies such as 3 Ravens Brewing and Hardwick Meatworks are in the process of deploying this technology to reduce the use of gas boilers, with Hardwick estimating this to reduce gas usage by 75 per cent and cut energy costs.[92]

Electrolysers

Electrolysers use electricity to split water into hydrogen and oxygen via an energy intensive process called electrolysis.[93] When an electrolyser is powered with 100% renewable energy, it produces 'green' hydrogen gas, which will be an important source of clean fuel for industry and long distance transportation in the future. Electrolyser technology is advancing rapidly, meaning bigger and more efficient electrolysers are being developed to meet large forecast demand for green hydrogen globally.

It is important to note that renewable hydrogen is a valuable resource that should only be used for a process that has no other viable alternative, such as a chemical feedstock or for green steel. Where possible, electrification is a much more energy-efficient process.

Table 5: Beyond Zero Emissions' view of different hydrogen use cases[94]

Use of renewable hydrogen	Beyond Zero Emissions view
Electricity generation	✓
Hydrogen export	✓
Industrial feedstock	✓
Industrial heat processes*	✓
Gas network	✗
Building heating	✗
Cars & buses	✗
Large trucks, ships, trains*	✓

*Only if electricity and other renewable methods are not an option.

In addition to the headline technologies outlined in this report, we have considered electric mining equipment, in particular electric mining vehicles in this section. Deploying zero-emissions technology into mine sites is the mission of the Electric Mine Consortium, which includes Australia-based companies such as 3ME, Zenith Energy and VivoPower. These organisations are working to decarbonise mining operations, while the Charge On initiative, established by the largest global miners including BHP, Rio Tinto and Vale, is leading the electrification of mining vehicles. The Charge On Innovation Challenge recently named Australian companies Tritium and AmpControl as technology winners.

Meeting the industrial challenge

Fortescue Future Industries, Gladstone, Central Queensland

Fortescue Future Industries (FFI) develop and patent new electrolyser technology with a focus on green hydrogen for hard-to-decarbonise industry sectors. In 2022, FFI signed a memorandum of understanding with Airbus to study regulation, infrastructure and supply chains needed to deploy green hydrogen as a zero-emissions jet fuel.

A division of Fortescue Metals Group, FFI currently employs more than 50 staff based across Gladstone and Perth. The company aims to produce 1 GW of electrolysers per year in Gladstone once fully operational.

Gladstone, Central Queensland

7. Next steps

This report shows that we have the technology to decarbonise the economy.

The heavy lifting can be done by just six existing, mature and available technologies deployed to our buildings, across our industries and roads, supported by a massive build-out of new renewable energy in an upgraded energy network.

We need investment and coordination, skilled people and reliable supply chains to deliver materials. Deploying the technology described in this report can decarbonise and grow Australia's economy, and set us on a path to meet our Paris climate target. Each sector needs ambitious, individualised plans to ensure they cut their emission contribution as rapidly and deeply as possible, finding ways to remove inertia and allow the momentum to build. However, these plans must also integrate to sequence new and existing large-scale projects in electrification, energy savings and renewable energy deployment to achieve a cumulative, coordinated impact.

Land based carbon sequestration will enable Australia to go beyond zero emissions and is a key comparative advantage with additional benefits for agriculture resilience and biodiversity restoration and rural livelihoods. By planning a coordinated effort across sectors we can rapidly reduce and remove emissions to reach and go beyond zero emissions.

Image courtesy Janus Electric

Appendix

Technology units and key assumptions

Sector	Technology	Unit assumption notes
Buildings (households)	Heat pumps - split-systems	Assumes 2.5 reverse cycle air conditioners per household.
	Heat pumps - hot water	1 gas unit for 1 heat pump. Upgrade 100% of homes on gas hot water.
	Insulation	Assumes one unit is equal to an insulated household
Buildings (commercial)	Heat pumps - hot water	Assumes two 315L systems per office upgrade (in half of stock), and four per shopping centre (in half of stock).
Electric transport	Electric passenger cars	Assumes electrification of passenger vehicles
	Electric buses	Assumes electrification of all sizes of buses from 16 to 64 seaters.
	Electric light commercial vehicles	Assumes electrification of light commercials vehicles and includes utilities, vans, and cab-chassis
	Electric trucks	Assumes electrification of both articulated trucks and rigid trucks
	Farm machines	Assumes electrification of machines with under 60kW in power
	Public charging units	Assumes ratio of one charger per ten electric vehicles
	Residential chargers	Assumes 0.8 home chargers per home with an electric vehicle
Industry	Electrolysers	Assumes a 1MW average electrolyser size.
	Heat pumps (100 kW equivalent)	Assumes industrial heat pump with COP 4 and average size of 100kW. For industries that cannot deploy heat pumps, technologies such as improved energy efficiency, electrification, waste heat utilisation are deployed
	Mining truck	Assumes a 1,000 kW mining vehicle
Renewable energy / Electricity	Wind turbines	Assumes 5.5MW wind turbine units
	Utility-scale PV	Assumes 600W solar panels for utility deployment.
	Residential PV	Assumes 400W solar panels for residential deployment.
	Commercial PV	Assumes 500W solar panels for commercial deployment.
	Utility batteries	Assumes each unit is a Tesla 1.5MW/3MWh mega pack.
	Building batteries	Assumes 7kW/13.5kWh Tesla Powerwall 3.

Methodology

We examined the level of emissions reduction that could be reached with ambitious deployment of key technologies in four sectors of the economy: buildings, transport, industry and land use – also including the energy sector itself. We included technologies that we considered mature, commercially available and deployable at scale within the next five years.

Baseline Emissions:

- We focused on buildings, transport, industry and land use using 2019 as a baseline. This used data shared by Climateworks which combines scope 1 and 2 emissions to include energy emissions at point of use. We appreciate Climateworks sharing the data behind Decarbonisation Futures.[95]
- Top line figures were later compared to a 2005 baseline. This was calculated using data from the National Inventory by Economic Sector.[96] We excluded emissions from fossil fuel extraction (coal mining and oil and gas extraction) as well as those from carbon drawdown (forestry - changes in inventory) where applicable to compare like-for-like in calculations.

Sector emissions: Each sector was examined independently asking how fast we need to push technology deployment over the next five years to stay in line with a maximum 1.5 degrees of warming.

- **Electricity:** used the AEMO Strong Electrification Sensitivity scenario of the 2022 ISP[97] to estimate capacity and generation of wind, solar and battery technologies from 2023 to the end of 2030. We took average unit sizes (outlined in the key assumptions table) and multiplied them by the capacity estimated.
  - All sector calculations worked from the Strong Electrification Sensitivity scenario which suggests the grid could be 84% renewable in 5 years, coupled with 100% renewable by 2030. (The AEMO scenario suggest 94-96% renewable by 2030, however we propose that any remaining fossil fuel generation be replaced using sustainably sourced biomethane or renewable hydrogen.)
- **Buildings:**
  - Households - backcast from five and 10 years on 2019 baseline emissions, assuming no technological barriers to decarbonisation.
  - Commercial - backcast from five and 10 years on 2019 baseline emissions, assuming that 50% of gas heating and gas boilers are electrified.
- **Transport:** Vehicle calculations were made by using an increasing percentage of new vehicle sales being electric, aiming for 100% in five years and then scrapping and replacing more vehicles in the following four years. It is assumed that emissions at year five are relatively low - 90% (drawing from an 84% renewable grid as modelled in electricity, and factoring in daytime EV charging via household or commercial solar), and emissions are zero by 2030, drawing from a 100% renewable grid
- **Industry:** calculated according to each technology (emissions from fossil fuel extraction were not included in our analysis):
  - **industrial heat pumps -** we replaced all end-of-life gas boilers in the Food, Beverages and Textiles and Pulp Paper and Print Industries with renewable powered heat pumps, using an average asset life of 30 years and correlating to gas usage from these sectors from the ABS Energy Accounts to determine GJ equivalents. Final conversion to heat pump numbers assume a coefficient of performance of 4 and an average heat pump power rating of 100 kW.
  - **electrolysers -** were estimated through a combination of users - 15% hydrogen substitution into the chemicals industry to displace natural gas as a feedstock, 10% hydrogen substitution into alumina refining to displace gas for heating and hydrogen for green steel applications; specifically a hydrogen/gas mix DRI plant in Whyalla and direct hydrogen injection into the blast furnace at Port Kembla.

- **mining vehicles -** were used as a proxy for the broader electrification of mining sites as they make up the majority of energy use at mine sites. Assuming an average truck asset life of 10 years and average diesel consumption of a 1,000 kW truck with a load factor of 35% operating 5,000 hours a year, we combined this with data from the ABS Energy Accounts.

- **Drawdown:** We forward estimated Australia's emissions sequestration at five and 10 years, focusing on three mechanisms:
  - maintaining existing carbon stocks and sequestration rates reported in National Inventory Record 2019
  - additional sequestration rates enhanced by regeneration/revegetation across farmland without impacting farming productivity – sequestration rates assumed at ~2.5tCO2/ha/yr
  - biochar via mobile pyrolysis machines with sequestration rates for biochar assumed at ~10tCO2/ha/yr.

Job calculations: Using an internal jobs ratio database, the number of units of technology that we identified for deployment were multiplied by the ratio to give us an average FTE per year. These ratios draw on job projections from real world project proposals and have been supplemented by independent research reports, government figures and interviews with business stakeholders.

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