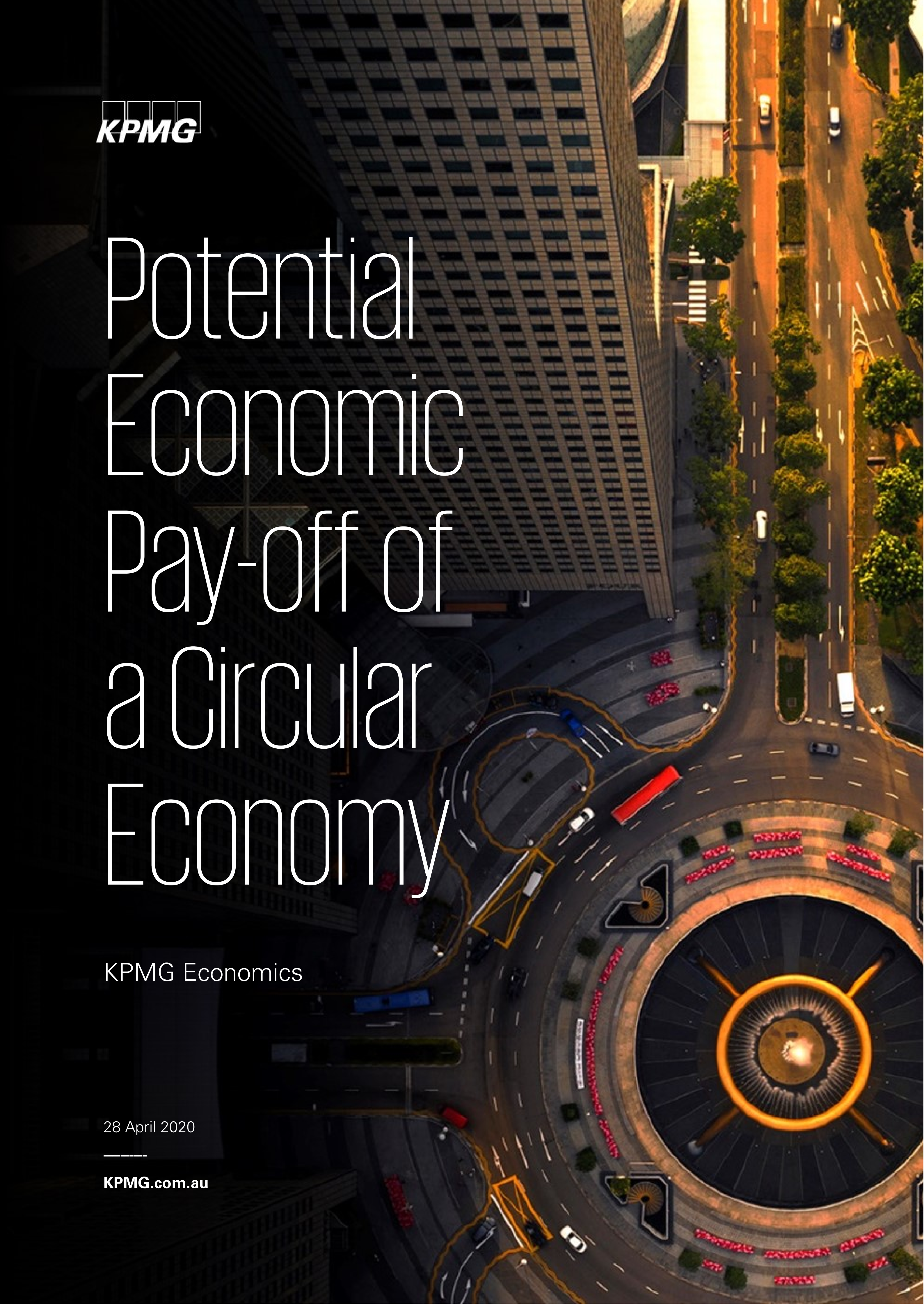

KPMG

Potential Economic Pay-off of a Circular Economy

KPMG Economics

28 April 2020

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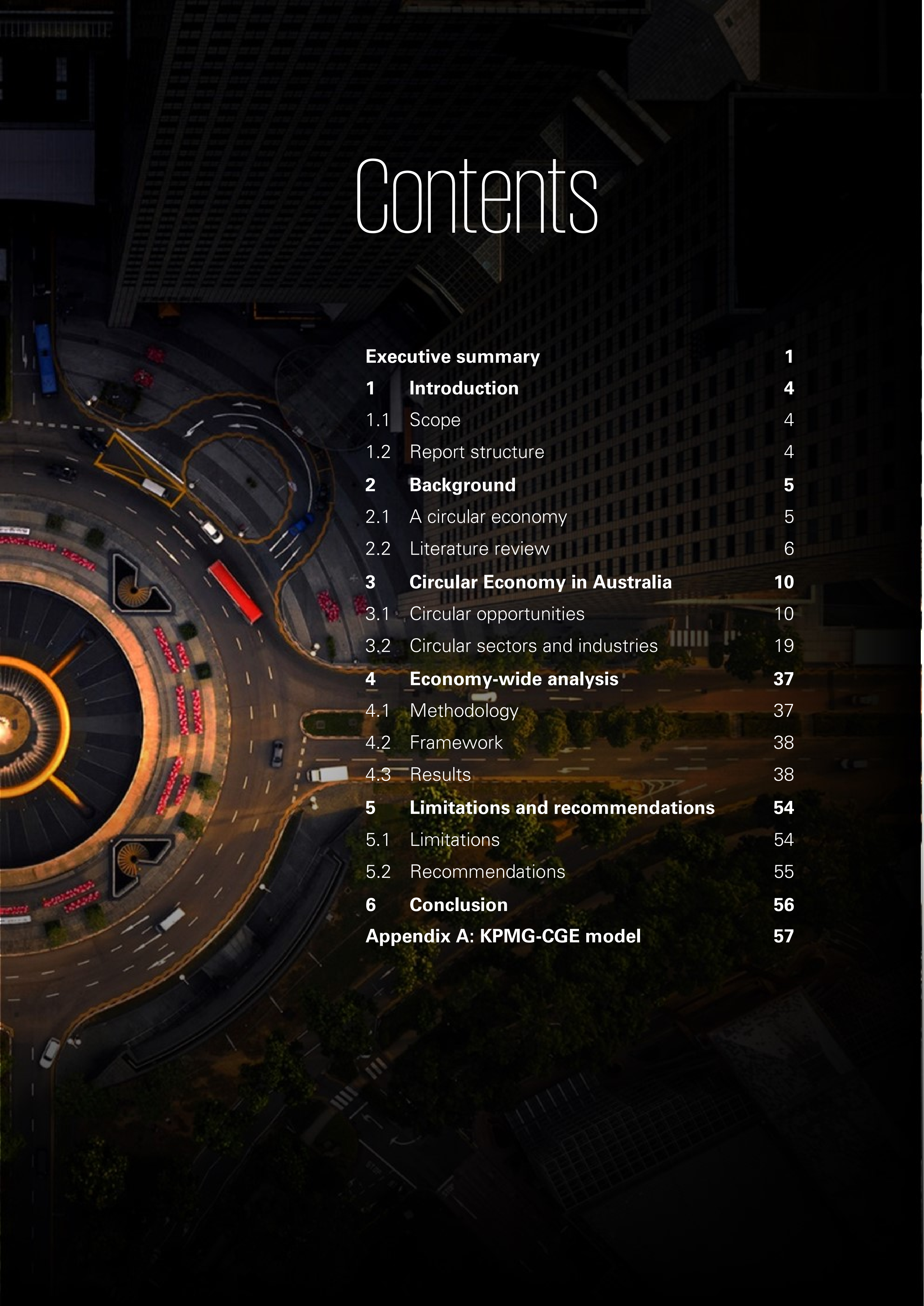

Contents

Executive summary

This report investigates the potential benefits of a circular economy in Australia embodied by eight different circular economy opportunities. It has been commissioned by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to develop a case for increased circularity in the Australian economy in line with initiatives taken in many countries across the world.

In 2014 the World Economic Forum (WEF) estimated that the global material cost savings of adopting a more restorative economy could be over US$1 trillion per year by 2025.[1] Eliminating waste from the industrial chain by reusing materials promises production cost savings and less resource dependence. Circularity in manufacturing and fast-moving consumer goods are anticipated to yield the greatest degree of savings. Based on these findings, the Institute for Sustainable Futures (ISF) at the University of Technology, Sydney estimated the size of the circular economy in Australia. Using Australia's relative share of global GDP as a proxy for opportunity in Australia, material costs savings due to a circular economy is estimated at AU$26 billion by 2025.[2] Nevertheless, the inherent simplicity of this calculation does not bear any relationship to the real country-specific opportunities that exist for Australia.

A transition to circular economy represents an ambitious movement - in all industries and across all aspects of the economy - towards a low-waste, high-resource-efficiency future. While a core motivation of a circular economy is to minimise environmental impacts such as reducing greenhouse gas (GHG) emissions or primary resource use, our study mainly articulates the case for such a transition from an economic value perspective. Circular activities and processes not only extend the usable life of products but also extend their value, create new jobs and raise economic growth. Our study measures the potential economic benefit of a circular economy to Australia in terms of GDP and employment.

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[1] WEF, 2014. Towards the Circular Economy: Accelerating the scale-up across global supply chains.

[2] Florin N., Dominish, E., and Giurco, D., 2015. Action Agenda for resource productivity and innovation: opportunities for Australia in the circular economy.

This report investigates the potential economic effects of circular opportunities in three key sectors of interest, namely Food, Transport and the Built Environment. The scope of this study extends beyond the estimate produced by the ISF, which fails to consider impacts outside material cost savings; for example, creating biogas from organic waste. As such, this report uses country-specific circular opportunities to estimate economy-wide impacts for Australia. As a first attempt at estimating the potential economy-wide pay-off of transitioning to a more circular economy in Australia, this study is intended to lay the basis for more detailed future analysis.

Without assigning any value to the accompanying environmental or social impacts, our report suggests that a future circular economy in Food, Transport and the Built Environment together represents a potential economic benefit of $23 billion in GDP in present values by 2025.[3] Note that our estimated economic benefit of a circular economy cannot be directly compared to the ISF's estimate of $26 billion due to differences in circular opportunities analysed and methodology. By 2047-48, we estimate that the benefit of a circular economy will likely rise to a present value of $210 billion in GDP and an additional 17,000 full-time equivalent (FTE) jobs for Australia. These effects are relative to a business-as-usual scenario, representing the current level of circularity in the Australian economy. The more specific approach applied here involves identifying potential opportunities across the key sectors based on Australia's current business and economic environment. The economy-wide impacts of each circular opportunity is estimated in 2047-48, taking into account investment needs, costs and benefits. Figure 1 summarises the selected circular opportunities and their potential GDP and employment impacts.

Figure 1: Economy-wide impacts for Australia of select circular opportunities

Opportunity	Description	Real GDP (2047-48, present value $million)	Employment (2047-48, FTE)
Food			
Nutrient recovery and recycling	Converting nutrients in organic waste into fertiliser	1,597	233
Biogas from organic waste	Converting organic waste to renewable energy	8,834	823
Water use efficiency	Improving the efficiency of water use	29,899	4,510
Food waste	Reducing waste in the consumption of food	37,141	-2,936
Transport			
Electrification of transport	Transitioning towards electric vehicles	-1,510	40
Car sharing	Transitioning towards car pooling to work	5,083	3,001
Built Environment			
Compact dwellings	Optimising space in construction of new dwellings	32,302	34,942
Energy efficient buildings	Lowering energy consumption in buildings	96,806	-23,276

Source: KPMG analysis

[3] This is the average of our 2024-25 and 2025-26 estimates.

The potential value of each circular opportunity to the Australian economy is briefly explained below:

- A major part of agricultural activity in Australia presents the opportunity to recover nutrients from waste and use them to make fertilisers. The economic effects follow from treating a certain share of pig manure generated in Australia to produce fertilisers for agricultural use, which can result in potential cost savings of purchasing fertiliser as well as disposing manure.
- A similar opportunity exists in converting agricultural organic waste to biogas, which can then be processed to generate electricity. The biogas-generated electricity has a lower per unit cost as compared to the retail price thus resulting in millions of dollars saved by the agricultural sector.
- Water being a depleting resource, reducing the amount of water leakage and implementing water recycling processes is a necessary step towards achieving a circular economy. The resulting amount of water saved valued at its long-run unit price results in substantial savings.
- The growing amount of food waste is another global concern the reduction of which requires a concerted effort at an individual level. Cutting down food waste as a proportion of the total household food consumption directly translates into reduced household expenditure.
- Electric vehicles have had a slow start in the Australian vehicles market due to a higher upfront purchasing cost and perceptions around convenience. A scenario analysis of increased switching from fuel-based to electric-powered vehicles reveals the potential long-term ongoing saving in costs of fuel compared to electricity and lower maintenance costs of electric vehicles.
- With an increase in road traffic and associated economic losses in terms of lost productivity hours, car sharing presents the circular opportunity of increasing utility of each existing car. In a scenario where three individuals travel to and from work in one car during the work week directly results in lower costs of fuel, parking and car maintenance per individual.
- The current mismatch between household size and house size, resulting in excess capacity, presents the opportunity to optimise space utilisation. In particular, reducing the average dwelling size in construction of new housing stock results in potential savings due to lesser use of capital resources and reduced household expenditure on utilities associated with a smaller living space.
- Constructing energy efficient buildings is gaining momentum in urban areas. This has the potential to generate long-term savings in terms of reduced expenditure on electricity, gas, water and waste services.

We find that opportunities such as energy efficiency in dwellings and food waste reductions represent the greatest impacts in dollar terms, in part, due to the importance of these sectors in the Australian economy. The former, for example, is estimated to increase the output of the dwellings sector by 3.2% by 2047-48, with significant flow-on impacts across the construction, manufacturing and service sectors.

This report likely presents a conservative estimate of the impacts of a move towards a circular economy. Although we have considered a broad range of sectors and industries that encompass the key areas of economic activity in Australia, our list is by no means exhaustive and only identifies areas where the circular opportunities are most viable.

The estimates produced provide an understanding of the potential magnitude of positive impacts that could result from the adoption of the circular opportunities. This report highlights a substantial pay-off under a circular economy that is above and beyond its environmental benefits, reinforcing findings for other countries and jurisdictions.

1 Introduction

1.1 Scope

KPMG was engaged by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to estimate the potential economic benefits of a transition to circular economy in Australia.

To achieve this, KPMG's research and analysis has included extensive desktop research, analysis of publically available data, and economy-wide analysis of different transition scenarios of potentially viable circular technologies in Australia.

Specifically, the scope of this report covers:

- A brief literature review of circular economy estimation methods, investment needs and potential economic benefits of transitioning to a circular economy in Australia;
- Economic and environmental impact profiles of agreed upon sectors and industries;
- Estimates of the investment needs and potential gains of implementing circular economy practices in the selected sectors;
- Economy-wide analysis under different transition rates to circular economy;
- Limitations of the research study; and
- Lessons learned, if any, and recommendations for future economic estimation studies.

1.2 Report structure

The remainder of this report is structured as follows:

- Section 2 provides a brief background on the concept of a circular economy and summarises the key findings from the literature review including circular processes. This section also identifies research methods employed in previous studies to estimate the economic impacts of a circular economy.
- Section 3 discusses potential circular opportunities for Australia and presents a profile of key relevant sectors and industries.
- Section 4 presents modelling results of the overall effects of selected circular economy practices on the Australian economy.
- Section 5 outlines the limitations of this study and recommendations for further study.
- Appendix A provides an overview of the KPMG–CGE model used to estimate the overall economic contribution of a transition to circular economy in Australia.

2 Background

2.1 A circular economy

The concept of a circular economy is grounded in the ideas of sustainability and resource efficiency, and seeks to keep products, commodities and resources "in the loop" for as long as possible. Keeping them "in the loop" means to maximise their utilisation and to extend the lifespan of what we use in order to increase resource productivity and reduce waste. To achieve this, processes, activities and technologies need to be developed and designed with reusing and recycling in mind. Throughout this report, the processes, activities, and technologies that support a transition towards a circular economy will be collectively referred to as circular opportunities.

Identifying areas where circular opportunities potentially exist is an important part of analysing the economic pay-offs of transitioning to a circular economy. One commonly adopted approach is the ReSOLVE framework developed by the Ellen Macarthur Foundation (EMF), which identifies different categories of circular opportunities that can be leveraged.[4] This is shown in Figure 2 below.

Figure 2: ReSOLVE framework

Action area	Relevance to this report
Regenerate	Transition towards renewable sources of energy and materials
Share	Reduce resource dependency by sharing
Optimise	Increase the utility of resources by improving efficiency and reducing waste
Loop	Maintain and extend resource loops by recycling and extracting value from waste
Virtualise	Disentangle resource use from actual use
Exchange	Replace existing materials, processes and technologies with circular ones

Source: Adapted from EMF, 2015. Growth within: a circular economy vision for a competitive Europe.

It is possible to analyse the benefits from transitioning to a circular economy in terms of circular opportunities that may exist or be created at the production, utilisation or disposal stage, as discussed below.[5]

- **Production stage:** Circular economy opportunities at this stage imply lower usage of primary resources, including a reduction in the use of non-renewable energy in production. These opportunities most closely relate to resource efficiency concepts, and generally aim at producing more with less. This includes opportunities such as those involving the substitution of production inputs with recycled material.

[4] EMF, 2015. Growth within: a circular economy vision for a competitive Europe.
[5] Rizos, V., Tuokko, K., and Behrens, A., 2017. The Circular Economy: A review of definitions, processes and impacts. CEPS Research Report No 2017/8, April 2017.

- **Utilisation stage:** Circular opportunities at this stage include new methods or approaches that represent a more judicious use of available products and services. This could include leveraging existing opportunities at an individual level, such as using water or energy efficiency appliances, or larger scale opportunities such as transitioning towards a sharing economy or greater virtualisation in the workplace.
- **Disposal stage:** Circular opportunities here relate to how products are viewed and treated at the end of their lifecycle. An important part of the shift towards a circular economy is to increasingly treat products at this stage as an opportunity for creating value, instead of as a waste management issue. This includes generating value from waste streams, such as fertiliser from manure or electricity from biomass.

Ultimately, a circular economy represents a shift away from the 'linear economy', where goods are produced, consumed and then disposed of.[6] Moving away from the current status quo requires a clear understanding of the impacts of employing circular practices. This will need to consider not only the direct benefits and costs of circular opportunities but also the indirect or flow-on effects on the broader economy.

2.2 Literature review

This section provides an overview of the research methods employed as well as key findings from existing literature on the economic impacts of transitioning to a circular economy. While still at a nascent stage in Australia, the concept of circular economy is widely recognised and adopted across Europe, which is the source of most research papers and studies on this subject.

2.2.1 Modelling methods

Estimating the economic impacts of transitioning to a circular economy is a complex exercise. Within the literature estimation methods can range from relatively simple scaling up techniques to more complicated general equilibrium models. The following discussion examines broadly-used modelling techniques for such estimations.

Input-output models

Input-output (IO) models, and its variations, are a major workhorse in economic impact assessments and have been represented early on in studies on the circular economy.[7] Drawing on IO tables, such as those published by the Australian Bureau of Statistics (ABS),[8] IO models account for detailed intersectoral linkages within the economy. Thus, they are often used to estimate inter-industry responses to a level of activity based on the current structure of the economy.

In the literature, one extension of IO models are Environmentally Extended Input-Output (EEIO) models. A relatively recent application of this model is seen in the study *The potential benefits of a circular economy in South Australia*,[9] which is also the first economic impact assessment of a more circular economy in an Australian jurisdiction. An advantage of EEIO models over traditional IO models is the ability to account for environmental impacts. Since circular economy transitions are generally motivated by concerns such as carbon and other greenhouse gas (GHG) emissions, EEIO models can yield useful insights on the potentially positive environmental impacts associated with a circular economy.

[6] WRAP, 2015. Economic growth potential of more circular economies.
[7] Wijkman, A. and Skånberg, K., 2015. The circular economy and benefits for society. Club of Rome.
[8] ABS, 2018. 5209.0.55.001 - Australian National Accounts: Input-Out Tables, 2015, 2016.
[9] Lifecycles et al., 2018. The potential benefits of a circular economy in South Australia, Methods Report.

However, IO models have several limitations. The ABS summarises these limitations as follows:[10]

- **Lack of supply–side constraints**: it is assumed that extra output can be produced in one area without taking resources away from other activities, thus overstating economic effects.
- **Fixed prices**: Prices are assumed to be unaffected by policy and any crowding out effects are not captured.
- **Fixed ratios for intermediate inputs and production**: it is assumed that there is a fixed input structure in each industry and fixed ratios for production.
- **No allowance for purchasers' marginal responses to change**: it is assumed that households consume goods and services in exact proportions to their initial budget shares. This equally applies to industrial consumption of intermediate inputs and factors of production.
- **Absence of budget constraints**: it is assumed that household and government consumption is not subject to budget constraints.

Computable general equilibrium models

Computable general equilibrium (CGE) models, like IO models, use IO tables as a key data input, but they go one step further by making more sophisticated assumptions regarding economic behaviour. In particular, CGE models have additional features that make them better suited for economic impact assessments, including:

- price and wage adjustments driven by resource constraints;
- price, tax and government spending adjustments driven by budget constraints;
- input substitution possibilities in production (e.g., allowing the combination of labour, capital, and other inputs required to produce a particular output to vary in response to relative price changes); and
- economic impacts driven by the responses of consumers, investors, foreigners and other agents to changes in prices, taxes, technical change and taste changes.

By introducing these additional assumptions, CGE models allow us to analyse more than just the first round impact of an event or policy. In particular, this added sophistication means that a CGE model allows for feedback responses by producers, consumers and foreign economic agents. Taking into account these flow on effects means that the results are less likely to be overstated, particularly in the medium to long run.

Other modelling methodologies

Besides simple scaling techniques,[11] other methods including econometric models such as the E3ME model by Cambridge Econometrics have also been occasionally used in the literature.[12] Although it has been pointed out that econometric models are usually used in short- to medium-term analyses,[13] the authors suggest that this model is suitable for long-term forecasts and holds an advantage by allowing for non-optimal economic behaviour.

[10] Australian Bureau of Statistics (2016), Australian National Accounts: Input-Output Tables, 2012-13, cat. no. 5209.0.55.001, 'Input output multipliers', Canberra.
[11] See Bastein, A.G.T.M., Roelofs, E., Rietveld, E. and Hoogendoorn, A., 2013. Opportunities for a Circular Economy in the Netherlands (pp. 1-13). Delft: TNO.
[12] Cambridge Econometrics, Trinomics, and ICF, 2018. Impacts of circular economy policies on the labour market.
[13] Woltjer, G., 2018. Methodologies for measuring the macroeconomic and societal impacts of the circular economy.

In conclusion, a wide-ranging review of the literature suggests that there has been extensive use of CGE models and it is recognised as a state-of-the-art method for estimating impacts of circular economy transitions.[14] Investigating a more circular Australian economy warrants the use of a similar tool, thus one of KPMG's proprietary CGE models (KPMG-CGE) has been used in this report to assess the potential economic pay-offs of various circular economy scenarios in Australia.

2.2.2 Impacts of a circular economy

In this section, we focus on articulating the economic impacts of a circular economy, as presented in the literature, specifically in terms of GDP and employment. Even though ideas of a circular economy were motivated primarily by environmental concerns, positive *economic* impacts in terms of higher productivity, income or additional jobs are undoubtedly crucial for the uptake of circular opportunities by business and government.

The literature on investigating circular practices is relatively well-developed for European economies. Studies and reports conducted by the Waste and Resources Action Programme (WRAP), the Club of Rome (COR) and the Ellen MacArthur Foundation (EMF) have broadly identified substantial positive impacts from transitioning towards a circular economy.

For example, WRAP estimates 1.2 million jobs could be created across Europe by 2030, simply by continuing on the current pathway towards a circular economy.[15] COR found similar positive economic impacts ranging from 75,000 additional jobs for Sweden to half a million in France by 2030, under an optimistic scenario combining energy and material efficiency with renewable energy use.[16] The 2015 EMF report, *Growth Within,* focused on circular economy impacts in terms of increased GDP. It was found that by 2030, adopting circular technologies would generate an annual benefit of €0.6 trillion due to resource productivity, rising to €1.8 trillion when taking non-resource and externality benefits into consideration.[17]

Economic impact assessments by the EMF were also conducted for China and India. For China, the authors found that adopting ambitious circular economy principles could result in a ¥70 trillion saving by 2040, or 16% of China's projected GDP.[18] In India, the savings from circular economy were estimated at an annual benefit of US$ 624 billion in 2050 for the current development path.[19]

The findings from similar studies suggest that Australia can also reap the benefits of a transition towards a circular economy. Using Australia's share of global GDP and WEF estimates[20] of global circular economy material cost-savings, the Institute for Sustainable Futures at the University of Technology, Sydney provides an indicative estimate of Australia's potential benefit at $26 billion annually by 2025.[21]

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[14] See various EMF reports, Bohringer and Rutherford (2015), Tuladhar, Yuan and Montgomery (2016), and Ekin and Hughes (2018).

[15] WRAP, 2015. Economic growth potential of more circular economies.

[16] COR, 2015. The circular economy and benefits for society.

[17] EMF, 2015. Growth within: a circular economy vision for a competitive Europe.

[18] EMF, 2018. The circular economy opportunity for urban & industrial innovation in China.

[19] EMF, 2016. Circular economy in India: rethinking growth for long-term prosperity.

[20] WEF, 2014. Towards the Circular Economy: Accelerating the scale-up across global supply chains.

[21] Florin N., Dominish, E., and Giurco, D., 2015. Action Agenda for resource productivity and innovation: opportunities for Australia in the circular economy.

Within Australia, the report *The potential benefits of a circular economy in South Australia*[22] estimated 25,700 additional jobs by 2030 due to a more circular economy against a business-as-usual scenario.[23] Significant reductions in GHG emissions and energy use were also predicted, at around 27% and 20%. Economic impacts in terms of GDP were not provided. Circular economy initiatives and strategies have also been gaining momentum recently in other states and territories, including New South Wales[24] and Victoria.[25]

At the time of writing, the aforementioned South Australian report is the only study that quantifies the economic impact of a circular economy for an Australian jurisdiction. This report uses an environmentally extended input-output (EEIO) model, and specifically focused on the impact of a circular economy on jobs, GHG emissions and energy efficiency. In this report, it is also assumed that dollar savings due to greater circularity in the economy such as from lower energy use, higher material efficiency or a change in energy use, will go towards the implementation of the technology change. Thus, a transition towards a circular economy in their analysis will have a cost-benefit ratio of one. On the other hand, our analysis does not make any explicit assumptions on the ratio of costs to benefits.

Hence, this report provides an important contribution to the growing body of literature as the first economy-wide analysis of a transition to a more circular economy in Australia.

[22] Lifecycles et al., 2018. The potential benefits of a circular economy in South Australia, Methods Report.
[23] Lifecycles, 2017. Creating value: the potential benefits of a circular economy in South Australia.
[24] NSW Government, 2018. Too good to waste: discussion paper on a circular economy approach for NSW
[25] Victoria Government, 2019. A circular economy for Victoria: creating more value and less waste

3 Circular Economy in Australia

3.1 Circular opportunities

Amid rising awareness of the negative environmental impacts associated with current linear economy practices, steps towards creating new or leveraging existing circular opportunities are starting to gain momentum. The concept of a circular economy has also gained traction in relation to achieving the Sustainable Development Goals (SDG) set by the United Nations, as 2030 targets for all countries towards global sustainable development.

In consultation with CSIRO, a number of potential circular technologies and processes have been identified, which could set Australia on the path to becoming a more circular and resource-efficient economy. There are certain processes, such as generating energy from biogas, which are already present and have seen relatively widespread applications. For such opportunities, we envision adoption at a larger scale as Australia transitions towards a circular economy. Other opportunities, such as the electrification of transport, are more distant goals, as these have been identified by industry bodies and represent sustainability targets, but not been widely taken up yet.

In the following sub-sections, each of the selected opportunities are described and the rationale for choosing them is presented. We also draw out how each opportunity fits global sustainability strategies and policies – by identifying key relevant action areas within the ReSOLVE framework and by referring to the specific SDG that each opportunity most closely relates to.

3.1.1 Nutrient recovery and recycling

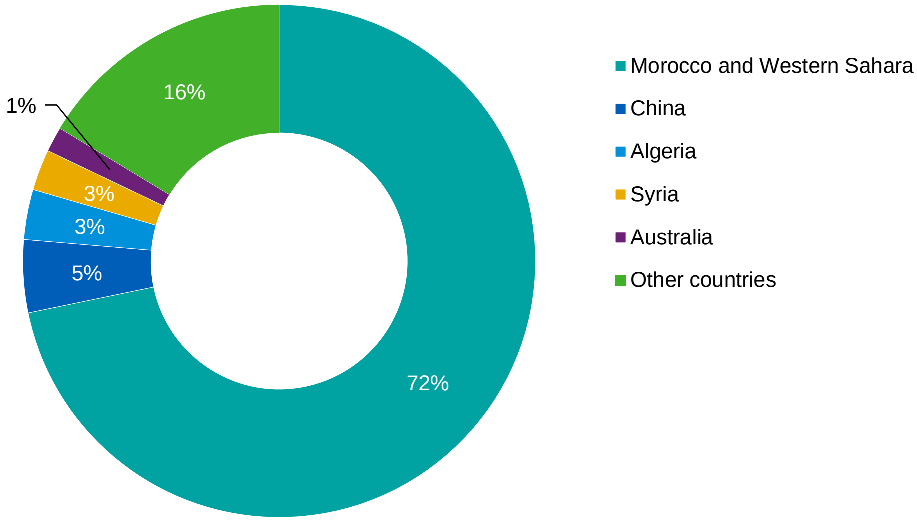
In a circular economy, Australia's agriculture industry recaptures the nutrients embedded in agricultural waste including phosphorus and nitrogen. Being non-renewable and having no close substitutes in food production makes phosphorus a key element for recovery. Another motivator for closing the nutrient loop for phosphorus is the geographic concentration of phosphate rock in Africa and Asia.

Figure 3 shows the top four sources of global phosphate rock reserves, with Australia included for comparison. Around three-quarters of the global phosphate ore reserves are located in Morocco and Western Sahara, with the remainder primarily distributed between China, Algeria and Syria and smaller proportions distributed across a range of other countries. Australian reserves account for around 1%. While the literature indicates that there are no imminent shortages of phosphate rock, the essential nature of phosphorus to agriculture and the geographic concentration of global stock poses a potential risk to food security.[26]

Despite the importance of phosphorus to food security, current usage of phosphorus is highly wasteful. For example, it has been estimated that the use efficiency of phosphorus from the mining of phosphate rock to human consumption is only around 5%,[27] highlighting a potential opportunity for reducing nutrient waste.

[26] The Hague Centre for Strategic Studies, 2012. Risks and opportunities in the global phosphate rock market.
[27] Scholz, R.W. and Wellmer, F., 2015. Losses and use efficiencies along the phosphorus cycle.

Figure 3: Global phosphate rock reserves



Source: United States Geological Survey 2019. Mineral Commodity Summaries 2019.

In addition, as stated in Section 3.2, manure management accounts for around 5% of the GHG emissions in the agricultural sector. Conventional processes of manure management for piggeries usually involve the application of manure on farms after treatment and storage, such as in effluent ponds. The costs involved with transporting manure imply that manure reuse tends to occur on-farm,[28] which can be associated with groundwater and soil pollution if improperly managed. In addition, excess application can result in nutrient-runoff, causing eutrophication of waterways and accumulation of manure can also result in nutrient imbalances in the soil that inhibit crop growth.

For the aforementioned reasons, the importance of nutrient recovery and recycling has been widely recognised in the circular economy literature.[29] One strategy for implementing a circular practice for nutrients is by transforming agricultural waste streams such as manure into nutrient-rich fertiliser products.

Under the ReSOLVE framework, this opportunity relates to the *Regenerate*, *Optimise*, and *Loop* levers:

- *Regenerate*: This opportunity reduces our reliance on non-renewable mined sources of fertiliser such as rock phosphate.
- *Optimise*: this opportunity transforms manure into fertilisers with higher nutrient concentrations, and is more marketable and transportable. This reduces the over-application of manure locally as well as minimises the associated environmental impacts, including water pollution.[30]
- *Loop:* this opportunity maintains the available nutrients from waste streams at a higher level of utility. This means that manure waste streams are transformed into higher-value, processed fertiliser compared with conventional methods of manure processing.

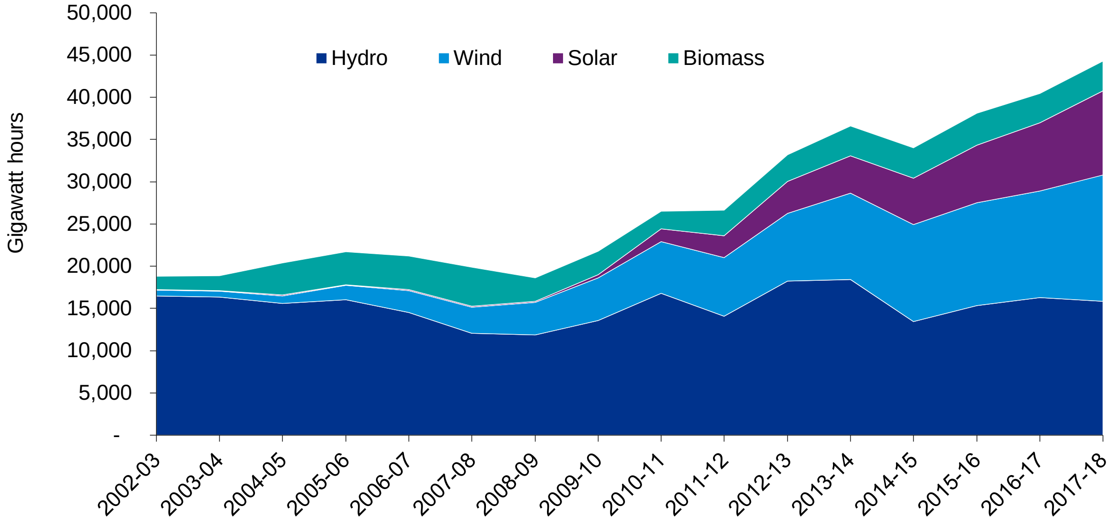
This circular opportunity links with **Goal 2: Zero Hunger**. Developing nutrient recovery and recycling capabilities can improve food security in Australia by reducing our reliance on imported sources of fertilisers. Secondly, transforming agricultural waste into higher-value fertiliser mitigates the environmental impacts of the over-application of manure, and improves the sustainability of agriculture.

[28] Australian Pork Limited, 2015. Piggery manure and effluent management and reuse guidelines.
[29] See for example Impact of circular economy policies on the labour market.
[30] Mallela, J., Lewis, S.E. and Croke, B., 2013.Coral skeletons provide historical evidence of phosphorus runoff on the Great Barrier Reef.

3.1.2 Biogas from organic waste

Another similar opportunity exists for Australia's agriculture industry to help limit the quantity of organic waste disposed of in landfill. In a circular economy, the agriculture industry produces biogas from the anaerobic digestion of unavoidable organic waste generated by agricultural processes. Biogas is a combination of methane and carbon dioxide produced from the bacterial degradation of organic waste. More importantly, it is a renewable and clean source of energy, which can be converted into heat or electricity.

Figure 4: Australian electricity generation by renewable energy fuel type (2002-18)



Source: Australian Energy Statistics, Table O Electricity generation by fuel type, 2017-18
Note: Measured in gigawatt hours, geothermal produces a negligible amount of electricity.

The potential for electricity generation from biogas remains largely untapped in Australia. Figure 4 compares different renewable sources of electricity generation over the period 2002-18. It is clear that hydro and wind are currently the main sources of renewable energy in Australia, with solar-sourced energy on the rise in the past decade. Biomass includes all organic material that can be treated to produce biogas and energy. The use of this source in generating electricity has been relatively stagnant over the period.

As Australia moves towards clean energy technology, biogas presents a great opportunity to meet renewable energy targets, limit its carbon emissions and manage waste. There is an estimated 242 digesters operational in Australia as of December 2016,[31] the majority of which are landfill and wastewater plants. In 2016-17, biogas-generated electricity accounted for 0.5% (4,320 terajoules) of national electricity generation, while the estimated potential is 371,000 terajoules – comparable to Germany's current biogas capacity.

Under the ReSOLVE framework this opportunity relates to the *Regenerate* and *Loop* levers:

- *Regenerate*: this opportunity supports the transition towards renewable sources of energy.
- *Loop:* this opportunity maintains the available nutrients from waste streams at a high level of utility, instead of more conventional methods of manure processing.

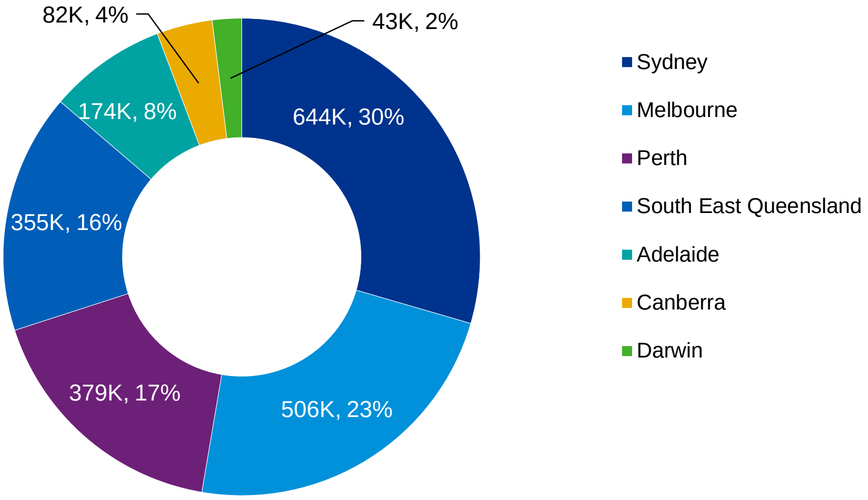
This opportunity links with **Goal 7: Affordable and Clean Energy**. Using organic materials waste, otherwise destined for disposal, to generate electricity reduces our reliance on non-renewable sources of electricity generation such as coal and natural gas.

[31] World Biogas Association, 2016, Anaerobic digestion market report, Australia.

3.1.3 Water use efficiency

In a circular economy, Australia reduces the current level of water wasted from leaky pipes and takes measures to improve water recycling. In 2017-18, major urban centres in Australia sourced 2,200 giga litres from a combination of surface water, groundwater, desalination, and recycled water.[32] This provides an approximation of the water supply to Australian urban centres; this is further broken down by major urban centres in Figure 5.

Figure 5: Volume (mega litres) and share of water extracted in urban centres



Source: BOM, 2019. National Performance Report 2018-19: Urban water utilities

According to the Bureau of Meteorology, an average 10% of water extracted by urban water utilities is wasted, and is among the lowest levels in the world.[33] This translates to around 600 mega litres (ML) of water wasted per day, or the equivalent daily water usage of 1.9 million people.[34] [35]

Under the ReSOLVE framework, this opportunity relates to the *Optimise* lever:

- *Optimise:* In this opportunity, Australia reduces the current level of wasted water. This implies that water supply industries will become more efficient and extract less water as inputs.

This opportunity links with **Goal 6: Clean water and sanitation**. In 2017-18, Australia's water stress – the ratio of the total volume of freshwater extracted to the total renewable freshwater resources - was estimated at 6.8%, rising from 5.9% in 2015-16.[36] However, Australia's water stress compares extremely favourably against other parts of the world. For example, Europe's water stress levels were reported at 8.2%, while that for North America was 12.7%.

3.1.4 Food waste reduction

The generation of food waste is of growing concern for Australian consumers, producers and policy makers. In a circular economy, there is more judicious and complete use of available food in the market, thus reducing the amount that gets thrown away.

[32] BOM, 2019. National performance report 2017-18: urban water utilities.
[33] Water Services Association of Australia, 2019. Reducing leakage in Australia.
[34] Estimated from 112 KL annual water consumption per person.
[35] Sydney Water, 2018. Water Conservation Report 2017-18.
[36] BOM, 2019. Water in Australia 2017-18.

In 2016-17, Australians generated around 7.3 million tonnes of food waste, of which around two-thirds were generated by households and primary producers. On a per capita basis, Australia ranks as the fourth largest food waster, after the US, Belgium and Canada,[37] translating to around 300 kg per capita of food annually.[38] In another study conducted by Rabobank, it was found that although the amount of food waste generated has fallen between 2016 and 2018, the average Australian household loses $890 every year to food waste.[39] Estimated at costing the Australian economy $20 billion per annum,[40] efforts to tackle this issue are gaining prominence and Australia has committed to halve its food waste by 2030 under the National Food Waste Strategy.

Under the ReSOLVE framework this opportunity relates to the *Optimise* lever:

- *Optimise:* this opportunity aims to reduce food waste at the household level, which has economy-wide impacts across the entire supply chain.

This opportunity links with **Goal 12: Responsible consumption and production.** The target set by Australia under the National Food Waste Strategy is consistent with the SDG target of halving food waste by 2030.

3.1.5 Electrification of transport

In a circular economy, there is expansion of electric mobility in Australia, with a move away from fossil-fuel-based transportation towards electric vehicles (EV).[41] Currently, the Australian vehicle market is dominated by conventional internal combustion engine (ICE) vehicles, with EV representing only around 0.2% of total car sales in 2017.[42]

The sale of EV as a proportion of total annual car sales in Australia sits well below the global average of around 5.2%. The current global leader in terms of EV market share is Norway, with EV accounting for 46% of its total car sales in 2018.[43]

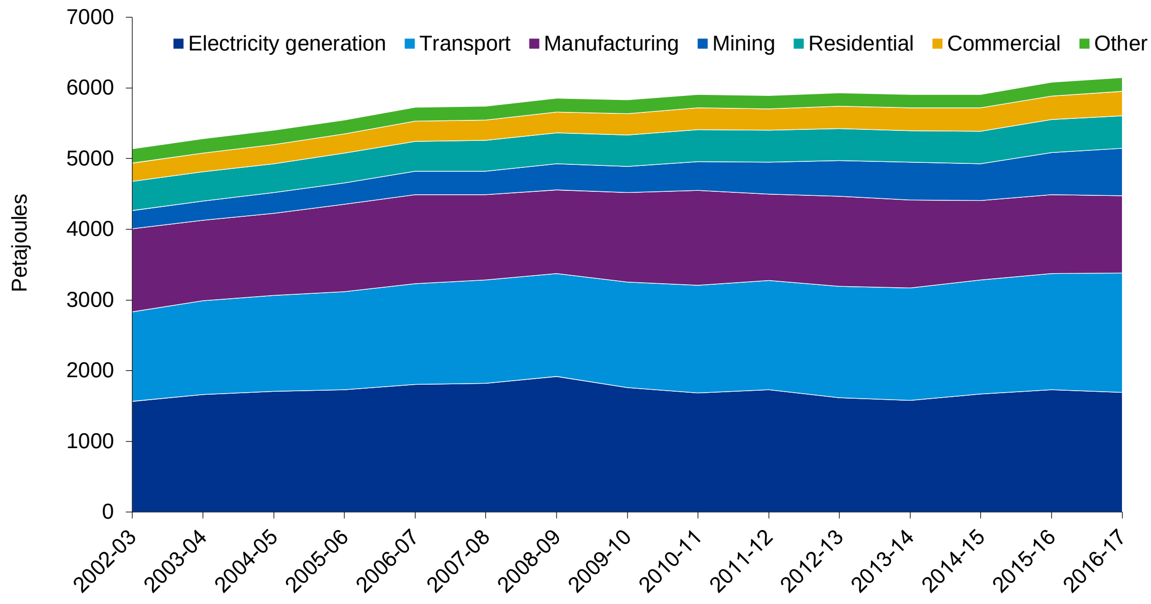
A large part of the motivation to switch to electrically driven vehicles comes from the transport sector's current high share of energy consumption in Australia. In addition, the transport sector is highly reliant on non-renewable sources of energy. Figure 7 shows that, on average, 75% of the energy consumed has been consistently obtained from fossil fuels, mainly petrol and diesel, over the last 15 years. On the other hand, electricity accounted for only 1% of the transport sector's total used energy in 2016-17. In addition, the transport sector is highly reliant on non-renewable sources of energy. Figure 7 shows that, on average, 75% of the energy consumed has been consistently obtained from fossil fuels, mainly petrol and diesel, over the last 15 years. On the other hand, electricity accounted for only 1% of the transport sector's total used energy in 2016-17.

Figure 6: Australian energy consumption by sector (2002-2017) highlights the high energy consuming sectors of the economy and the transport sector second only to the electricity generation sector, consuming 28% of the total energy produced.

In addition, the transport sector is highly reliant on non-renewable sources of energy. Figure 7 shows that, on average, 75% of the energy consumed has been consistently obtained from fossil fuels, mainly petrol and diesel, over the last 15 years. On the other hand, electricity accounted for only 1% of the transport sector's total used energy in 2016-17.

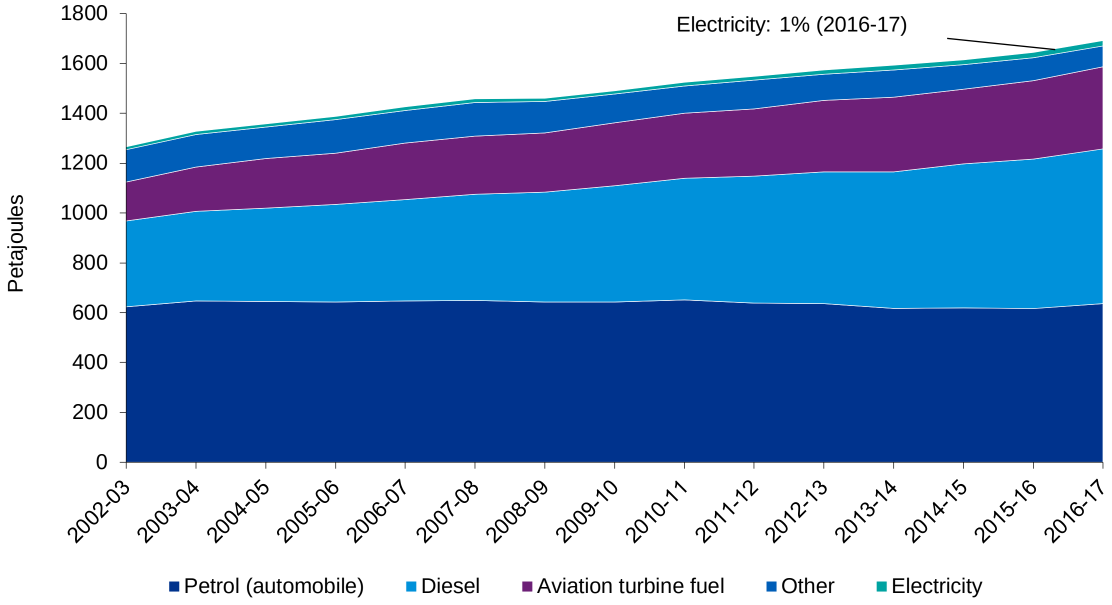
[37] The Economist and Barilla Center for Food & Nutrition .Food sustainability Index: 2018.
[38] Arcadis, 2019. National Food Waste Baseline.
[39] See https://www.rabobank.com.au/savings/2019/03/26/05/27/financial-health-barometer-food-waste-infographic-2018/
[40] Australian Government, 2017. National Food Waste Strategy.
[41] Electric vehicles include Battery Electric Vehicles and Plug-in Hybrid Electric Vehicles.
[42] V-facts 2018, reported by ClimateWorks Australia and EVC, 2018. The state of electric vehicles in Australia.
[43] International Energy Agency, 2019. Global EV Outlook 2019: Scaling-up the transition to electric mobility.

Figure 6: Australian energy consumption by sector (2002-2017)



Source: Australian Energy Statistics, 2018. Australia Energy Update 2018 – Table E
Note: Other includes the Agriculture and Construction sectors as well as all other unclassified energy use.

Figure 7: Energy consumption in Australian transport (2002-17)



Source: Australian Energy Statistics, 2018. Australia Energy Update 2018 – Table F
Note: Electricity use does not take into account of generation type.

This opportunity envisions an accelerated uptake of EV in Australia thus reducing use of fossil fuels and switching to electric sources. In order to achieve the complete benefits of this opportunity it is also important that the increased demand for electricity is met by renewable sources of energy.

Under the ReSOLVE framework, this opportunity relates to the *Regenerate* lever:

- *Regenerate:* Australia's vehicle fleet comprises an increased number of EV resulting in lower consumption of petrol and diesel but higher consumption of electricity.

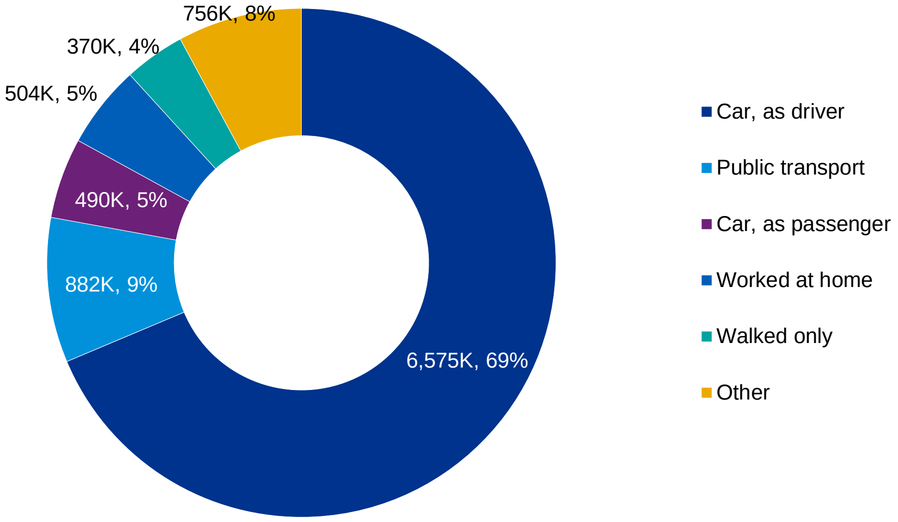
This opportunity links with **Goal 7: Affordable and Clean Energy**. Australia reduces its demand for petroleum, diesel and the like, by substituting towards electric-powered vehicles. To meet clean energy targets and reap full environmental benefits, it is imperative to eventually generate the additional required electricity from renewable sources.

3.1.6 Car sharing

In a circular economy, we expect a greater number of Australians to participate in car or ride sharing for commuting to work. In particular, the target group for this circular practice is working individuals who currently own their own vehicle and could transition towards the use of transportation as a service. This means car-pooling during the work week with one car used by three individuals.

The reduction in the use of private vehicles is an important circular priority due to the high prevalence of car use in Australia as well the current reliance of transportation on fossil fuels. Figure 8 highlights the different modes of travel used by working Australians based on the 2016 Census. Driving to work remains the most preferred way of travelling with nearly 70% using their own car to commute and only about 10% using public transport.

Figure 8: Methods of travel to work by number of commuters



Source: ABS Census 2016

Australia's high reliance on cars also imposes significant environmental costs. As reported in section 3.2, the *Transport* sector accounted for around 28% of energy consumption in Australia in 2016-17 primarily from non-renewable sources. The transport sector accounts for around 19% of the nation's total GHG emissions. Within this total, cars make up around 45% of the transport sector's total emissions and around 8.5% of Australia's total emissions.

The benefits of adopting car sharing go beyond environmental benefits. A study on the impact of car sharing for the City of Sydney found that each car share vehicle in the sharing network represented a $60,000 annual net value to the City, translating to an annual benefit of $48 million for the current network of around 800 vehicles.[44] This included direct benefits such as savings associated with not owning a car, as well as savings accruing to reductions in congestion and car crashes due to lower private car use.

[44] Phillip Boyle & Associates, 2016. The Impact of Car Share Services in Australia.

Under the ReSOLVE framework, this opportunity relates to the *Share* lever:

- *Share:* As a higher number of individuals use private vehicles on a sharing basis, there will be less instances of private vehicles on the road that are under-occupied or in parking lots where they remain idle.

This opportunity links with **Goal 7: Affordable and clean energy.** All else equal, higher utilisation of private vehicles due to an uptake of car sharing will reduce the number of cars on the road, and thus the transport sector's fuel consumption.

3.1.7 Compact dwellings

In general, house sizes today are not commensurate with household sizes, thus highlighting the presence of excess capacity in Australia's housing stock. The circular opportunity is to improve the utilisation of the housing stock by aligning Australia's housing needs with dwelling sizes. This can be achieved by shifting towards more compact dwellings in the creation of new housing stock.

In 2017, the size of an average Australian home, including houses and apartments, had fallen to a 20 year low.[45] But this is due to the fact that the housing market is seeing more apartments being built, which generally have smaller floor sizes. Looking specifically at houses, the average Australian house today is 30% bigger than 30 years ago, despite no significant changes to household sizes over this period.

Reducing excess capacity will directly result in fewer resources committed towards supplying underutilised housing in the economy, such as less construction material and services used. Further, all else equal, more compact houses will also consume less electricity and water, representing a substantial saving in household utility bills. The outcome of this circular opportunity is thus to satisfy Australia's housing needs with greater resource efficiency.

Under the ReSOLVE framework, this opportunity relates to the *Share* and *Optimise* levers:

- *Share:* Australians will make more efficient use of the built environment by having dwelling sizes match up better to household sizes.
- *Optimise:* a more compact built environment will help mitigate issues around urban sprawl for Australia's highly urbanised population.

This opportunity links with **Goal 11: Sustainable cities and communities**. The highly urbanised nature of Australia's population means that more compact and high-density dwellings will be crucial in addressing challenges associated with the status quo, such as urban sprawl and congestion.

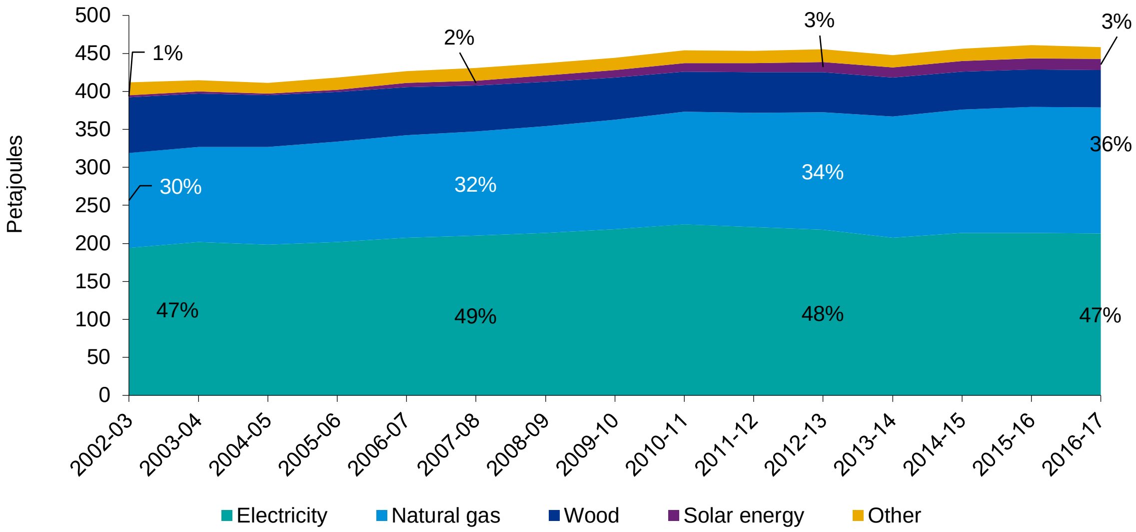
3.1.8 Energy efficient buildings

In a circular economy, buildings in Australia will be built with increasingly higher standards of energy efficiency with a goal towards zero carbon emissions. The 2018 *Built to Perform* report argues that, in contrast to sectors such as aviation or steel, potential improvements for the buildings sector can be achieved using existing technologies.[46] This includes incremental improvements, such as better glazing, better insulation or improved shading in buildings.[47]

Figure 9 shows the energy consumption for the residential sector, by type of fuel consumed. The shares of electricity, natural gas and solar energy in overall energy consumption is shown as percentages. For this sector, electricity is the main source of energy, maintaining a stable share of around 47% to 49% over the period 2002-2017. Strong growth has been observed in natural gas as well as solar energy, albeit the latter growing from a smaller base.

[45] Commsec, 2017. Australian home size hits 20-year low
[46] ASBEC and Climateworks, 2018. Built to Perform.
[47] Ibid.

Figure 9: Energy consumption in the Australian residential sector (2002-17)



Source: Australian Energy Statistics, 2018. Australia Energy Update 2018 – Table F

From 2019 to 2030, Australia's residential and commercial building stock is estimated to grow by around 700 million square metres and 115 million square metres, respectively.[48] Existing technologies for improving energy efficiency in buildings, combined with the size of the sector suggests that this opportunity is likely to play an important part in achieving circular economy in Australia.

Under the ReSOLVE framework, this opportunity relates to the *Optimise* lever:

- *Optimise:* greater energy efficiency in buildings reduces consumption of utilities, like electricity and gas.

This opportunity links with **Goal 13: Climate action**. Improving the energy efficiency of buildings will be crucial in reducing Australia's overall emissions. A 2016 report suggests that reducing emissions from both new and existing buildings could contribute towards 28% of Australia's 2030 emissions reduction target under the Paris Agreement.[49]

[48] Strategy. Policy. Research, 2017. National Construction Code Energy and Emissions Savings Calculator.
[49] ASBEC, 2016. Low Carbon, High Performance.

3.2 Circular sectors and industries

The circular opportunities for Australia identified in Section 3.1 relate to specific industries within the broad sectors of Food, Transport, Built Environment and Utilities. This section provides a profile of these key industries that form an important part of the transition to a circular economy due to a combination of environmental and economic factors.[50]

To capture all related economic activities and impacts, our model database is consistent with the ABS's Australian and New Zealand Standard Industrial Classification (ANZSIC). By design, the KPMG-CGE model has 117 sectors covering a wide range of economic activities in the agriculture, manufacturing, transport and service sectors. We aggregate these industries into a more manageable number of 21 broad sectors tailored for the application at hand.

Selected industries directly used in our modelling are profiled based on economic indicators, such as employment and gross value-added (GVA). Further, the profiles include data on upstream industries (those that supply inputs to the industry of interest), downstream industries (those that use as inputs the output of the industry of interest), and final users (households, government, exports, etc).

Environmental factors are primarily gauged by identifying the top pollutants from the National Pollutant Inventory (NPI) 2017-18. The NPI provides data on 93 toxic substances identified as having negative impacts on human health and the environment. To draw out the environmental impacts of each industry we present emissions in their proportional emission units. This is calculated as the industry's share of a particular pollutant of total emissions for that pollutant. Summing the proportional emission units across all pollutants for a particular industry yields the total proportional units, which allows us to gauge top polluting industries in the economy.[51] Nevertheless, note that this metric does not consider differences across pollutants in terms of toxicity or impact on environmental health.

Further, since the NPI list is restricted to non-greenhouse gases, thus excluding emissions data on carbon dioxide, methane and the like, we have supplemented the NPI using data based on the Australian Greenhouse Emissions Information System (AGEIS). Sources of emissions outlined in AGEIS are generally not consistent with Australian industry-level data, and are hence presented in terms of broader categories.

The bottom-line economic impact of the transition to a circular economy will clearly hinge on sectors and industries that are large in economic terms, such as value-added or employment. In addition, this will also need to consider upstream and downstream linkages, as well as industries that are dependent on scarce or non-renewable resources. Focusing specifically on impacts within Australia, important circular industries would be expected to form a large part of household consumption.

The broad categories discussed in the report are comparable to the ones presented in EMF reports as well as the European Commission report on circular economy policies. For example, EMF reports consider the broad categories of Mobility, Food and Built Environment, with further disaggregation into 16 sectors for modelling.[52] Similarly, the European Commission considers five broad sectors—food products & beverages, motor vehicles, construction, electronics and electrical equipment, and waste collection and treatment.[53]

In addition, the selected sectors are also suited to Australia's current industrial structure. For example, motor vehicle manufacturing and electronics or electrical equipment manufacturing are not explicitly analysed due to their smaller roles in Australia in comparison with the European economy. We have also considered the utilities sector separately as their impacts are felt across a broad range of other sectors.

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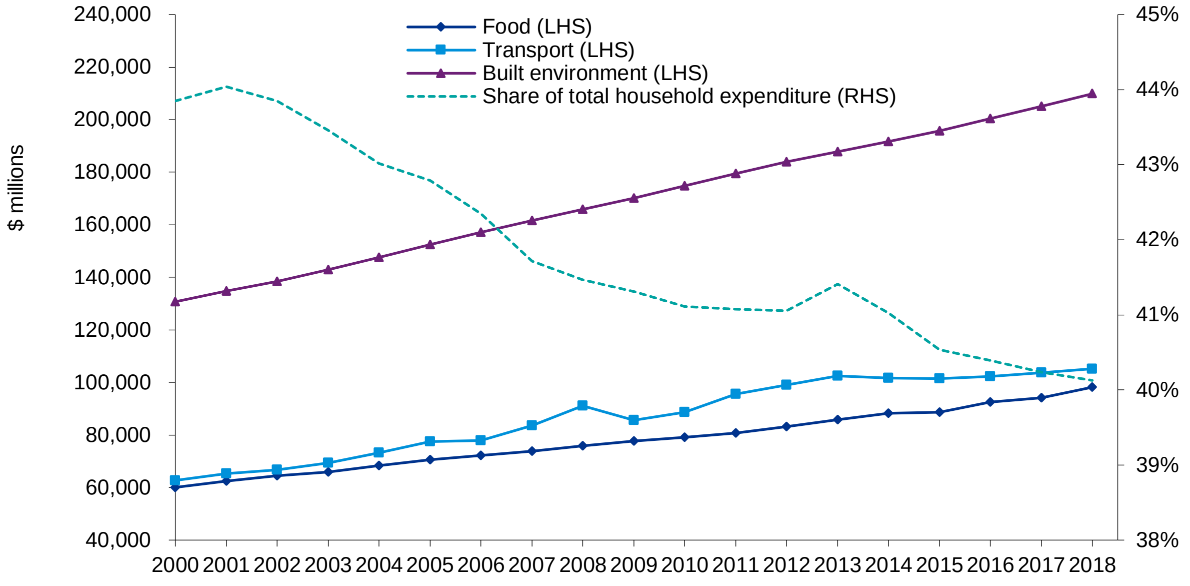
[50] Bicket, M., Guilcher, S., Hestin, M., Hudson, C., Razzini, P., Tan, A., Ten Brink, P., Van Dijl, E., Vanner, R. and Watkins, E., 2014. Scoping study to identify potential circular economy actions, priority sectors, material flows and value chains.
[51] Ellson, A., Johnston, D., 2005. Interpretive Guide for the NPI: a guide to understanding South Australia's NPI data. Environmental Protection Agency
[52] Böhringer, C. and Rutherford, T.F., 2015. The circular economy–an economic impact assessment. Report to SUN-iza, pp.1-33.
[53] Cambridge Econometrics, Trinomics, and ICF, 2018. Impacts of circular economy policies on the labour market.

The circular opportunities considered in this study relate to twelve industries, and are organised under the categories of Food, Utilities, Transport and Built Environment, as shown in Figure 10. We see that Food, Transport and the Built Environment sectors collectively accounted for around 40% of total household final consumption in 2018, with the Built Environment as the main consumption category.

Table 1: Broad industry categories in circular economy

Sectors	Key Industries
Food	Poultry and Other Livestock
	Sheep, Grains, Beef and Dairy Cattle
	Food Manufacturing
	Basic Chemical Manufacturing
Transport	Road Transport
	Petroleum and Coal Product Manufacturing
	Motor Vehicle and Parts Manufacturing
Built environment	Residential Building Construction
	Non-residential Building Construction
	Ownership of Dwellings
Utilities	Water Supply, Sewerage and Drainage Services
	Electricity Generation

Figure 10: Household consumption in Food, Transport and Built environment



Source: ABS 5204.0 Australian System of National Accounts
Note: Chain volume measures of Food, Total rent and other dwelling services, and Total transport

Food

The *Food* sector in this report refers to a broad group of industries across Agriculture as well as the Food and Basic Chemical Manufacturing. These industries have been grouped due to their relevance to the production and supply of food-related products.

Table 2 shows the GHG emissions from the Agriculture industry in Australia. The Agriculture industry accounted for nearly 14% of the nation's greenhouse gas emissions in 2017, primarily resulting from enteric fermentation, which occurs when livestock, primarily ruminants such as cattle and sheep, digest feed into methane. Other contributors to agricultural emissions include agricultural soils, manure management and urea application.

Table 2: Greenhouse gas emissions in Agriculture

Agriculture	000s tonnes	% of Agriculture	% of Australian Total
Enteric Fermentation	51,544	70.6%	9.7%
Manure Management	3,675	5.0%	0.7%
Rice Cultivation	285	0.4%	0.1%
Agricultural Soils	14,170	19.4%	2.7%
Field Burning of Agricultural Residues	468	0.6%	0.1%
Liming	1,318	1.8%	0.2%
Urea Application	1,543	2.1%	0.3%
Agriculture Total	**73,004**	**100.0%**	**13.8%**
Australian Total	**530,841**	**-**	**100.0%**

Source: Australian Greenhouse Emissions Information System, 2017
Note: Measured in terms of CO2 equivalent.

The prime sources of agricultural emissions include methane and nitrous oxide. While the use of lime and urea does emit carbon dioxide, these emissions are usually not counted, as it is considered part of the natural carbon cycle.

Agriculture's consumption of energy in 2016-17 was only 2% of the total net energy consumption in Australia.[54]

3.2.1 Poultry and Other Livestock

The *Poultry and Other Livestock* industry includes poultry, horse and pig farming as well as apiculture. It is a small industry in Australia in terms of employment and value-added. However, the industry's environmental impact is not commensurate with its size, being the third largest source of greenhouse gas emissions in the agricultural sector and direct livestock emissions accounting for 11% of the nation's total emissions. In addition, livestock manure contributes 56% of the total methane emissions and 73% of total nitrous oxide emissions in Australia.[55] According to the NPI, nearly 17 proportional emission units come from the *Poultry and Other Livestock* industry.

[54] Department of the Environment and Energy, Australian Energy Statistics, Table E.
[55] https://www.agric.wa.gov.au/climate-change/reducing-livestock-greenhouse-gas-emissions

Table 3: Industry profile - Poultry and Other Livestock

Poultry and Other Livestock	
Basic Industry Data	• Number of employees: 25,914 (0.23% of total employment)
	• Industry gross value added: $5,101 million (0.33% of total GVA)
Value Chain	**Top three upstream industries:**
	• Other Food Product Manufacturing (13.02%)
	• Other Agriculture (10.71%)
	• Construction Services (8.19%)
	Note: Percentages represent share of total intermediate use
	Main users:
	• Meat and Meat product Manufacturing (51.61%)
	• Private Capital (10.56%)
	• Households (10.05%)
	Note: Percentages represent share of total industry supply
Environmental profile	**Top three pollutants, by proportional emission units:**
	• Ammonia (total) (16.66)
	• Oxides of Nitrogen (0.04)
	• Formaldehyde (methyl aldehyde) (0.03)
Total proportional units: 16.9	

Source: ABS Input-Output Tables 2015-16, Labour force Survey 2015-16, and National Pollutant Inventory 2017-18
Note: Employment numbers are the average of Aug 2015, Nov 2015, Feb 2016 and May 2016 mid-quarter data.

3.2.2 Sheep, Grains, Beef and Dairy Cattle

The *Sheep, Grains, Beef and Dairy Cattle* industry represents a larger component of the overall agriculture industry, but for the Australian economy, it accounts for only around 1% of total industry GVA and total industry employment each. A quarter of Australia's cattle gets exported to Asian countries including China, Indonesia and Vietnam. In terms of environmental impacts, this industry alone accounts for nearly half of Australia's total ammonia emissions.

Table 4: Industry profile—Sheep, Grains, Beef and Dairy Cattle

Sheep, Grains, Beef and Dairy Cattle	
Basic Industry Data	• Number of employees: 123,218 (1.11% of total employment)
	• Industry gross value added: $15,758 million (1.02% of total GVA)
Value Chain	Top three upstream industries:
	• Agriculture, Forestry and Fishing Support Services (11.7%)
	• Sheep, Grains, Beef and Dairy Cattle (9.74%)
	• Other Agriculture (7.49%)
	Note: Percentages represent share of total intermediate use
	Main users:
	• Meat and Meat product Manufacturing (33.36%)
	• Exports (25.53%)
	• Dairy Product Manufacturing (13.08%)
	Note: Percentages represent share of total industry supply
Environmental profile	**Top three pollutants, by proportional emission units:**
	• Ammonia (total) (46.23)
	• Phosphoric acid (7.76)
	• 1,3-Butadiene (vinyl ethylene) (1.59)
	Total proportional units: 56.4

Source: ABS Input-Output Tables 2015-16, Labour force survey 2015-16, and National Pollutant Inventory 2017-18
Note: Employment numbers are the average of Aug 2015, Nov 2015, Feb 2016 and May 2016 mid-quarter data.

3.2.3 Food Manufacturing

The *Food Manufacturing* industry as defined in this report is an aggregation of the following industries:

- Meat and Meat product Manufacturing
- Processed Seafood Manufacturing
- Dairy Product Manufacturing
- Fruit and Vegetable Product Manufacturing
- Oils and Fats Manufacturing
- Grain Mill and Cereal Product Manufacturing
- Bakery Product Manufacturing
- Sugar and Confectionery Manufacturing
- Other Food Product Manufacturing

From Table 5, this broad industry represents around 1.3% of the total industry GVA. The main upstream industries from which it derives inputs are agricultural. This means that changes to primary production processes in agriculture will likely have significant implications for *Food Manufacturing*.

Table 5: Industry profile—Food Manufacturing

Food manufacturing	
Basic Industry Data	• Number of employees: 169,304 (1.53% of total employment)
	• Industry gross value added: $19,674 million (1.28% of total GVA)
Value Chain	**The top 3 upstream industries are:**
	• Sheep, Grains, Beef and Dairy Cattle (37.23%)
	• Poultry and Other Livestock (7.65%)
	• Other Agriculture (6.92%)
	Note: Percentages represent share of total intermediate use
	The top 3 downstream industries are:
	• Households (42.5%)
	• Exports (22.99%)
	• Food and Beverage Services (10.73%)
	Note: Percentages represent share of total industry supply
Environmental profile	**The top 3 pollutants, by proportional emission units:**
	• Phosphoric acid (64.46)
	• Nitric acid (25.39)
	• Ethanol (19.92)
	Total proportional units: 163.1

Source: ABS Input-Output Tables 2015-16, Labour force survey 2015-16, and National Pollutant Inventory 2017-18
Note: Employment numbers are the average of Aug 2015, Nov 2015, Feb 2016 and May 2016 mid-quarter data.

Comprised of major food product manufacturing industries, this broad category accounts for nearly two-thirds of the total phosphoric acid emissions and a quarter of nitric acid emissions, the latter known to adversely affect marine life.

Basic Chemical Manufacturing

The *Basic Chemical Manufacturing* industry is important to consider in the context of the food sector in Australia because this industry supplies chemical organic and inorganic fertilisers to various agricultural industries, including *Sheep, Grains, Beef and Dairy Cattle*, as well as *Poultry and Other Livestock*. In particular, the former is the fifth largest downstream industry consuming around 6.6% of the industry's total supply.

This industry provides nearly 18% of its own intermediate inputs (i.e., intra-industry usage) and exports a fifth of its output. Within the *Food* sector, as classified in this study, the *Basic Chemical Manufacturing* industry is the largest emitter of pollutants.

Table 6: Industry profile—Basic Chemical Manufacturing

Basic Chemical Manufacturing	
Basic Industry Data	• Number of employees: 14,640 (0.13% of total employment)
	• Industry gross value added: $4,297 million (0.28% of total GVA)
Value Chain	**Top three upstream industries:**
	• Basic Chemical Manufacturing (18.13%)
	• Oil and gas extraction (16.36%)
	• Non Ferrous Metal Ore Mining (5.96%)
	Note: Percentages represent share of total intermediate use
	Main users:
	• Exports (19.4%)
	• Households (10.81%)
	• Polymer Product Manufacturing (10%)
	Note: Percentages represent share of total industry supply
Environmental profile	**Top three pollutants, by proportional emission units:**
	• 1,2-Dichloroethane (84.58)
	• Cyclohexane (77.88)
	• Acrylic acid (57.64)
	Total proportional units: 888.2

Source: ABS Input-Output Tables 2015-16, Labour force survey 2015-16, and National Pollutant Inventory 2017-18
Note: Employment numbers are the average of Aug 2015, Nov 2015, Feb 2016 and May 2016 mid-quarter data.

Transport

The *Transport* sector comprises the *Road Transport, Motor Vehicle and Parts Manufacturing* and *Petroleum and Coal Product Manufacturing* industries. This group of industries primarily focuses on the transportation-related circular opportunities of higher uptake in EV and car sharing.

The *Transport* sector in Australia is a large emitter of GHG. The *Transport* sector accounted for around 28% of energy consumption in Australia in 2016-17, primarily from non-renewable sources.

Table 7 gives a breakdown of the GHG emissions by different means and modes of transportation. Road transport is the largest emitter of GHG, accounting for 85% of total GHG emissions, followed at a distance by domestic aviation and railways, at around 9% and 4% respectively. Within road transportation, cars and light commercial vehicles alone account for 61.5% of the total sectoral emissions.

The *Transport* sector accounted for around 28% of energy consumption in Australia in 2016-17, primarily from non-renewable sources.

Table 7: Greenhouse gas emissions in Transport

Transport	000s tonnes	% of Transport	% of Australian Total
Domestic aviation	8,757	8.9%	1.6%
Road Transportation	83,437	84.5%	15.7%
Cars	45,005	45.6%	8.5%
Light Commercial Vehicles	15,679	15.9%	3.0%
Heavy-Duty Trucks and Buses	22,451	22.7%	4.2%
Motorcycles	302	0.3%	0.1%
Other	Data not available	-	-
Railways	3,937	4.0%	0.7%
Domestic Navigation	1,933	2.0%	0.4%
Other Transportation	668	0.7%	0.1%
Transport Total	98,732	100.0%	18.6%
Australian Total	530,841	-	100.0%

Source: Australian Greenhouse Emissions Information System, 2017
Note: Measured in terms of CO2 equivalent.

3.2.4 Road Transport

The *Road Transport* industry represents around 1.6% of total GVA and around 2.2% of total employment in Australia. One of *Road Transport's* main upstream industries is the *Professional, Scientific and Technical Services* industry. With technological advancements in the way we travel and increased automation, the need for skilled personnel to operate newer, advanced systems is expected to increase the *Professional, Scientific and Technical Services* industry's share of inputs in the near future.

It is important to note that the NPI does not capture the entire environmental impact of the *Road Transport* sector because GHG emissions are not included. As shown above, GHG emissions attributable to transport are significant. Further, direct pollutants from this industry are small because *Road Transport* is a service-providing industry while the direct polluting industries tend to be in agriculture or manufacturing.

Table 8: Industry profile—Road transport

Road Transport	
Basic Industry Data	• Number of employees: 263,688 (2.38% of total employment)
	• Industry gross value added: $24,315 million (1.58% of total GVA)
Value Chain	**Top three upstream industries:**
	• Automotive Repair and Maintenance (15.78%)
	• Professional, Scientific and Technical Services (12.95%)
	• Petroleum and Coal Product Manufacturing (12.82%)

Road Transport	
	Note: Percentages represent share of total intermediate use
	Main users:
	• Households (23.68%)
	• Exports (18.85%)
	• Construction Services (5.11%)
	Note: Percentages represent share of total industry supply
Environmental profile	**Top three pollutants, by proportional emission units:**
	• Cumene (1-methylethylbenzene) (0.02)
	• Particulate Matter ≤2.5 µm (PM2.5) (0.01)
	• Oxides of Nitrogen (0.003)
	Total proportional units: 0.03

Source: ABS Input-Output Tables 2015-16, Labour force survey 2015-16, and National Pollutant Inventory 2017-18
Note: Employment numbers are the average of Aug 2015, Nov 2015, Feb 2016 and May 2016 mid-quarter data.

3.2.5 Petroleum and Coal Product Manufacturing

Clearly, the *Petroleum and Coal Product Manufacturing* industry has significant linkages with the Transport sector as a whole, and the key upstream industry is *Oil and gas extraction*. It is also the largest polluter within the *Transport* sector, as classified in this study.

Table 9: Industry profile—Petroleum and Coal Product Manufacturing

Petroleum and Coal Product Manufacturing	
Basic Industry Data	• Number of employees: 8,182 (0.07% of total employment)
	• Industry gross value added: $4,767 million (0.31% of total GVA)
Value Chain	Top three upstream industries:
	• Oil and gas extraction (54.31%)
	• Petroleum and Coal Product Manufacturing (10.11%)
	• Basic Chemical Manufacturing (5.14%)
	Note: Percentages represent share of total intermediate use
	Main users:
	• Households (26.24%)
	• Road Transport (9.33%)
	• Air and Space Transport (9.12%)
	Note: Percentages represent share of total industry supply
Environmental profile	Top three pollutants, by proportional emission units:
	• Biphenyl (1,1-biphenyl) (61.32)

Petroleum and Coal Product Manufacturing	
	• 1,2-Dibromoethane (61)
	• Cumene (1-methylethylbenzene) (20.13)
	Total proportional units: 272.7

Source: ABS Input-Output Tables 2015-16, Labour force survey 2015-16, and National Pollutant Inventory 2017-18
Note: Employment numbers are the average of Aug 2015, Nov 2015, Feb 2016 and May 2016 mid-quarter data.

3.2.6 Motor Vehicle and Parts Manufacturing

Motor Vehicle and Parts Manufacturing industry is a major part of circular economy strategies in Europe, but is a relatively small industry in Australia, mainly restricted to parts manufacturing. Australia's key strength in parts manufacturing also reflects the fact that *Wholesale Trade* is one of the top upstream linkages.

Table 10: Industry profile—Motor Vehicle and Parts Manufacturing

Motor Vehicles and Parts; Other Transport Equipment manufacturing	
Basic Industry Data	• Number of employees: 43,891 (0.40% of total employment)
	• Industry gross value added: $3,138 million (0.20% of total GVA)
Value Chain	Top three upstream industries:
	• Motor Vehicles and Parts; Other Transport Equipment manufacturing (23.93%)
	• Wholesale Trade (11.85%)
	• Internet Service Providers, Internet Publishing and Broadcasting, Websearch Portals and Data Processing (8.69%)
	Note: Percentages represent share of total intermediate use
	Main users:
	• Households (41.79%)
	• Private Capital (30.71%)
	• Automotive Repair and Maintenance (6.22%)
	Note: Percentages represent share of total industry supply
Environmental profile	**Top three pollutants, by proportional emission units:**
	• Methyl isobutyl ketone (35.46)
	• Xylenes (individual or mixed isomers) (28.53)
	• Methyl ethyl ketone (23.22)
	Total proportional units: 170

Source: ABS Input-Output Tables 2015-16, Labour force survey 2015-16, and National Pollutant Inventory 2017-18
Note: Employment numbers are the average of Aug 2015, Nov 2015, Feb 2016 and May 2016 mid-quarter data.

Built environment

The *Built Environment* sector covers industries relating to construction and ownership of buildings. In particular, the *Residential and Non-Residential Building Construction* and *Ownership of Dwellings* industries are grouped under this sector. It is worth noting that GHGs are not shown explicitly for this sector, as emissions generated directly in the residential or other built environment sectors are generally small. Instead, much of the GHG emissions attributable to the construction and maintenance of Australia's built environment occurs from electricity generation and heat production (via natural gas).

3.2.7 Residential Building Construction

Construction Services is a major upstream industry for both *Residential and Non-Residential Building Construction* industries and is one of the largest industry employers in Australia, representing around 6% of total employment. In terms of environmental impacts, the building construction industries are a major contributor to Australia's waste output.

Figure 11 shows the waste generated in Australia by different streams or sources. Note that this includes both waste ash - produced from incinerators and furnaces in electricity generation – and core waste from other sources. Around one-third of nearly 67 million tonnes of waste generated in Australia in 2017 can be attributed to the Construction and Demolition sector, which includes waste materials such as masonry, metals or glass.[56]

Table 11: Industry profile—Residential Building Construction

Residential Building Construction	
Basic Industry Data	• Number of employees: 104,649 (0.94% of total employment)
	• Industry gross value added: $16,660 million (1.08% of total GVA)
Value Chain	**Top three upstream industries:**
	• Construction Services (44.15%)
	• Other Wood Product Manufacturing (8.49%)
	• Structural Metal Product Manufacturing (5.69%)
	Note: Percentages represent share of total intermediate use
	Main users:
	• Private Capital (99.42%)
	• General Government Capital (0.32%)
	• Public Enterprise Capital (0.25%)
	Note: Percentages represent share of total industry supply

Source: ABS Input-Output Tables 2015-16, Labour force survey 2015-16, and National Pollutant Inventory 2017-18
Note: Employment numbers are the average of Aug 2015, Nov 2015, Feb 2016 and May 2016 mid-quarter data.

[56] Blue Environment and Randell Environmental Consulting, 2018. National Waste Report 2018.

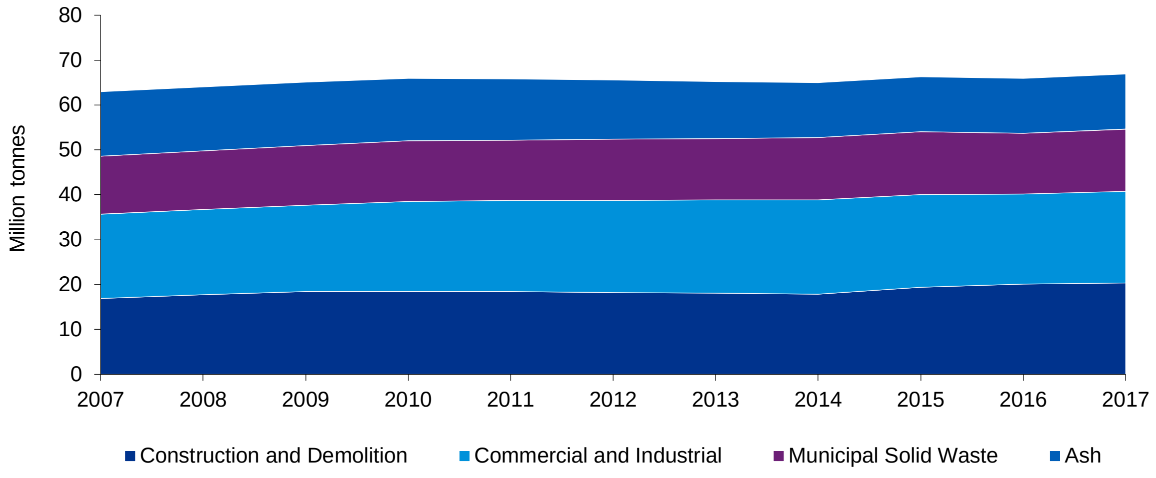
3.2.8 Non-residential Building Construction

Table 12: Industry profile—Non-residential Building Construction

Non-Residential Building Construction	
Basic Industry Data	• Number of employees: 36,254 (0.33% of total employment)
	• Industry gross value added: $10,709 million (0.69% of total GVA)
Value Chain	Top three upstream industries:
	• Construction Services (53.13%)
	• Professional, Scientific and Technical Services (6.19%)
	• Cement, Lime and Ready-Mixed Concrete Manufacturing (4.75%)
	Note: Percentages represent share of total intermediate use
	Main users:
	• Private Capital (79.31%)
	• General Government Capital (19.1%)
	• Public Enterprise Capital (1.28%)
	Note: Percentages represent share of total industry supply

Source: ABS Input-Output Tables 2015-16, Labour force survey 2015-16, and National Pollutant Inventory 2017-18
Note: Employment numbers are the average of Aug 2015, Nov 2015, Feb 2016 and May 2016 mid-quarter data.

Figure 11: Waste generation by stream in Australia (2007-2017)



Source: National Waste Report 2018
Note: Includes interpolated data for some years.

3.2.9 Ownership of Dwellings

Table 13 shows the industry profile for *Ownership of Dwellings*, which includes both landlords as well owner-occupiers. This is one of the largest industries of the economy, accounting for 9% of total GVA. As one would expect, the main user is households consistent with this industry's large proportion of household consumption. We also see that the Food, Transport and the Built Environment sectors collectively accounted for around 40% of total household final consumption in 2018, with the Built Environment as the main consumption category. Note that *Ownership of Dwellings* is assumed to use no labour in the National Accounts.

Table 13: Industry profile—Ownership of Dwellings

Ownership of Dwellings	
Basic Industry Data	• Number of employees: Not applicable
	Note: The Ownership of Dwellings does not use any labour as defined by the National Accounts.
	• Industry gross value added: $143,602 million (9.31% of total GVA)
Value Chain	**Top three upstream industries:**
	• Finance (55%)
	• Construction Services (29.52%)
	• Insurance and Superannuation Funds (6.41%)
	Note: Percentages represent share of total intermediate use
	Main users:
	• Households (98.49%)
	• Exports (1.37%)
	• Government (0.14%)
	Note: Percentages represent share of total industry supply

Source: ABS Input-Output Tables 2015-16, Labour force survey 2015-16, and National Pollutant Inventory 2017-18
Note: Employment numbers are the average of Aug 2015, Nov 2015, Feb 2016 and May 2016 mid-quarter data.

3.2.10 Utilities

The *Utilities* sector includes the *Water Supply, Sewerage and Drainage Services* and *Electricity Generation* industries. These industries are considered separately as their effects range across multiple circular opportunities and associated industries discussed previously. For example, the *Electricity Generation* industry will affect energy use in the *Road Transport* industry due to further uptake of electric vehicles, as well as *Ownership of Dwellings* due to more energy efficient buildings.

Table 15 further disaggregates the Fuel Combustion category. Public Electricity and Heat Production, which falls under Energy Industries, is the dominant source of GHG emissions, not just for the Fuel Combustion category, but also for Australia as a whole. This category alone accounts for around 36% of total GHG emissions.

Table 14 shows GHG emissions from the 'Energy' category as detailed in AGEIS, which includes the energy industries and transport industries, under the subcategory of Fuel Combustion. The former, which includes electricity generation, contributes to around 41% of Australia's total GHG emissions.

Table 15 further disaggregates the Fuel Combustion category. Public Electricity and Heat Production, which falls under Energy Industries, is the dominant source of GHG emissions, not just for the Fuel Combustion category, but also for Australia as a whole. This category alone accounts for around 36% of total GHG emissions.

Table 14: Greenhouse gas emissions in Energy

Energy		000s tonnes	% of Energy	% of Australian Total
Fuel Combustion		383,808	88.1%	72.3%
	Energy Industries	218,064	50.1%	41.1%
	Manufacturing Industries and Construction	41,328	9.5%	7.8%
	Transport	98,732	22.7%	18.6%
	Other Sectors	24,759	5.7%	4.7%
	Other (not elsewhere classified)	925	0.2%	0.2%
Fugitive Emissions		51,841	11.9%	9.8%
From Fuels	Solid Fuels	25,801	5.9%	4.9%
	Oil and Natural Gas	26,039	6.0%	4.9%
Energy Total		435,649	100.0%	82.1%
Australian Total		530,841	-	100.0%

Source: Australian Greenhouse Emissions Information System, 2017
Note: Measured in terms of CO2 equivalent.

Table 15: Greenhouse gas emissions in Fuel Combustion

Fuel Combustion		000s tonnes	% of Fuel Combustion	% of Australian Total
Energy Industries		218,064	56.8%	41.1%
	Public Electricity and Heat Production	189,771	49.4%	35.7%
	Petroleum Refining	2,986	0.8%	0.6%
	Manufacture of Solid Fuels and Other Energy Industries	25,308	6.6%	4.8%
Manufacturing Industries and Construction		41,328.38	10.8%	7.8%
Transport		98,731.78	25.7%	18.6%
Other Sectors		24,758.86	6.5%	4.7%
Other (not elsewhere classified)		924.55	0.2%	0.2%
Fuel Combustion Total		435,649	100.0%	82.1%
Australian Total		530,841	-	100.0%

Source: Australian Greenhouse Emissions Information System, 2017
Note: Measured in terms of CO2 equivalent.

3.2.11 Water Supply, Sewerage and Drainage Services

The *Water Supply, Sewerage and Drainage Services* industry supplies water to households and industries.

Table 16: Industry profile—Water supply, sewerage and drainage services

Water Supply, Sewerage and Drainage Services	
Basic Industry Data	• Number of employees: 30,277 (0.27% of total employment)
	• Industry gross value added: $12,780 million (0.83% of total GVA)
Value Chain	**Top three upstream industries:**
	• Finance (18.96%)
	• Construction Services (12.3%)
	• Auxiliary Finance and Insurance Services (11.11%)
	Note: Percentages represent share of total intermediate use
	Main users:
	• Households (47.76%)
	• Professional, Scientific and Technical Services (5.41%)
	• Non-Residential Property Operators and Real Estate Services (3.96%)
	Note: Percentages represent share of total industry supply
Environmental profile	**Top three pollutants, by proportional emission units:**
	• Chlorophenols (di, tri, tetra) (99.83)
	• Total Phosphorus (89.67)
	• Total Nitrogen (89.64)
	Total proportional units: 563.1

Source: ABS Input-Output Tables 2015-16, Labour force survey 2015-16, and National Pollutant Inventory 2017-18
Note: Employment numbers are the average of Aug 2015, Nov 2015, Feb 2016 and May 2016 mid-quarter data.

3.2.12 Electricity Generation

In 2018, Australia generated 261,405 gigawatt hours (GWh) of electricity, including generation by power plants and by businesses and households for their own use. Figure 12 illustrates the fuel sources of electricity generation in Australia over the period 1989 to 2018. While renewable sources of energy have grown over the period, non-renewable sources such as coal and natural gas remain dominant. Within non-renewable sources, there has been a slight switch in electricity generation from coal towards natural gas since early 2000s.

Table 17In 2018, Australia generated 261,405 gigawatt hours (GWh) of electricity, including generation by power plants and by businesses and households for their own use. Figure 12 illustrates the fuel sources of electricity generation in Australia over the period 1989 to 2018. While renewable sources of energy have grown over the period, non-renewable sources such as coal and natural gas remain dominant. Within non-renewable sources, there has been a slight switch in electricity generation from coal towards natural gas since early 2000s.

Table 17 shows the industry profile for the *Electricity Generation* industry in Australia. Historically reliant on coal-fired power stations, as reflected in the industry's top upstream linkages, Australia is making a slow, yet steady transition towards renewables.

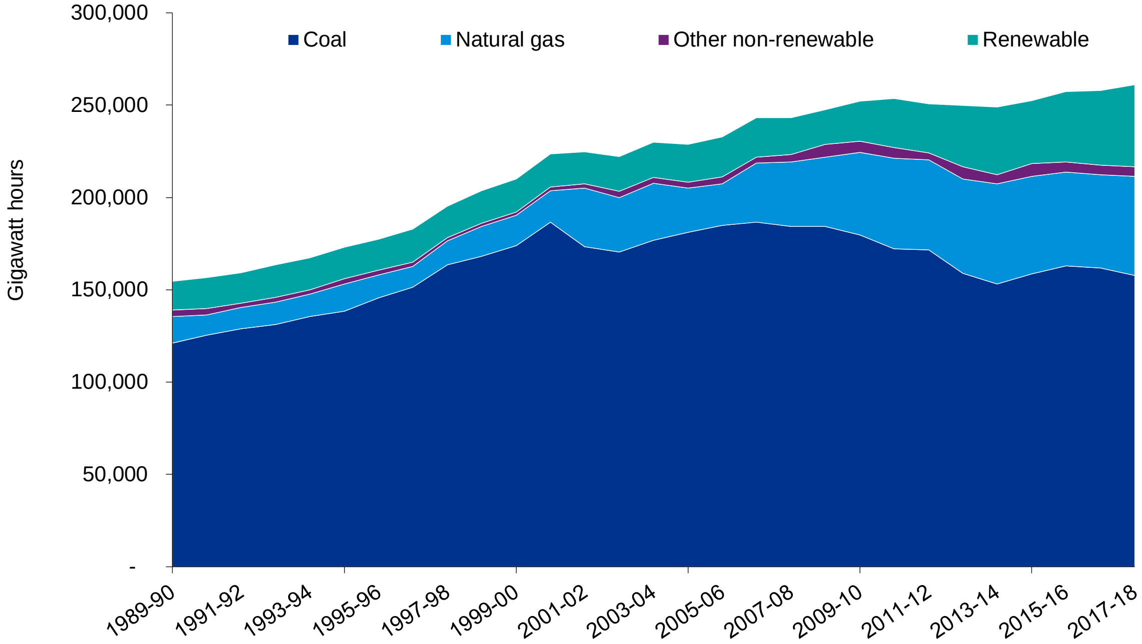
Table 17: Industry profile—Electricity Generation

Electricity Generation	
Basic Industry Data	• Number of employees: 12,859 (0.12% of total employment)
	• Industry gross value added: $1,498 million (0.10% of total GVA)
Value Chain	Top three upstream industries:
	• Electricity Transmission, Distribution, On Selling and Electricity Market Operation (32.86%)
	• Coal mining (12.97%)
	• Finance (11.9%)
	Note: Percentages represent share of total intermediate use
	Main users:
	• Households (37.78%)
	• Public Administration and Regulatory Services (7.5%)
	• Basic Non-Ferrous Metal Manufacturing (4.31%)
	Note: Percentages represent share of total industry supply
Environmental profile	Top three pollutants, by proportional emission units:
	• Hydrochloric acid (93.59)
	• Chromium (VI) compounds (62.63)
	• Oxides of Nitrogen (59.38)
	Total proportional units: 593.8

Source: ABS Input-Output Tables 2015-16, Labour force survey 2015-16, and National Pollutant Inventory 2017-18
Note: Employment numbers are the average of Aug 2015, Nov 2015, Feb 2016 and May 2016 mid-quarter data.

In 2018, Australia generated 261,405 gigawatt hours (GWh) of electricity, including generation by power plants and by businesses and households for their own use. Figure 12 illustrates the fuel sources of electricity generation in Australia over the period 1989 to 2018. While renewable sources of energy have grown over the period, non-renewable sources such as coal and natural gas remain dominant. Within non-renewable sources, there has been a slight switch in electricity generation from coal towards natural gas since early 2000s.

Figure 12: Electricity generation by fuel type in Australia (1989-2018)



Source: Australian Energy Statistics, Table O Electricity generation by fuel type, 2017-2018
Note: Measured in Gigawatt hours, Renewable includes hydro, wind, solar, geothermal and biomass

4 Economy-wide analysis

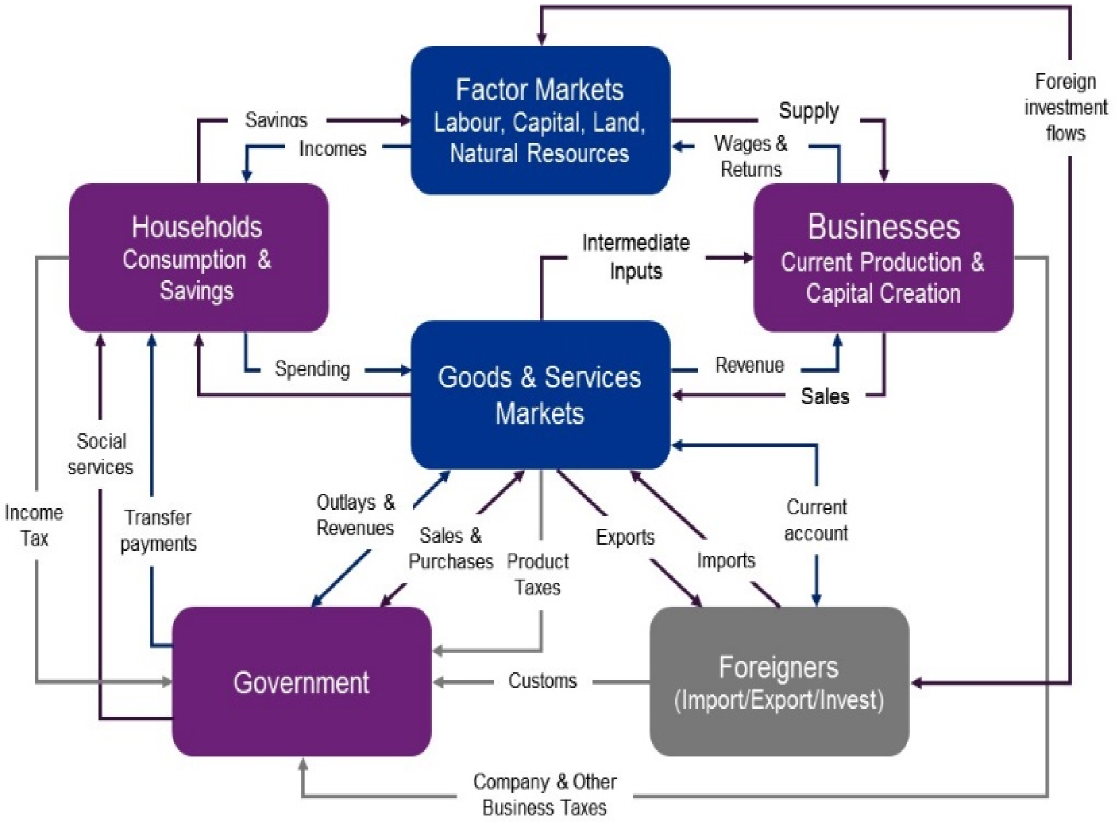
4.1 Methodology

This section provides a brief overview of the methodology employed for this study. As discussed in Section 2.2.1, we model the potential economic benefits of circular activities in Australia using the KPMG-CGE model. The main idea of a circular economy revolves around the efficient use of resources. Although circular technologies refer to specific industries, it is more than likely that circular technologies generate the economic benefits beyond specific industries and indirectly affect other sectors of the economy via changes in resource use and competition, price movements and commodity flows.

The KPMG-CGE model is capable of tracing and quantifying the impact of circular technologies from one sector to another. Figure 13 shows the transmission channels through which the impact of circular opportunities flow through the whole economy. Economic activities that are explicitly modelled include the production of goods and services by firms, creation of capital by investors, supply of factor inputs and consumption by households, spending and tax revenue collection by government, and commodity demands and supplies by foreigners. Most of these economic agents are assumed to behave in an optimising manner and to operate in competitive markets.

Further details of KPMG-CGE are provided in Appendix A.

Figure 13: Linkages across economic agents in KPMG-CGE



4.2 Framework

In assessing the potential economic benefits of the circular opportunities, results of a counterfactual circular economy scenario are compared against that of a baseline scenario.

- *Baseline* scenario – Under this scenario the economy is operating in a business-as-usual mode without the circular activity in place. The baseline represents an estimate of how the size and structure of the economy will evolve in the absence of a circular economy. This is initially calibrated by a steady-state in the first year of the simulation (2018-19). The economy then moves to a new steady-state over a 30 year time horizon. Throughout the baseline the economy moves along a balanced growth path. The economy reaches a new-steady state at the end of the simulation horizon when the capital-labour ratio stops changing. We implement this balanced growth path via a 3.2% annual growth (the 30-year average GDP growth rate) in all quantities and a 2% annual growth in the consumer price index (CPI). The unemployment rate is held fixed and labour productivity grows by 1.6% per annum.
- *Counterfactual* scenario – This scenario introduces the circular activities described in Section 3.1 into the baseline scenario. For each circular opportunity under consideration, the direct impacts (costs and benefits) are quantified outside the model, based on research and case studies of similar processes in other economies. These direct impacts are then implemented as shocks in the model. As we are running a dynamic simulation over a 30 year period, the direct benefits are spread out over the simulation period. The investment costs are usually applied in the first year (i.e., capital build-up) of the simulation, and then the annual cost of capital maintenance is applied thereafter. The calculation of the shocks (benefits and costs) are discussed in detail in the following section.

To calculate the economic effects of a circular economy using KPMG-CGE, we compare the difference in values of economic variables between the baseline and counterfactual scenarios.

4.3 Results

Each circular opportunity is modelled under certain assumptions regarding adoption rates, that is, the extent to which we expect a particular circular practice to be implemented across the economy. In this section we outline the simulation design, including modelling assumptions and estimated direct impacts that determine the value of the relevant model variables. In estimating the overall economic impacts it is imperative to understand the investment needs for each circular opportunity. Where possible, the potential level of investment required has been stated.

The simulation results presented comprise macroeconomic impacts, including changes to real GDP and employment, as well as flow-on effects on related (upstream and downstream) sectors. These results are presented in percentage change and dollar change (present values) terms.

4.3.1 Nutrient recovery and recycling

Simulation design

Industry data indicates that there are 2.5 million pigs[57] in Australia, which is equivalent to 2.8 million standard pig units (SPU).[58] Each SPU generates 115 kg of total solids (TS) per year.[59] Assuming a 6% dry matter content in pig manure,[60] we estimate that about 5.4 million tonnes of pig manure are available annually for recycling.

As a comparison for our estimate, a recent study by Loyon (2018) estimated that a total of 25.4 million tonnes of slurry and 828,000 tonnes of solids were generated from 13.8 million pigs.[61] This translates to approximately 1.9 tonnes of waste per pig per year. Applying this conversion factor to the number of pigs in Australia, around 5.37 million tonnes of pig manure is available for recycling.

For this scenario, it is assumed that 70% of total pig manure in Australia is converted into fertiliser by 2030-31 using a technology such as BioEcoSIM.[62] This target rate is equivalent to the treatment of 3.8 million tonnes of pig manure.

Processing this amount of manure can result in an annual gain of $125 million via the following outputs:

(1) Phosphate, nitrogen, and bio-charcoal soil improver valued at $32 million per annum; and

(2) Disposal cost of manure valued at $22-25 per tonne giving a total of $93 million.[63]

This amount is the cost of fertiliser input saved by the agriculture sector when it produces its own fertiliser from organic waste. We apply this benefit to the model as input-saving technical change in the use of fertiliser by the agriculture sector.

The investment cost includes purchasing, installing and maintaining the technology or capital stock for converting waste manure to bio fertilisers. The total investment cost is valued at $93 million annually. This includes the cost of the capital asset and a 3% maintenance cost per year. It is assumed that labour and energy costs remain at baseline levels.

Economic outcomes

Figure 14 shows the percentage changes in industry output relative to the baseline. The first-round effect of the circular economy shock is a 65% reduction in fertiliser input costs for the *Agriculture, forestry and fishing* industry. This increases the economic activity of the sector, producing an additional output of around 0.09% by 2047-48. The second-round effects are the indirect effects on other industries. There is an expansion in *Food product manufacturing* and *Accommodation and food services*. This is due to the price-reducing effect of the shock to agricultural commodities, i.e., lower input costs are reflected in lower farm output prices. More is now demanded by downstream industries as agricultural output becomes cheaper. In contrast, the *Non-food manufacturing* sector contracts due to two main factors: a reduction in the agricultural sector's demand for fertiliser inputs from the manufacturing sector, and household substitution from non-food to food commodities. The *Mining* sector also declines as this is the main source of minerals used in the manufacturing of fertiliser chemicals.

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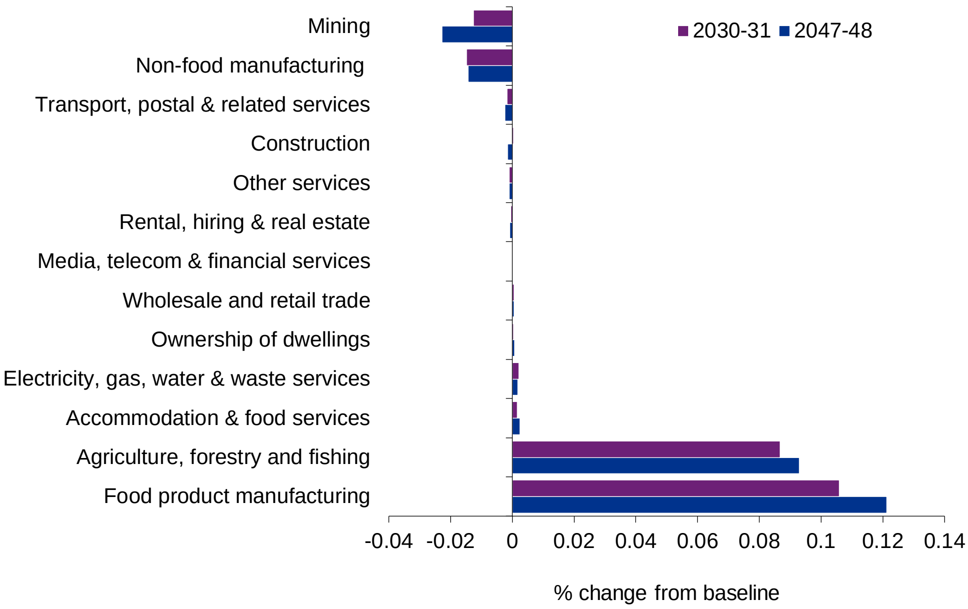
[57] ABS, 2019. Agricultural Commodities.
[58] Australian Pork Limited, 2010. National Environmental Guidelines for Piggeries.
[59] Smits, M.J.W., Woltjer, G.B., Luesink, H.H., Beekman, V., de Koeijer, T.J., Daatselaar, C.H.G. and Duin, L., 2018. Phosphorus Recycling from manure–A Case Study on the Circular Economy: Work package 4. EU.
[60] Ibid
[61] Loyon, L., 2018. Overview of Animal Manure Management for Beef, Pig, and Poultry Farms in France. Frontiers in Sustainable Food Systems, 2, p.36. estimates around 25.4 million tonnes of slurry and 828,000 tonnes of solids from the 13.8 million pigs in France. This
[62] Smits, M.J.W., Woltjer, G.B., Luesink, H.H., Beekman, V., de Koeijer, T.J., Daatselaar, C.H.G. and Duin, L., 2018. Phosphorus recycling from manure–A Case Study on the Circular Economy: Work package 4. EU.
[63] Bentley, J. et al, 2014. The economics of dairy manure management in Iowa.

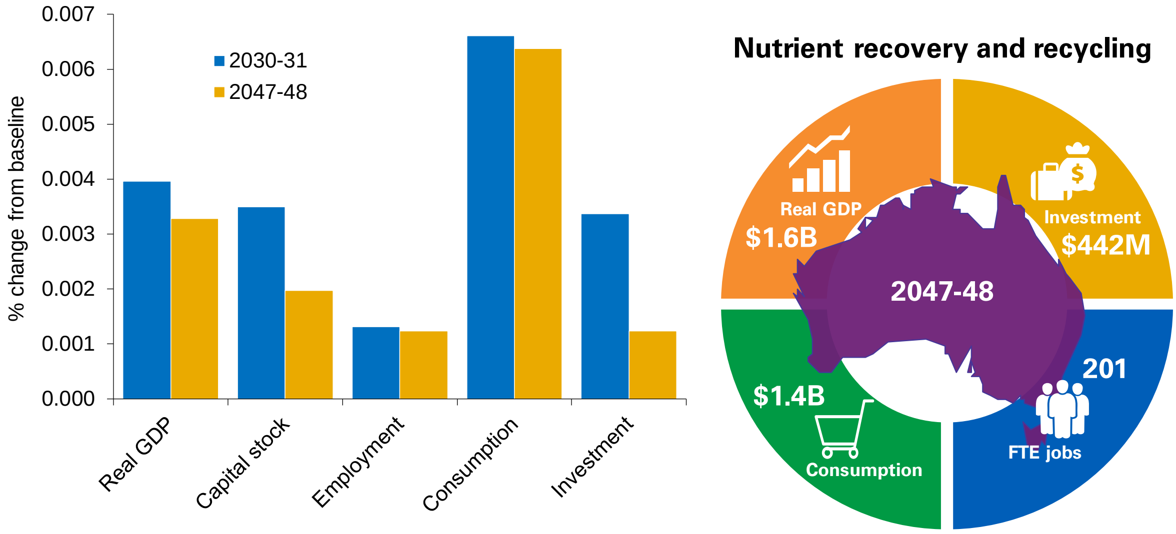
Figure 14: Industry impacts—Nutrient recovery and recycling



Source: KPMG analysis

At the macroeconomic level Figure 15 shows there is a slight increase in real GDP (0.003 %). This is mainly attributed to the increase in value added of the agriculture sector. The economy invests in processing plants, which increases the available capital stock. Workers supply slightly more labour due to the shock-induced increase in real wage rates. This is caused by the movement of workers across industries, particularly into the agricultural and food products sectors. The biggest effect at the macroeconomic level is the increase in real consumption, as the prices of agricultural output and processed food products fall. Agricultural and food products accounts for a large share of the consumer basket, hence a reduction in the price of these commodities increases total household consumption. In addition, the increase in real wages will raise the purchasing power of households and thus increase consumption.

Figure 15: Macroeconomic impacts—Nutrient recovery and recycling



Source: KPMG anaysis

In dollar terms, the increase in real GDP is $1.6 billion (in present values) by 2047-48.[64] The circular opportunity in nutrient recovery and recycling will also boost investment by about $442 million and increase consumption by $1.4 billion. There are also 201 full time equivalent (FTE) jobs created in the economy.

4.3.2 Biogas from organic waste

Simulation design

In 2016-17, Australia generated 14.2 million tons of organic waste, of which roughly 22% was disposed of in landfill.[65] For this scenario we assume that 70% of this organic waste is instead processed into biogas and, in turn, converted into electricity. We simulate this circular technology as presented in a business case study for setting up a biogas plant in Northern Inland NSW.[66] We assume that the cost of transporting waste to landfill is equal to that of taking to it to the site of a biogas plant. Hence, we ignore the cost of transportation in our analysis.

Given a target waste input of about 2.2 million tons (or 70% of total organic waste sent to landfill), we estimate the need for 15 biogas plants with a processing capacity of 150,000 tonnes of organic waste per year. The total capital cost is thus estimated at $26 million. Aside from the capital cost, we assume a 2% maintenance cost per year for each plant. We apply these costs as an annual investment shock spread over the 15 year lifespan of the plants. The shock is calibrated at $34.46 million per year. However, bioenergy and the energy from waste sector represents a significant investment opportunity for Australia estimated to be at between $3.5 billion and $5 billion by 2020.[67]

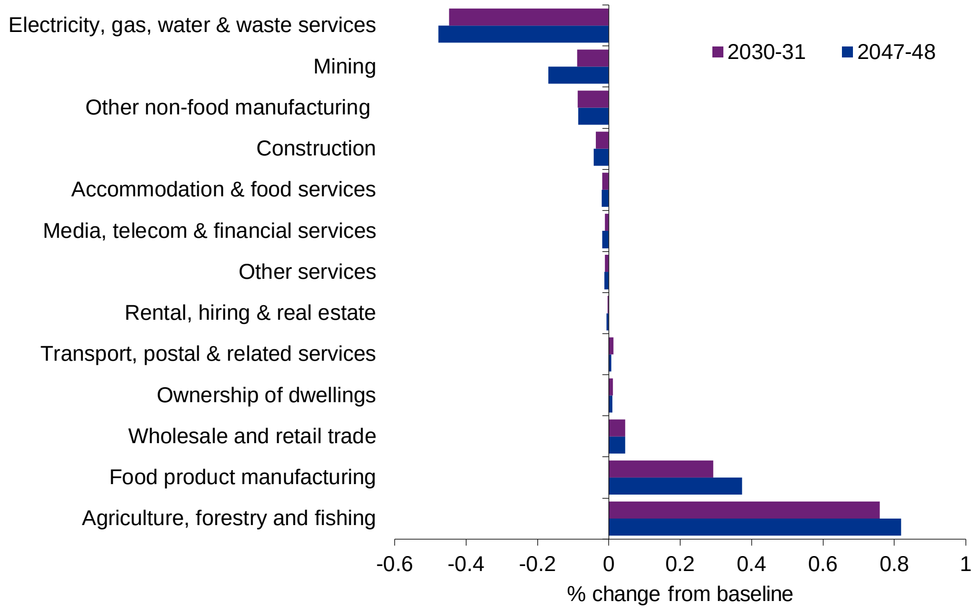
Each plant can produce 26.5 million cubic metres of biogas from the targeted amount of organic waste input. This can generate 55 million kilowatts per hour (kWh) of electricity per plant. The price of electricity from a biogas plant is 7-10 cents/kWh (we consider the upper limit) while the current retail price of electricity in the network grid is 20 cents/kWh. This amounts to a cost saving of 10 cents/kWh due to using biogas-generated electricity. Multiplying this cost differential with the potential biogas electricity output, the agriculture sector can save $82.5 million of electricity cost per year. This benefit is implemented as input-augmenting technical change for the agriculture sector in the use of self-generated electricity input.

Economic outcomes

The sectoral and macroeconomic effects are presented in Figure 16 and Figure 17. The direct effect of the shock is an expansion of the *Agriculture, forestry and fishing* industry by 0.80% over the simulation period. Downstream industries, such as *Food product manufacturing* industry, also expand as they purchase more outputs from the *Agriculture, forestry and fishing* industry due to lower farm-gate prices. The additional sales of *Agriculture, forestry and fishing* output requires additional services from the *Wholesale and retail trade* industry resulting in their expansion. In contrast, the *Electricity, gas, water & waste services* industry contracts as the agriculture sector demands less of its output. That is, it substitutes its own production of biogas electricity for network electricity. The *Mining* sector also contracts as coal is the main input to the utilities sector.

[64] All dollar amounts shown are in present value terms (2018-19 dollars).
[65] National Waste Report 2018
[66] Business proposal- Energy from biogas in NSW
[67] Clean Energy Finance Corporation, 2015. The Australian bioenergy and energy from waste market.

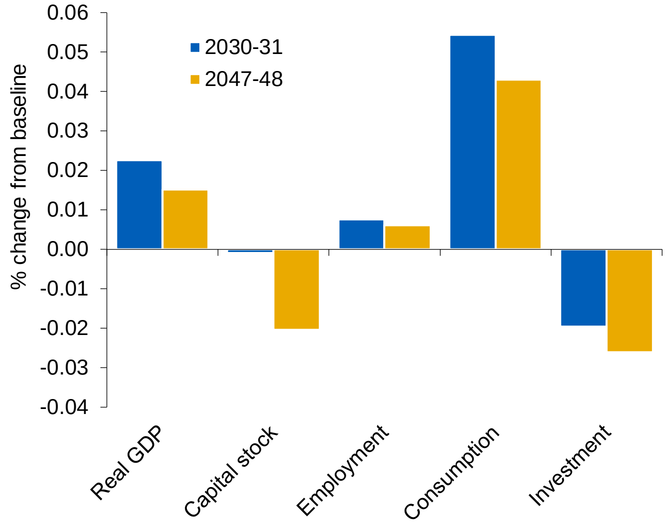
Figure 16: Industry impacts—Biogas from organic waste

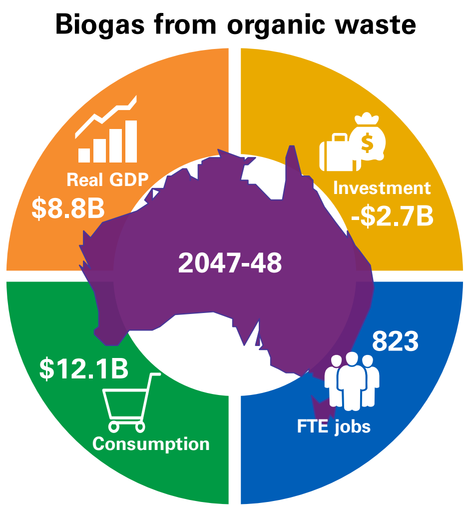


Source: KPMG analysis

In terms of the economy-wide effects, this circular opportunity causes a rise in real GDP by 0.02%, which is attributed mainly to the increase in consumption expenditure. This translates to an $8.8 billion increase in GDP in present values by 2047-48. More labour is supplied by households due to a shock-induced increase in real wage rates. An additional 823 full-time workers are employed in the economy. The increase in real wages improves the purchasing power of households resulting in an increase in real consumption in the economy by $12.1 billion. The economy becomes less capital intensive due to the contraction in capital-intensive industries and expansion in labour-intensive industries. These changes in capital industry composition reduces the demand for investment and leads to a smaller capital stock.

Figure 17: Macroeconomic effects—Biogas from organic waste





Source: KPMG analysis

4.3.3 Water use efficiency

Simulation design

We consider the opportunity to reduce the amount of water wasted in Australia by recycling water. Current literature suggests that around 10% of extracted water by urban utilities is wasted in Australia. The potential reduction in the amount of water wasted is quantified using estimates from Economic Level of Leakage (ELL) and Economic Level of Water Conservation (ELWC).[68]

Estimated water extracted by urban utilities is 6000 ML per day,[69] of which 10% gets wasted (600 ML per day). One case study suggests that the level of waste could be economically lowered by 17%.[70] We use this to calibrate the additional amount of water that can be saved or recycled in the circular economy at about 102 ML.

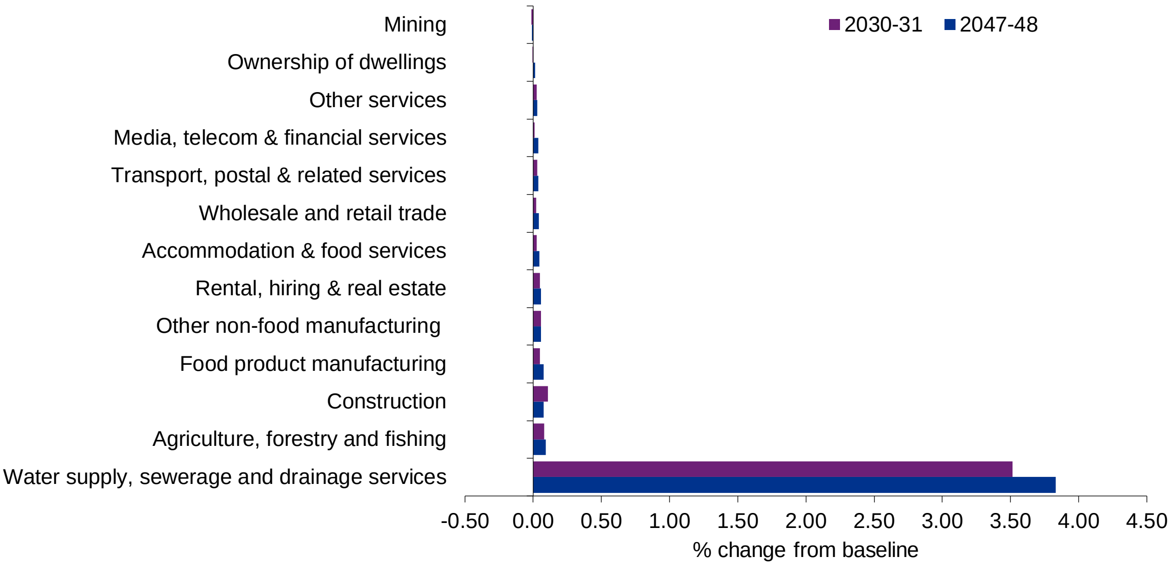
Sydney Water estimated the cost of the technology per kilolitre (KL) saved and compared this against long-run values of water. The cost of future water recycling schemes (for use in irrigation of golf courses, farms and industrial purposes) is estimated at $1.66/KL while the cost of active leak detection is estimated at $0.9/KL (i.e., this is the lower bound of costs of water efficiency measures).[71] Taking into account this cost difference and the target amount of water waste to be recycled, the annual investment cost is estimated at $62 million. The annual economic benefit of this circular technology is valued at $77 million. This is calculated with the following assumptions: water saved per day is 102 ML and the long-run price of water is $2.08/KL.

Economic outcomes

By making the water system more efficient (i.e., reducing water leakages or recycling wasted water), the *Water supply, sewerage and drainage services* industry is effectively producing more output with the same inputs. Hence, the first-round effect of the shock is an expansion of the *Water supply, sewerage and drainage services* industry. This is depicted by the large positive deviation in Figure 18. Consequently, the price of water falls and this benefits all users of water. The magnitude of this effect on other industries depends on their intensity of water use. In particular, the *Agriculture, forestry and fishing* is a major user of water for irrigation purposes and thus benefits noticeably from the lower price of water.

[68] BOM, 2019. National performance report 2017-18: urban water utilities
[69] Water Services Association of Australia, 2019. Reducing leakage in Australia
[70] Sydney Water, 2019. Sydney Water: Water Conservation Report 2017-2018.
[71] Ibid.

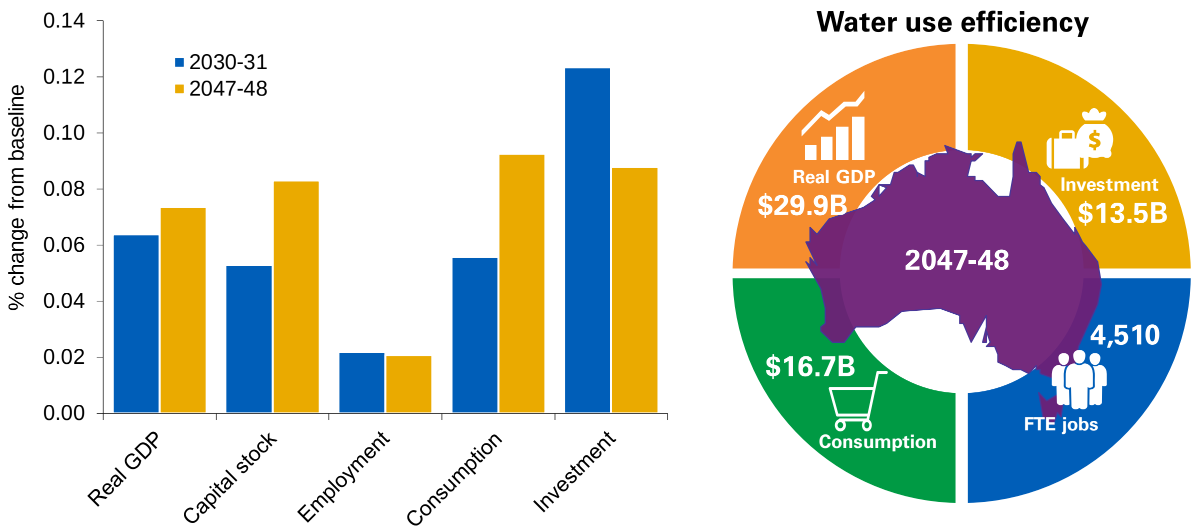
Figure 18: Industry impacts—Water use efficiency



Source: KPMG analysis

At the aggregate level Figure 19 indicates that reducing water waste is favorable to the economy as the resources saved from the production and consumption of wasted water are reallocated to more productive purposes. It leads to $29.9 billion in higher real GDP and employs 4,510 more FTE workers. The most significant indicator of the economic benefit is investment expenditure in the medium-term and household consumption in the long-run. There is a $13.5 billion increase in investment expenditure by 2047-48 and a $16.7 billion increase in household consumption.

Figure 19: Macroeconomic impacts—Water use efficiency



Source: KPMG analysis

4.3.4 Food waste reduction

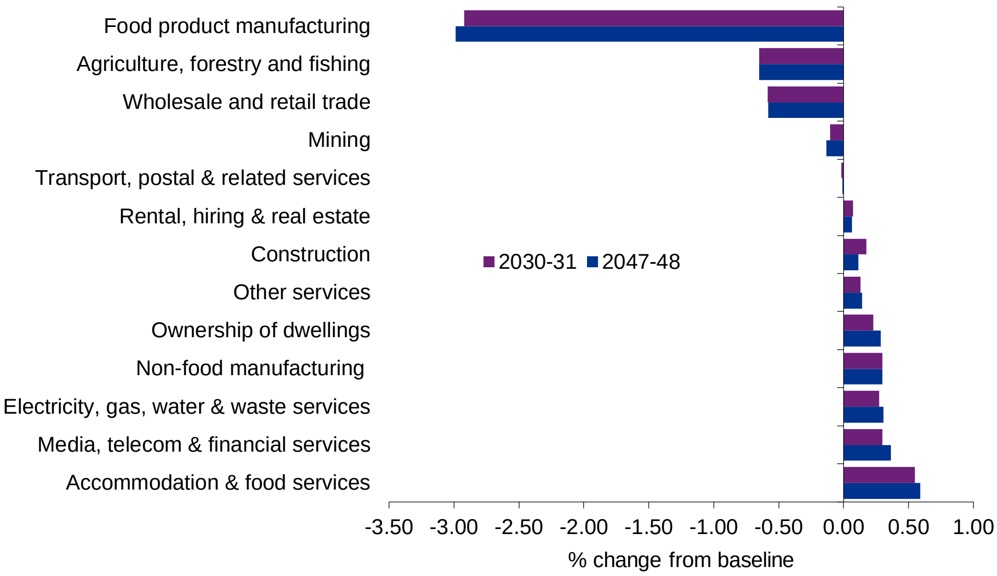
Simulation design

Over the period 2016-18, the value of food wasted by households was $9.5 billion per year on average. This accounts for approximately 10% of the value of total household food consumption.[72] We consider the circular opportunity of reducing food waste in Australia. In particular, we target the current food waste to be reduced from 10% to 3% of total food consumed over a 10-year period and simulate the dynamic effects for 30 years.

Economic outcomes

The simulation results are presented in Figure 20 and Figure 21. A reduction in food waste is modelled as a reduction in food expenditure by households, i.e., they only buy what they can consume. The demand shock reduces the food output required in the circular economy. This is reflected in the contraction in the production of the *Food product manufacturing* sector and its main supplier of food commodity inputs – the *Agriculture, forestry and fishing* industry. With lower food purchases in the market, trade services by the *Wholesale and retail trade* industry are also reduced. In contrast, non-food industries expand as households substitute non-food commodities for food commodities. That is, income saved from reduced food waste is now spent on non-food commodities. Also, other industries in the economy expand, as primary factors (labour, in particular) move from food to non-food industries.

Figure 20: Industry impacts—Food waste reduction

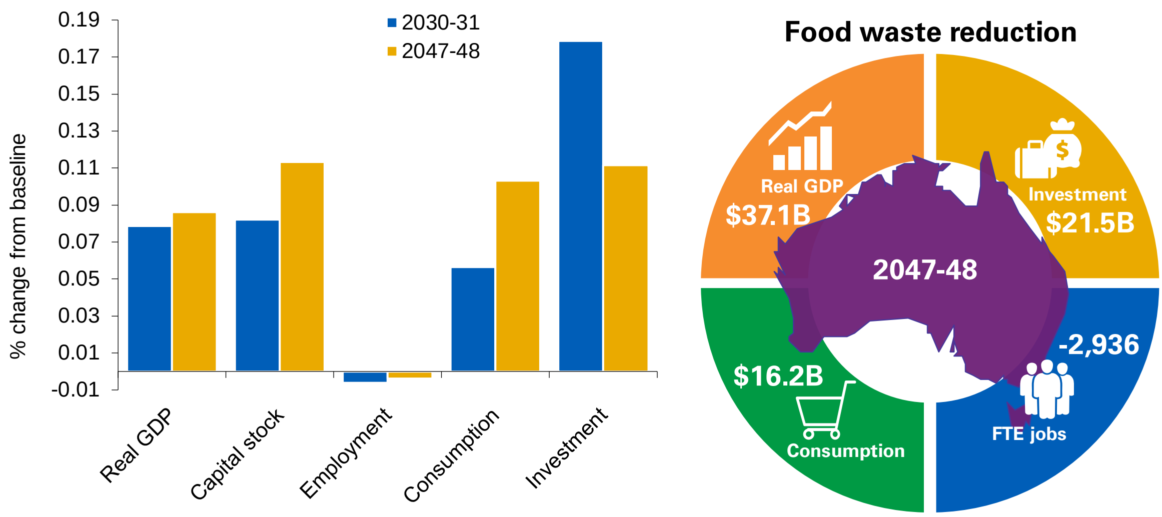


Source: KPMG analysis

At the macro level Figure 21 indicates an expansion in real GDP of 0.09% as the resources saved (i.e., labour and capital) from the production of wasted food are reallocated to other productive uses. The reduction in food waste is also favourable to total consumption and investment. The money saved from food waste generates extra capacity to consume or invest in the economy. In dollar terms, GDP increases by $37.1 billion in present value terms, with consumption and investment increasing by $16.2 billion and $21.5 million respectively by the end of the simulation horizon. Employment falls mainly due to the contraction of the food manufacturing and service sectors, which are labour-intensive. There are about 2,936 displaced workers in the economy.

[72] See https://www.rabobank.com.au/savings/2019/03/26/05/27/financial-health-barometer-food-waste-infographic-2018/

Figure 21: Macroeconomic impacts—Food waste reduction



Source: KPMG analysis

4.3.5 Electrification of transport

Simulation design

We consider the increasing electrification of motor vehicles in Australia. Primary impacts of this opportunity are the cost difference between fossil-fuel and electricity, and reduced maintenance costs of electric vehicles (EV) compared with internal combustion engine (ICE) vehicles.

The Electric Vehicle Council (EVC) estimates that EV accounted for 0.2% of total car sales in Australia in 2017.[73] That is, 2,300 EV were sold out of 1.1 million total cars. These EV include both battery electric vehicles and plug-in hybrid electric vehicles. In our circular economy scenario, we assume that EV sales account for 10% of new car sales by 2030-31. This is equivalent to more than 550,000 units of EV sales by 2030-31.[74]

The switch from ICE vehicles to electric vehicles results in changing the mix of inputs in the road transport sector to using less fuel and more electricity. This change in the input mix is applied as an input-augmenting technical change in the road transport industry. The fuel costs of ICE vehicles and EV are assumed at $0.10/km and $0.03/km respectively.[75] The average distance travelled by Australian cars is 13,414 km/year.[76] Using their respective fuel costs and the average travel distance, the annual fuel cost for ICE vehicles is estimated at $1,341 and $402 for electric vehicles. This fuel cost difference, multiplied by the projected annual sales of EV, calibrates the value of the input-saving technical change applied to the model.

An investment shock is also implemented in the road transport industry to reflect the cost differential of purchasing an electric vehicle compared to a fuel vehicle. The price or purchasing an ICE vehicle is currently lower than an EV. This price differential is captured in our investment shock but at a gradually decreasing value until 2024-25, after which we assume price parity.[77] On top of this unit-cost differential, we assume that each EV is sold with a home charger costing $1500/unit, and EV maintenance cost is $2,350 cheaper relative to that of ICE vehicles. Note that the investment cost does not include the capital cost of building public charging stations.

[73] ClimateWorks and EVC, 2018. The state of electric vehicles in Australia.
[74] Energeia, 2017. Electric Vehicle Insights.
[75] EVC et al., Recharging the economy: The economic impact of accelerating electric vehicle adoption.
[76] ABS, 2018. Survey of Motor Vehicle Use.
[77] AEMO and Energeia, 2016. Electric Vehicles; ABS, 2018. Motor Vehicle Census

Economic outcomes

The sectoral effects are reported in Figure 22. The *Motor vehicle and parts manufacturing* industry expands as the number of EV sales are projected to increase over time. Note that currently all motor vehicles sold in Australia are imported. Thus the output of the *Motor vehicle and parts* industry reflects parts rather than complete vehicles; output expands by 0.70% in the circular economy. The shift to EV will require increased consumption of electricity and decreased consumption of petroleum. This substitution effect is prominent in the results where the generation of *Electricity, gas, water & waste services* expands while the production of *Petroleum and coal manufacturing* contracts. The *Road transport* industry also expands as the price of petroleum (a major input to this industry) falls due to the downward shift in demand for fuel.

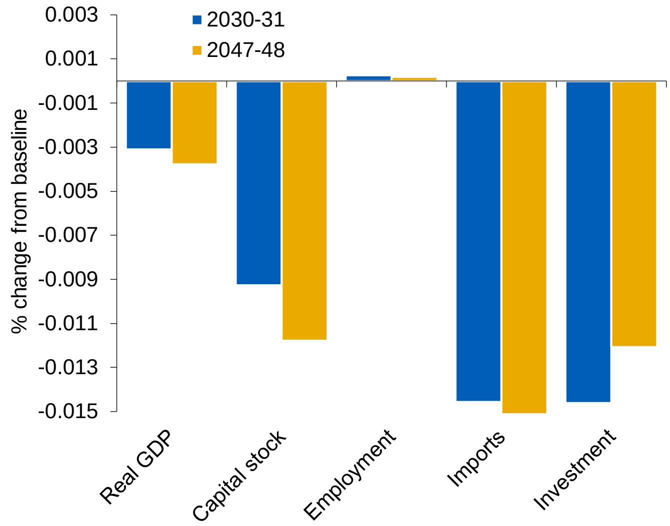
Figure 22: Industry impacts—Electrification of transport

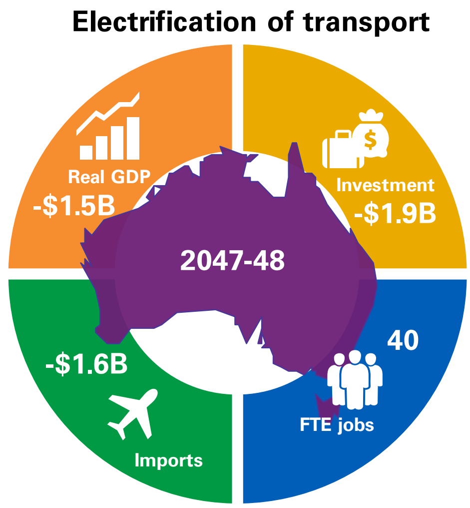
Source: KPMG analysis

Figure 23 presents the macroeconomic results of electrifying transport in Australia. The main effect is the reduction in imports amounting to about $1.6 billion by 2047-48. Australia is a net importer of *Motor vehicles and parts* and *Petroleum and coal products*. We do not assume any domestic manufacturing of EV. Hence in the circular economy scenario we project an increase in imported cars as more EV are sold in the market. This has the first-round effect of increasing imports of *Motor vehicles* (this occurs only in the early years of the simulation as the price of imported EV is expected to be at par in the long-run).

However, there is also a reduction in the demand for petroleum fuel as there is switching from ICE vehicles to EV. This has the second-round effect of reducing imports of *Petroleum and coal manufacturing* industry. The macroeconomic results show a reduction in imports, which implies that the second-round effect is larger than the first-round affect. Investment falls by $1.9 billion by the end of the simulation horizon. This is due to a higher investment price (particularly for the *Motor vehicles and parts manufacturing* industry) in the circular economy. Note that motor vehicles are an important input to investment. The increase in the price of investment reduces the rate of return for a given rental price; this leads to a fall in investment and a reduction in the capital stock. The contraction in the capital stock leads to a fall in real GDP by $1.5 billion lower in present value terms by 2047-48. Whilst the capital stock falls there is a minor increase in employment equivalent to 40 full time workers.

Figure 23: Macroeconomic impacts—Electrification of transport





Source: KPMG analysis

4.3.6 Car sharing

Simulation design

The impacts of this circular opportunity is estimated using the proxy of ride sharing or carpooling, i.e., a scenario where individuals decide to share a ride with other people to work and leave their cars at home. The direct effects of this are cost savings from fuel, parking, and car services and repairs that might have otherwise been incurred by workers driving their own car to work. To quantify these direct effects, we use the report produced by the Australian Railway Association (ARA) that provides cost comparisons of driving to work versus using public transport.[78] The ARA report revealed that workers who own a vehicle but travel to work by public transport can save $1,725 per year on average. In our circular economy scenario, we use this potential saving in our calculation but assume that workers share a ride with other car owners instead of taking public transport to work.

Data from the ABS 2016 census indicated that 69% of Australian workers drive a car to work while only 10% take public transport and 5% share a ride from car owners. These statistics translate to about 6.57 million private cars being used for commuting to work. In our circular economy scenario, this number of cars travelling from home to work and back can be substantially reduced if 2 or more workers decide to car share. Taking a conservative assumption of 2 passengers per car shared, then the number of cars used for work travel will be reduced by two-thirds or 4.38 million cars parked at home, or equivalently, 4.38 million workers sharing a ride. Multiplying this number of cars and workers with the estimated potential saving of ride sharing per passenger (using the potential saving of taking public transport as a proxy), the total cost saved is estimated at $7,560 million.

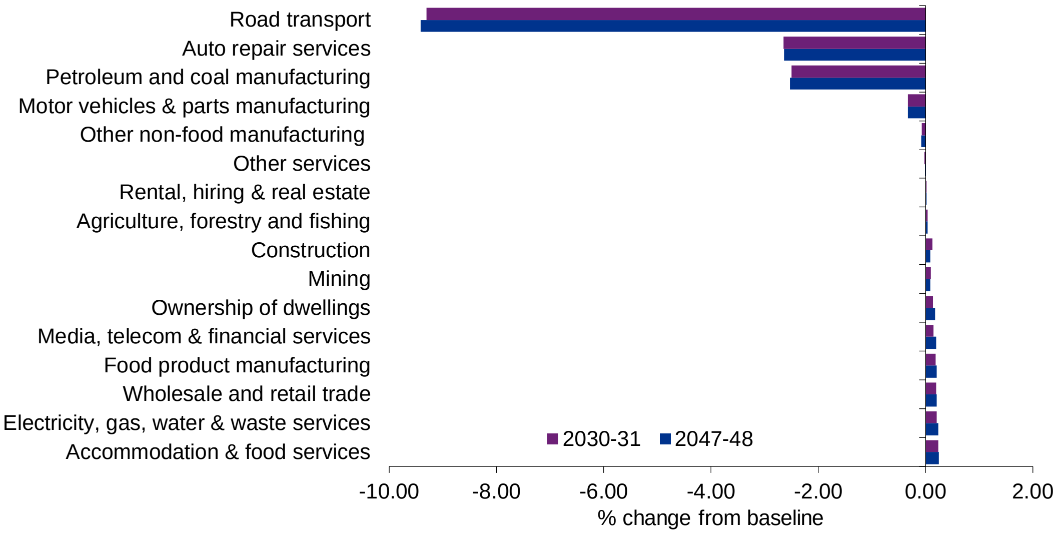
The total cost saved from ride sharing is implemented as a reduction in household expenditure in petroleum, road transport parking, and vehicle repairs. The magnitude of the shock in these three items is calculated using their cost shares from ARA data. Petroleum, parking and repairs account for 44%, 41% and 15% of total vehicle running expenses respectively. [79]

[78] Australian Railway Association, 2015. The Costs of Commuting: An Analysis of Potential Commuter Savings.
[79] Australian Railway Association, 2015. The Costs of Commuting: An Analysis of Potential Commuter Savings.

Economic outcomes

The economic activity of the *Road transport*, *Auto repair services*, and *Petroleum manufacturing* sectors contract, as shown in Figure 24. As some car owners now share the use of a vehicle with other users, there are effectively less cars in the economy and this reduces the demand for fuel, and road transport services like parking and tolls, and automotive maintenance works.

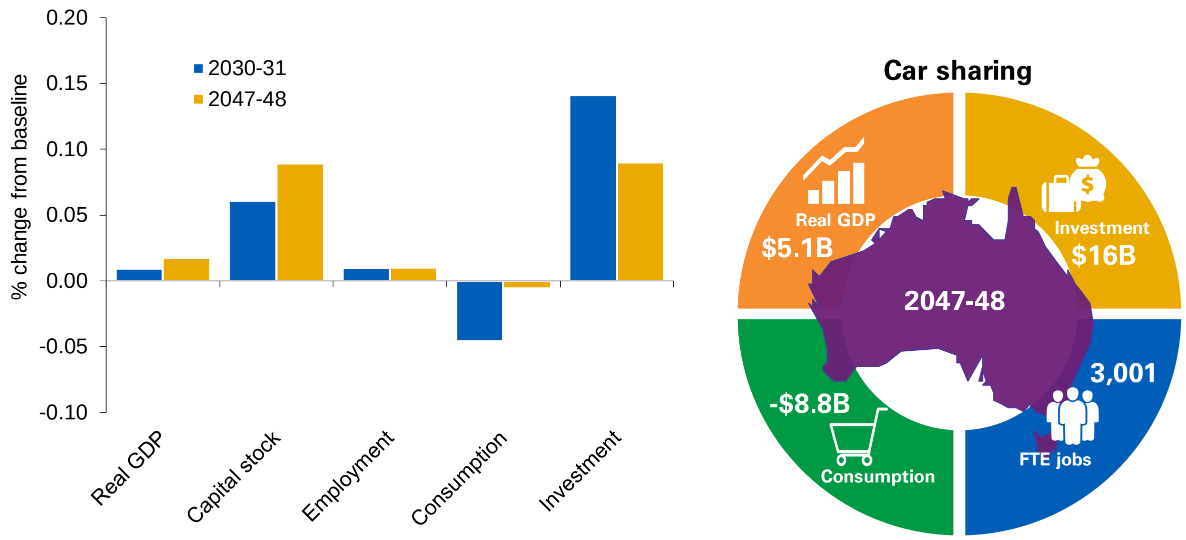
Figure 24: Industry impacts—Car sharing



Source: KPMG analysis

At the macro level, the savings from reduced household expenditure directly benefits investment as the changes in industry structure mean the economy becomes more capital intensive – see Figure 25. The increased investment leads to a larger capital stock and a less than proportional increase in employment. In dollar terms, the $8.8 billion contraction in real consumption is more than offset by a $16 billion cumulative increase in investment expenditure. This creates 3,001 more FTE jobs and increases real GDP by $5.1 billion by the end of 2047-48.

Figure 25: Macroeconomic impacts—Car sharing



Source: KPMG analysis

4.3.7 Compact dwellings

Simulation design

In the circular economy Australia will produce more compact dwellings. This is modelled as an improvement in technical efficiency in the use of capital resources in the dwelling sector. In applying this improvement in technical efficiency we assume that dwelling output is maintained at baseline levels but less capital is used in building dwellings. Housing data from the ABS shows that the current size of houses built in Australia is about 30 per cent bigger than 30 years ago. Using this figure, we impose a 1% improvement in the use of dwelling capital per year over the first ten years of the simulation period. This means that we are reversing approximately 10 years of growth in home size.

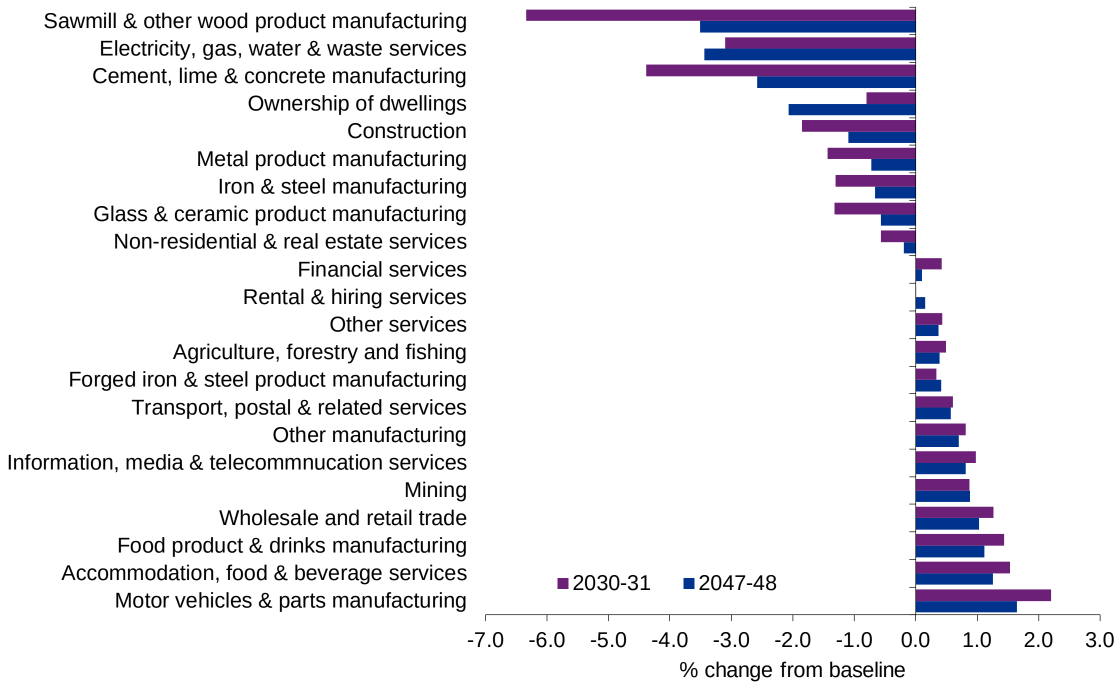
In addition to the improvement in capital productivity we also assume that household consumption of dwellings is maintained at baseline values. This reflects the idea that the reduction in average dwelling size reflects a change in household preferences, mandated reductions in dwelling size, or a combination of the two. Thus, households do not respond to the fall in the relative price of dwellings due to the productivity improvement.

Reducing the average home size translates to lower household expenditure on utilities such as electricity, gas and water. Hence, we also implement a reduction in household utility expenditure by the same magnitude as the capital productivity shock (1% per annum).

Economic outcomes

Figure 26 presents the percentage changes in sectoral output arising from this circular opportunity in residential construction. The size of the *Dwelling* sector shrinks as the size of housing units becomes smaller and cheaper. With smaller housing sizes, the use of intermediate inputs in dwellings falls and thus economic activity of industries supplying these intermediate inputs to *Dwellings* contracts, e.g., wood, cement, metal products, and construction works and services. The output of utilities (*Electricity, gas & water*) also falls as households use fewer of these with a smaller housing size. Household savings from dwelling and utility expenditure are spent on other consumption goods such as *Agricultural and food products*, and *Transportation*. The increase in household goods consumption is facilitated by an expansion of *Wholesale and retail trade*. The improvement in capital productivity causes a fall in the capital rental price of dwellings leading to a fall in the rate of return on *Dwellings*. This decreases investment in *Dwellings* and increases investment by other capital-intensive industries such as *Finance & insurance* and *Mining*.

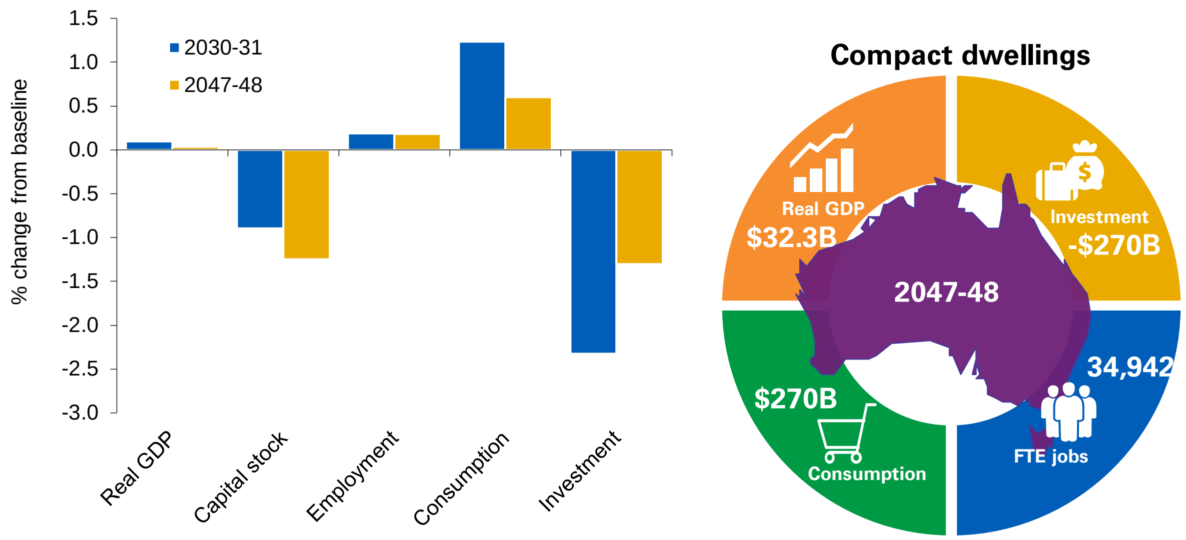
Figure 26: Industry impacts—Compact dwellings



Source: KPMG analysis

Macroeconomic effects of this circular opportunity are presented in Figure 27. Reducing the physical size of houses in Australia is implemented as an improvement in capital efficiency in the *Dwellings* sector. The *Dwellings* sector is a capital-intensive industry and represents around one-fifth of the total capital stock. Hence, an improvement in *Dwelling* capital efficiency in a circular economy translates to a reduction in the economy-wide capital stock. The fall in the demand for capital leads to a fall in the rental price, a fall in the rate of return and a fall in investment. The reduction in dwelling size causes the consumer price index to fall and this induces increased consumption. The fall in the consumer price index means there is a rise in the real wage rate, which in turn encourages an increased supply of labour. The dollar changes in macro variables indicate that the fall in investment expenditure is equally offset by the increase in consumption expenditure. This implies that real spending on investment goods is replaced by real expenditure on consumption goods. Overall, real GDP is $32.3 billion higher by 2047-48, with an increase in close to 35,000 FTE jobs.

Figure 27: Macroeconomic impacts—Compact dwellings



Source: KPMG analysis

4.3.8 Energy efficient buildings

Simulation design

For this circular opportunity, we assume that an increasing proportion of Australia's building stock is built with energy efficient building codes as outlined in the 2018 Built to Perform Report.[80] By 2028, we assume that 70% of buildings will conform to proposed 2028 code following a linear improvement from the current baseline.

Energy efficiency improvements were then modelled as a reduction in expenditure on *Electricity, gas, water & waste services* used by the *Dwellings* sector and by non-residential buildings. We also consider an increase in investment in the *Dwelling* sector and non-residential buildings to capture the capital costs associated with implementing energy efficiency measures. For example, estimates from Australian Sustainable Built Environment Council (ASBEC) and Climateworks (2018) indicate that implementing energy efficiency measures for an apartment in New South Wales to comply with the proposed 2028 code will result in an energy efficiency improvement of 13%, with an estimated up-front cost of $68 per square metre.[81] This is equivalent to around $5,200 for a 76 square metre apartment.

In aggregate, we estimate this circular technology to result in a 22% improvement in energy efficiency for affected buildings across Australia at a relatively significant average annual cost of around $2 billion from 2019 to 2030.

Economic outcomes

Figure 28 shows the impacts on industry output due to the circular opportunity of energy efficient buildings. Unsurprisingly, the *Dwellings* sector as well as the associated construction sectors are most affected by this circular opportunity. For the *Dwellings* sector, industry output is around 3.25% higher. For sectors such as *Sawmill & other wood product manufacturing* or *Cement, lime & concrete manufacturing*, industry output rises due to the increase in inputs required to provide, for example, better insulation. Similarly, the utilities sector is anticipated to see the greatest reduction in industry output. This is because buildings under this circular scenario are now more energy efficient and consume less electricity and gas.

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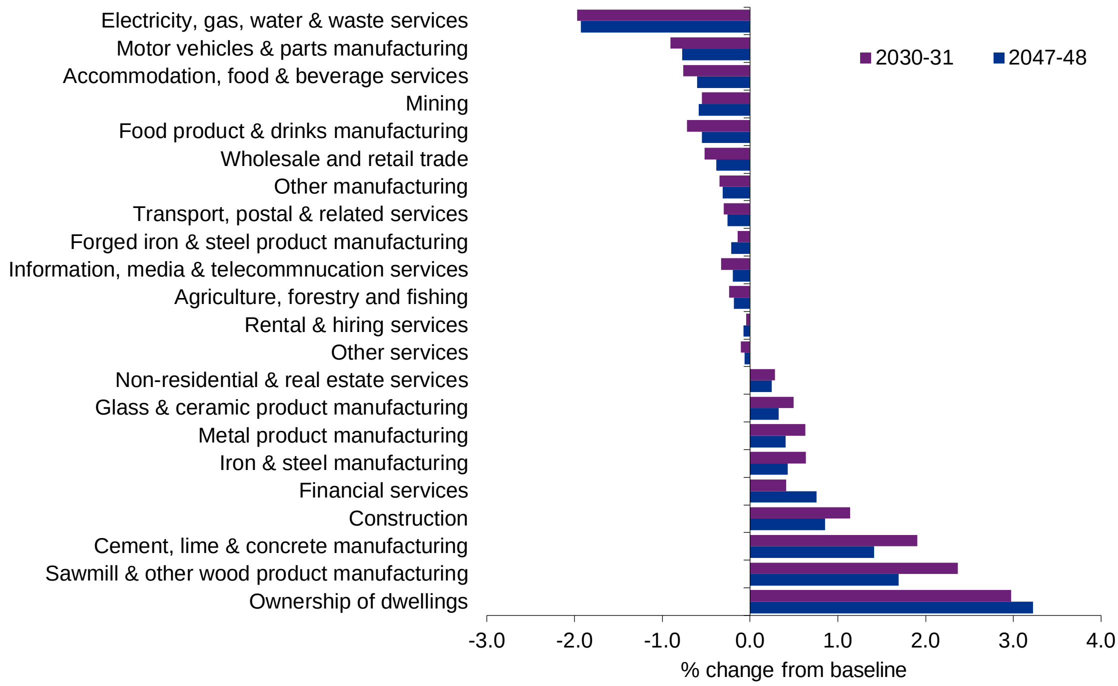
[80] ASBEC and Climateworks, 2018. Built to Perform.
[81] Ibid.

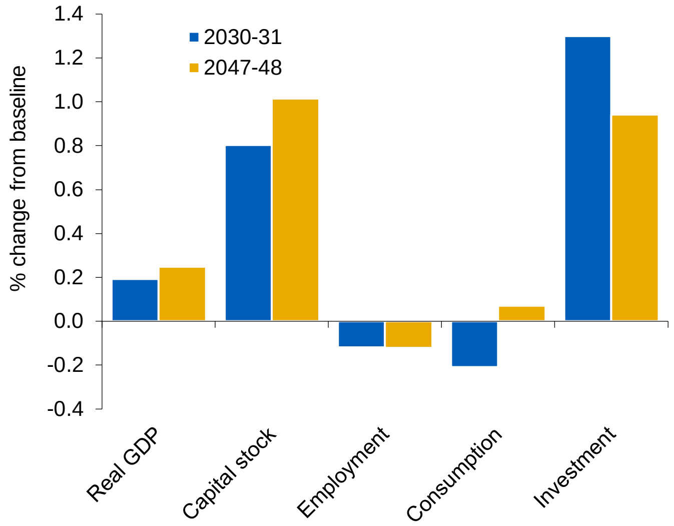
Figure 28: Industry impacts—Energy efficient buildings

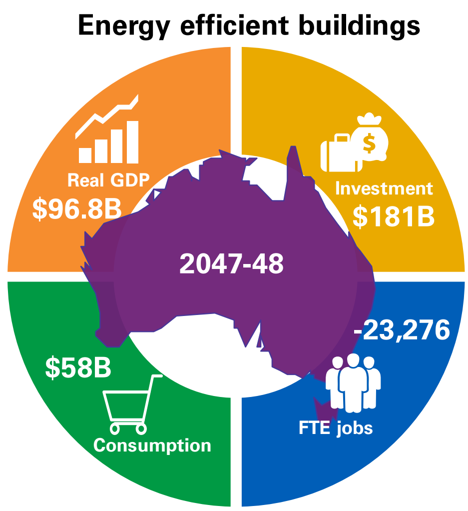


Source: KPMG analysis

Figure 29 shows the macroeconomic effects of this circular opportunity. Overall, real GDP increases by $96.8 billion. The main impact to the economy is a significant increase in investment resulting in a larger capital stock. This capital build-up reflects the additional investment required for installing circular dwelling designs amounting to $181 billion over a 30-year period. On the other hand, the reduction in consumption expenditure is mainly attributed to the reduction in household utilities as household dwellings become more energy efficient in the circular economy. The contraction of the *Electricity, gas and water* industry reduces total employment (around 23,276 FTE) as this service sector is labour intensive.

Figure 29: Macroeconomic impacts—Energy efficient buildings





Source: KPMG analysis

5 Limitations and recommendations

5.1 Limitations

This report focuses on the estimation of the potential economic impact of implementing specific circular opportunities in Australia. Our estimates should be considered in conjunction with the various limitations of our analysis.

A key limitation is that we did not account for the impact associated with externalities. For example, all of the circular opportunities analysed in this report have, to a various extent, environmental impacts such as reducing GHG emissions. Nevertheless, the results here do not include the monetary value associated with emission reductions. Other externalities, such as a reduction in water pollution from less phosphate runoff, or productivity improvements due to lower traffic congestion are also not modelled. Hence, the results presented here are likely to be conservative and should be taken only as indicative scenarios of the potential impact of circular economy.

One important aspect of our analysis is that we have attempted to capture the monetary cost and benefit of realising various circular opportunities using a bottom-up approach. This implies the estimation of various technological, financial and economic parameters is based on representative technologies, businesses and case studies, as well any of the assumptions outlined throughout Section 4. Necessarily, the impact of various circular opportunities may differ from our estimates due to unavoidable differences between our chosen examples and what will be realised in the future.

The detail and difficulty involved with estimating explicit parameters of circular opportunities, particularly the costs, is evident from the literature. For example, the EMF report relies on the central assumption that technology-induced efficiency gains such as the reduction of fuel consumption in transportation, comes as "manna from heaven".[82] Similarly, the EEIO-based estimation of circular economy benefits developed for South Australia tests the economy-wide impacts of various renewable energy and material efficiency assumptions.[83] In this example, the authors have generally assumed that any cost savings accruing to these changes are spent on the process of implementing and maintaining the technology. In other words, the benefits of circular opportunities such as improvements in energy efficiency were assumed to cancel out its costs.

Further, our report does not consider the impact of policies that may promote a circular economy. This means that we have only sought to capture circular opportunities that are likely to be viable from a financial and technological perspective based on current trends and patterns. For example, policies such as a carbon tax are potential measures to hasten a transition towards a low carbon economy and the electrification of transport or more energy efficient buildings.

In addition, we have restricted our analysis to individual circular opportunities and have not considered interactions when opportunities are simultaneously implemented. For example, our analysis of nutrient recovery and biogas both involve the transformation of organic waste into higher value outputs—fertiliser and electricity. In a circular economy future, these two opportunities are likely to be realised simultaneously.

Lastly, we have not made any restrictions to limit the rebound (or scale) effect. The rebound effect, as defined in the United Nations Environment Programme (UNEP) report on resource efficiency, is "… the phenomenon whereby financial savings arising from increased resource efficiency are then

[82] Böhringer, C. and Rutherford, T.F., 2015. The circular economy–an economic impact assessment. Report to SUN-iza, pp.1-33.
[83] Lifecycles et al., 2017. Creating value: the potential benefits of a circular economy in South Australia, Methods Report.

spent in ways that increase resource consumption, negating – either partially or wholly – the reduction in resource use achieved by the efficiency measure."[84] For example, in the case of food waste reduction, households will increase spending on other sectors due to lower expenditure on food. Another example is the electrification of transport vehicles. Households switching from the use of petroleum to electricity but using more of the latter may also mean greater usage of coal and fossil-based fuels in generating electricity unless there is a concomitant rising share of electricity produced through renewable energy sources.

5.2 Recommendations

Given our findings in this work we make the following recommendations for future work on the circular economy in Australia:

- The inclusion of externalities will provide a more comprehensive view of the full impacts of a circular economy. This requires an explicit modelling of carbon emissions and other environmental effects.
- Where possible, future studies should continue to explicitly estimate the size of the investment opportunity needed to realise a circular economy. In most cases, this requires more technical details on the capital that is to be created. For example, the price of building a biogas plant depends on highly variables factors such as the technical specifications of this capital as well as its geography.
- Interactions arising from simultaneously implementing different circular opportunities should be considered. For example, future work could consider the complementary impacts of reducing electricity consumption in energy efficient buildings with an increase in electricity demand from more EV.
- Supporting the realisation of a circular economy will require the explicit integration of policy when measuring economic impacts. For example, policies such as a tax on virgin resources or a carbon tax would most likely mitigate rebound effects owing to efficiency gains.
- Future work should apply an analytical framework that is explicitly designed to evaluate policies and technologies that promote a circular economy. Examples of such models exist for other countries but not for Australia. Such a framework would address most of the limitations listed above.

[84] UNEP, 2017. Resource efficiency: Potential and Economic Implications. A report of the International Resource Panel.

6 Conclusion

Momentum for a circular economy has been growing globally with the third World Circular Economy Forum concluding in June 2019. Closer to home, circular economy policies are being developed at the state level including South Australia, New South Wales and Victoria.

More broadly, circular economy concepts will likely play an important role in supporting progress towards the SDGs, as well as the Paris Agreement and the transition to a low-carbon future. Nevertheless, the literature also indicates significant economic gains arising from the transition to a circular economy.[85]

Apart from the 2018 *The potential benefits of a circular economy in South Australia* report, there has not been any detailed quantification of the economic benefits associated with a circular economy in Australia. Our findings show that a circular economy represents an important economic opportunity for Australia, with a potential benefit to real GDP of $210 billion in present value terms (or 11.4% of GDP) relative to the baseline where a circular transition did not occur. This result suggests that there is significant economic benefits associated with transitioning towards a circular economy in addition to any environmental or other benefits. Thus, our estimates should be considered as a lower bound on the benefits of a circular economy.

[85] See Section 2.2.2.

Appendix A: KPMG-CGE model

KPMG–CGE is a computable general equilibrium (CGE) model of the Australian economy.

Model theory and data

KPMG–CGE models the economy as a system of interrelated economic agents operating in competitive markets. Economic theory is used to specify the behaviour and market interactions of economic agents, including consumers, investors, producers and governments operating in domestic and foreign goods, capital and labour markets. Defining features of the theoretical structure of KPMG–CGE include:

- Optimising behaviour by households and businesses in the context of competitive markets with explicit resource constraints and budget constraints;
- The price mechanism operates to clear markets for goods and factors such as labour and capital (i.e., prices adjust so that supply equals demand); and
- At the margin, costs are equal to revenues in all economic activities.

The main features of KPMG-CGE are as follows.

- In dynamic mode, a simulation of the effects of a tax policy change involves running the model twice to create the baseline (or business-as-usual) scenario and the policy scenario. The baseline is designed to be a forecast of how the economy will evolve in the shortrun in the absence of the policy shock of interest. Thus, the paths of most macroeconomic variables are exogenous in the short-run and set in accordance with forecasts made by KPMG-MACRO (KPMG's macroeconomic model) and other macroeconomic forecasting groups (e.g., Commonwealth Treasury). In the long-run, the economy converges to a balanced growth path where all quantities grow by the 30-year average GDP growth rate and all prices by 2%. In the policy scenario, most macroeconomic variables are endogenous. With the exception of the policy variables of interest (e.g., tax rates), all exogenous variables in the policy scenario are assigned the values they have in the baseline scenario. The differences in the values of variables in the policy and baseline scenarios quantifies the effects of moving the variables of interest away from their baseline values.
- The key data input used by KPMG–CGE is an input–output table that quantifies the flows of goods and services between producers and various users (e.g., intermediate inputs to other producers, inputs to capital creators, households, governments and foreigners) and the flows associated with primary factor inputs (i.e., labour, capital, land and natural resources). In KPMG–CGE the input–output database is combined with the model's theoretical structure to quantify sophisticated

economic behavioural responses. KPMG-CGE distinguishes 117 sectors and commodities, based on an extended version of the 2015-16 input-output tables produced by the ABS.[86] The data is then updated to reflect the 2018-18 national accounts. This process gives base data that represents the Australian economy in 2017-18.

- Primary factors are distinguished by 117 types of capital (one type per industry), nine occupations, two types of land (primary and non-primary production land), natural resource endowments (one per industry), and owner-operator labour. There is a representative firm in each sector that produces only one commodity. Commodities are distinguished between those destined for export markets and those destined for domestic sales, so that the ratio of export prices and domestic prices is variable.
- Production technology is represented by nested CRESH functions (Hanoch, 1971)[87] allowing a high degree of flexibility in the parameterisation of substitution and technology parameters. Energy goods are treated separately to other intermediate goods and services in production, and are complementary to primary factors.
- There is an infinitely-lived representative household agent that owns the major share of factors of production with foreigners owning the remainder; the representative household can either spend or save its income. Total household consumption is assumed to be a function of household disposable income and the average propensity to consume. In the long-run, the average propensity to consume is endogenous and adjusts so that the ratio of net foreign liabilities to GDP stabilises. This mimics time-consistent behaviour by households and imposes a budget constraint on household behaviour in the long-run. Household consumption decisions by commodity are determined by a Stone-Geary utility function that distinguishes between subsistence (necessity) and discretionary (luxury) consumption (Stone, 1954).[88]
- The supply of labour is determined by a labour-leisure trade-off that allows workers in each occupation to respond to changes in after-tax wage rates thus determining the hours of work they offer to the labour market. The overall supply of labour is normalised on working-age population.
- KPMG-CGE includes detailed commonwealth and state government fiscal accounts including the accumulation of public assets and liabilities; these are based on the ABS's *Government Finance Statistics*.[89] Detailed government revenue flows are modelled, including over 20 direct and indirect taxes and income from government enterprises, and government expenditure includes government consumption, investment and the payment of various types of transfers (such as pensions and unemployment benefits).
- Investment behaviour is industry specific and is positively related to the expected rate of return on capital. This rate takes into account company taxation and a variety of capital allowances, including the structure of the imputation system.
- Foreign asset and liability accumulation is explicitly modelled, as are the cross-border income flows they generate and that contribute to the evolution of the current account. Along with other foreign income flows like labour payments and unrequited transfers, KPMG-CGE takes account of primary and secondary income flows in Australia's current account; these are particularly important for Australia as they typically comprise the significant share of the balance on the current account.

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[86] The ABS released IO tables for 2016-17 in June this year. We have not yet applied these in KPMG-CGE as the ABS sometimes revises the tables soon after release. In our experience it is more appropriate to use tables that have been in the public domain for at least one year as by then they can be considered as final.

[87] Hanoch, G. (1971), 'CRESH production functions', *Econometrica*, vol. 39, September, pp. 695–712.

[88] Stone, R. (1954), 'Linear Expenditure Systems and demand analysis: an application to the pattern of British demand', *The Economic Journal*, vol. LXIV, pp. 511–27.

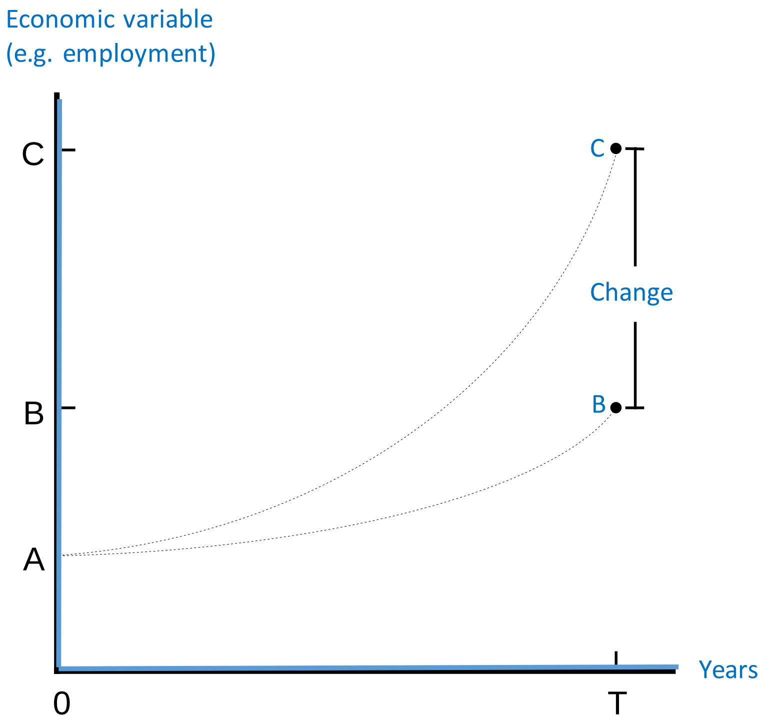
[89] Australian Bureau of Statistics (2019). *Government Finance Statistics, Australia, 2017-18,* Cat. no. 5512.0, Canberra, April.

Model outputs

To generate results, we run the model twice for each of the circular opportunities being assessed. First, we run a baseline simulation that captures the assumptions of the baseline scenario. Second, we run a policy simulation that captures the elements of the counterfactual circular scenarios in addition to the baseline.

The economic effects of each circular opportunity is measured by the difference in the values of economic variables between the baseline and counterfactual simulation results. This process is illustrated in Figure 30. Considering employment as a variable of interest, the current level of employment in the initial database is at point A. In running the baseline scenario, the model will generate a long-run forecast of employment without the circular activity. After T years the level of employment in the baseline is at point B. Then, in running the counterfactual analysis, we implement the circular activity and the model recalculates the long-run value of employment. Employment level is now at point C. The difference between the counterfactual and baseline result (C-B) gives the change in employment attributable to the circular activity. This calculation is repeated for all economic variables in the model.

Figure 30: Illustration of how simulation results are to be interpreted



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