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Creating value

THE POTENTIAL BENEFITS OF A CIRCULAR ECONOMY IN SOUTH AUSTRALIA

METHODS REPORT

Methods Report prepared by Lifecycles, EconSearch, Colby Industries and the University of Queensland, for Green Industries SA.
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introduction

This document explains the methods used in the study “Creating Value: The potential benefits of a circular economy in South Australia”.

This report is a companion document to the main report that was prepared as part of a study commissioned by Green Industries SA to analyse the potential benefits regarding employment and greenhouse gas emissions if South Australia were to move towards a more circular economy in the future.

It explains the project task and provides an overview of the modelling approach (Modelling Overview), before describing the modelling approach in more detail (Modelling Approach) and detailing the scenario descriptions and assumptions used (Scenario Descriptions).

modelling overview

The project task was to quantify the potential benefits of a more circular economy to South Australia, in terms of greenhouse gas emissions and jobs.

The project team extended the analysis to also examine energy consumption.

The year of comparison is 2030. This date is far enough away to be able to enact real change, but close enough to 2016 to be tangible.

The assumptions adopted to assess potential impacts of the scenarios were benchmarked against other similar international studies and tailored with Green Industries SA's guidance to reflect South Australia's particular circumstances. An international panel of circular economy experts reviewed key assumptions, modelling techniques and results.

The following four scenarios were modelled:

BUSINESS AS USUAL
Based on existing trends and implementation of current policy on renewable energy (State Strategic Plan).

EFFICIENT AND RENEWABLE ENERGY
South Australia implements its ambitious Climate Change Strategy 2015-2050.

MATERIAL EFFICIENCY
Products, components and materials are kept at their highest utility/value at all times.

CIRCULAR ECONOMY
The strategies from Material Efficiency and Efficient and Renewable Energy scenarios are combined to achieve a circular economy.

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In this study we analysed what effect a suite of energy and material 'decoupling[1]' measures would have on the structure of the SA economy in the year 2030. The effect was measured in terms of the economy-wide change in employment, greenhouse gas emissions and energy use between 'business-as-usual' and the three decoupling scenarios.

A purpose-designed environmentally extended input-output model of the South Australian economy was used to generate results across the 78 industry sectors[2] and households.

The input-output transactions table in the model reflects how different sectors buy and sell natural resources and intermediate goods and services from and to each other in often complex supply chains. The result is the delivery of a product or service to the final consumer within the SA economy or to export.

The adjustment of the input-output model to reflect the decoupling measures in the scenarios has been achieved by adjusting the supply chains and then rebalancing the sectoral trade in the transactions table in the input-output-model. The overall size of the economy (measured in terms of gross state product) is kept constant between all scenarios to observe the structural changes to the SA economy that could be expected and to assess the potential benefits in these terms. This conservative approach is consistent with modelling in the recent report to the Club of Rome [1], which analysed the greenhouse gas emissions and employment effects of adopting a circular economy in several European countries.

To maintain the same sized economy across scenarios, it was assumed that the total income (gross state product) generated by the economy remained constant. To create the structural change needed to achieve the decoupling measures, it was assumed that a proportion of purchases of goods and services (both intermediate and final demand) are redirected from some sectors to other sectors in the economy. The individual assumptions for each decoupling measure are described in more detail in the Scenario Descriptions section of this report.

International Expert Committee

- Stephanie Hubold, Government & Cities Programme Lead, Ella Jamsin, Research Manager and Lukasz Holec, Project Manager, Ellen MacArthur Foundation
- Dustin Benton, Acting Deputy Director, Green Alliance
- Peter Mitchell, Head of Economics, WRAP
- Anders Wijkman, Associate Senior Fellow, and Kristian Skånberg, Associate, Stockholm Environment Institute
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- Sonia Valdivia, Programme Manager, Sustainable Recycling Industries and Life Cycle Management, World Resources Forum

[1] Decoupling = reducing the rate of material or energy use per unit of economic activity.
[2] The 78 sectors are listed in appendix 1.

modelling approach

This section explains how the environmentally extended input-output (EEIO) model was developed and used in this study.

Why Input-Output modelling?

The input-output model framework has been chosen as it is the only approach that takes account of the multitude of impacts linked to changes in product and material flows, with a single consistent set of data. Other approaches based on process analysis are likely to suffer incompleteness and inconsistency in the results, especially given the budget and timeframe of the study.

The purpose built environmentally extended input-output (EEIO) model makes use of two existing models:

- The Australian Industrial Ecology Virtual Laboratory (IELab- http://ielab.info/) is a collaborative platform for multi-region input-output modelling used for environmental economic modelling, life-cycle assessment, environmental footprinting, triple bottom line and supply chain analysis.
- The Regional Industry Structure and Employment (RISE) input-output model for South Australia is used to assist regional planning at both state and regional levels.

RISE provides a detailed picture of the structure of an economy at a point in time. This is used as a basis for analysing inter-sectoral relationships within that economy, making it ideal for regional impact analysis.

Developed by EconSearch, the first set of South Australian RISE models were commissioned by the Regional Communities Consultative Council in 2004. They were updated in 2007 for the SA Department of Trade and Economic Development, and updated again in 2010 and then annually in each year from 2013 to 2016 for the SA Department of Premier and Cabinet.

The RISE model can be distinguished from the standard input-output model through add-ons that allow for more realistic assessments of regional economic impacts, including:

- The Price Response Model that overcomes the lack of flexibility to consider different scenarios of market response and regional adjustment in standard input-output models. The price sensitive RISE model provides for non-linearity in production in both primary and intermediate inputs delivering results (e.g. multipliers and simulated impacts) that are more closely aligned with CGE modelling yet with greater rigour and credibility for analysis at a local scale.
- The Demographic Economic Model that introduces a population ‘sector’ (or row and column in the model) to estimate the impact on local population levels of employment growth or decline, and an unemployed

'sector' to account for the consumption-induced impact of the unemployed in response to economic growth or decline.

Method

An overview of the EEIO approach, using both RISE and IElab, is provided in the figure and sections below. The model provides results across the 78 different economic sectors presented in Appendix 1.

The scenarios are described in detail in the next section.

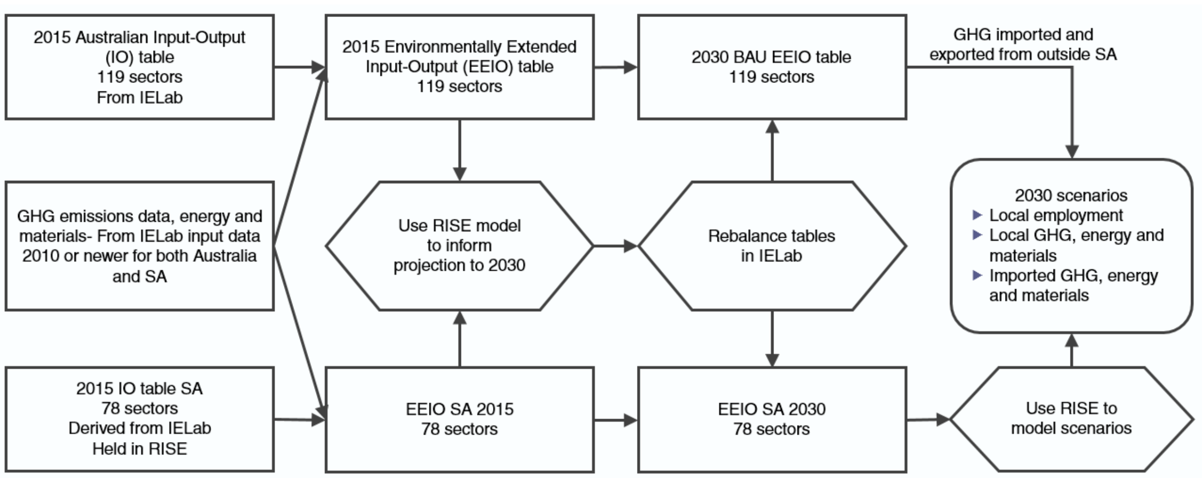

Figure 1 – Overview of the EEIO modelling approach.

1/ EEIO model for baseline year (2015)

EEIO models were developed for the SA economy and the Australian economy to take account of the embedded greenhouse gas emissions, energy and materials in imported goods and services to SA. Note that embedded emissions, energy and materials from goods imported from outside Australia were not specifically modelled.

2015 was used as the base year as this is the most recent year for which data for the economic datasets are consistently available. Environmental datasets, which were less up-to-date, have been extrapolated from the dataset's latest year to the base year using the most recently available intensity coefficients.

The environmental data sets were incorporated into the standard RISE models for SA and Australia as satellite accounts:

- The greenhouse emissions satellite was derived from state level data from Australian Greenhouse Emissions Information System (AGEIS) and covers 86 sectors.
- The energy data satellite was developed from Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) Energy Statistics series.

2/ Future EEIO model for business as usual scenario (2030)

Trend data and projection assumptions for the business as usual scenario were developed for 2030. Economic trend data for all sectors excluding mining was based on a geometric growth rate over 25 years of historical data from the ABS State accounts and labour force datasets. Mining was based on the trend data for the first 15 years of the last 25 years to remove the distorting effect of the latest mining boom.

A similar process was undertaken for the environmental satellite account data to determine any changes in the environmental intensities per sector in 2030 compared to 2015. All greenhouse gas intensities except for the electricity generation sector were kept the same. The greenhouse gas emissions intensity coefficient was reduced in line with the modelling in the Expert's Panel report [2], as detailed in the scenario descriptions section of this report.

Energy use coefficients (TJ/$m output) for the business as usual 2030 model were based on an average of 8 year's data (2006/07 – 2013/14).

These adjusted projection rates were used to generate models of the SA and Australian economies for 2030.

3/ Future EEIO models for SA for energy, materials and circular scenarios (2030)

Following a similar process described earlier, EEIO models for SA for the efficient and renewable energy, material efficiency and circular economy scenarios for 2030 were developed. Projection assumptions for these scenarios were adjusted from business as usual to factor in envisaged changes to the structure of the economy under each of these scenarios. Flow-on effects were incorporated into the projection assumptions using standard IO modelling.

The environmental 'footprint' of imports into SA are based on the Australian 2030 EEIO model.

4/ Hybrid EEIO models external to RISE

A waste model external to RISE was developed to analyse specific sector changes (see Figure 2 and Appendix 3). A physical account of waste management practice was modelled to determine both the changes in material demand due to recycling flows and the greenhouse gas emissions and energy from the waste management technologies.

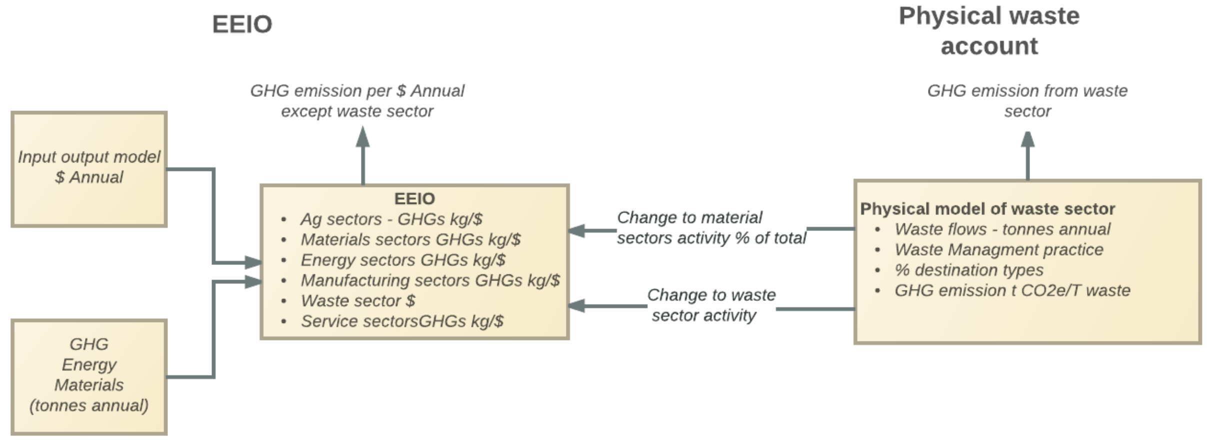

Figure 2 – Hybrid EEIO model for waste.

5/ Measuring Impact

The environmental and economic impacts were measured for each scenario as the difference between the business as usual profile and the scenario profile of that indicator.

scenario descriptions

Assumptions for each scenario were developed through the literature review (Appendix 2), a scenario planning workshop held with Green Industries SA, and discussions held with members of the international expert committee.

BUSINESS AS USUAL

Business as usual is established by examining the existing baseline trends in South Australia and projecting forward to 2030. This scenario forms the base case against which the other scenarios are compared.

The economy of the business as usual scenario in 2030 is 48% bigger than the 2015 SA economy in terms of gross state product (GSP), which equates to an annual growth rate 2.66%. The size of the business as usual economy is comparable with other studies[3].

Business as usual projections assume that current State policy on renewable energy is implemented and that electricity generation continues to de-carbonise, consistent with the targets in the State Strategic Plan (and reference case modelling undertaken for the SA's Low Carbon Economy Experts Panel). This means the share of renewables in the energy mix increases by 33 percentage points by 2030 in comparison with the current situation (i.e. a shift from today of approximately 23% to 56% of electricity generated coming from renewable energy sources by 2030). Reflecting the closure of South Australia's only coal mine and last coal-fired power station in 2015/16, it is assumed that there will be no coal-based electricity generation and no coal mining in SA in 2030. Other coal used within the SA economy is assumed to be imported into SA as per the current situation.

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[3] See, for example, SA's Low Carbon Economy Experts Panel and references within that report on other modelling, which used annual GSP growth rates of between 2.34% and 2.71%.

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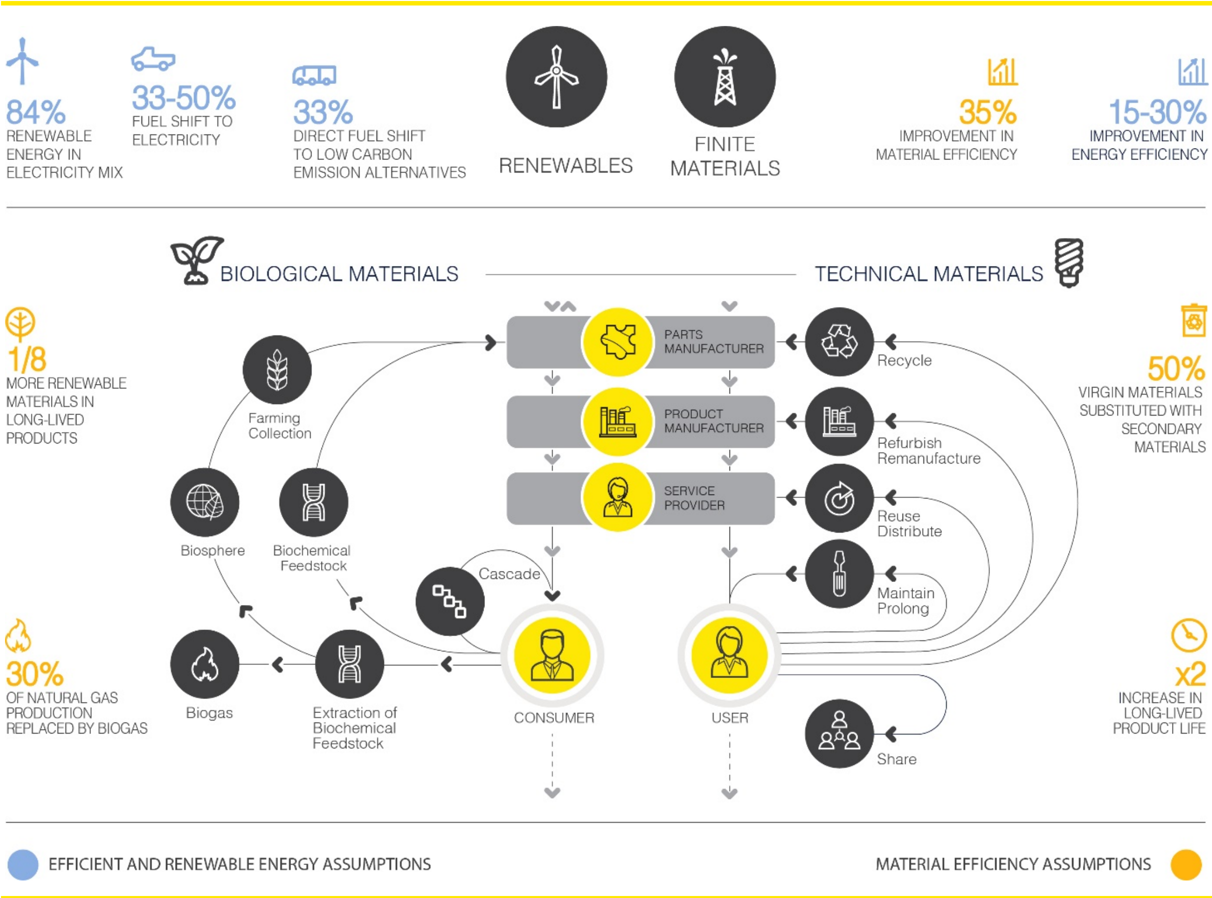
CIRCULAR ECONOMY

The circular economy scenario combines measures from both the material efficiency and the efficient and renewable energy scenarios.

This reflects that a truly circular economy is not just about circulating products, components and materials to optimise resource yields. It also addresses using finite stocks of both energy and material carefully. Hence energy and material efficiency needs to happen as a first step, and turning towards renewable sources of energy is also important.

The assumptions used for our modelling are mapped against the Ellen MacArthur Foundation's outline of a circular economy in Figure 3, and described in the following sections.

Figure 3 – Circular economy modelling assumptions.



Efficient and Renewable Energy Assumptions

This scenario assumes that South Australia is on-track with the energy efficiency and renewable energy measures set out in the SA Government's ambitious *Climate Change Strategy 2015-2050*. Our modelling includes the low carbon electricity, energy efficiency, electrification and fuel switching strategies set out in the Climate Change Strategy under Theme 2 (towards net zero emissions), as set out below. The modelling does not include the non-energy emission strategies set out under Theme 2, including offsets.

84%	15-30%	33-50%	33%
RENEWABLE ENERGY IN ELECTRICITY MIX	IMPROVEMENT IN ENERGY EFFICIENCY	FUEL SHIFT TO ELECTRICITY	DIRECT FUEL SHIFT TO LOW CARBON EMISSION ALTERNATIVES

These assumptions are based on the SA's Low Carbon Economy Experts Panel's decarbonised scenario modelling [2]. As these assumptions come from detailed modelling that forms the basis for the State's Climate Change Strategy, they are considered to be feasible to achieve in 2030[4]. They are still considered as "stretch" targets since they are not yet included in South Australia's Strategic Plan.

ASSUMPTION DESCRIPTIONS

84% RENEWABLE ENERGY IN ELECTRICITY MIX	Half of natural gas based electricity generation is replaced by renewable energy sources (e.g. solar, wind, wave, geothermal) compared with the business as usual scenario. In practical terms, this translates to 84% of electricity generated coming from renewable energy sources. Cost savings by the electricity generation sector from reduced purchases of natural gas is assumed to be spent on services supporting renewable energy generation. This measure results in a lowering of the carbon emission factor for all sectors using electricity in the model compared to business as usual.
15-30% IMPROVEMENT IN ENERGY EFFICIENCY	Energy consumption per unit output is reduced by 30% in commercial buildings and households, 18% in manufacturing and 15% in transport. Cost savings in energy use is assumed to be spent on services that drive that efficiency, increasing expenditures in the construction services, professional, scientific and technical services, personal and other services and other machinery and equipment manufacturing sectors.
33-50% FUEL SHIFT TO ELECTRICITY	Manufacturing industries substitute 50% of their petroleum-based fuel use and 33% of their coal use with electricity. The transport sector and households substitute 40% of their petroleum-based transport fuel use with electricity.
33% DIRECT FUEL SHIFT TO LOW CARBON EMISSION ALTERNATIVES	Manufacturing industries substitute 33% of their coal use with natural gas, and the transport sector and households substitute 33% of their petroleum-based fuel use with biofuels.

[4] The SA's Low Carbon Economy Experts Panel refers to these assumptions as being technically feasible and relatively cost effective.

Material Efficiency Assumptions

In this scenario by 2030 the South Australian economy keeps products, components and materials at their highest value through new policy and economic models that extend product life, reduce natural resource consumption, minimise waste generation, and maximize the reuse, recovery and/or recycling of materials.

The five measures to reduce material use intensity over business as usual that were modelled:

35%
IMPROVEMENT IN MATERIAL EFFICIENCY

x2
INCREASE IN LONG-LIVED PRODUCT LIFE

50%
VIRGIN MATERIALS SUBSTITUTED WITH SECONDARY MATERIALS

1/8
MORE RENEWABLE MATERIALS IN LONG-LIVED PRODUCTS

30%
OF NATURAL GAS PRODUCTION REPLACED BY BIOGAS

The first three measures were based on the 2015 report to the Club of Rome entitled “The Circular Economy and Benefits for Society” [1]. They were selected to examine broad structural changes that could result from transition to a circular economy. Their application in the modelling was adapted to the South Australian context.

The increase of biogas and renewable construction materials in the South Australian economy were selected as assumptions to further investigate the role of biological materials in a circular economy.

ASSUMPTION DESCRIPTIONS

Each assumption is discussed in detail below.

35%
IMPROVEMENT IN MATERIAL EFFICIENCY

Under this assumption, companies become more efficient in their use of durable raw materials, such as wood and metals, by 2% per annum, or 35% by 2030. This assumes that companies would produce the same output, using fewer raw materials through better design and less process wastage.

The reduced expenditure on durable raw materials is assumed to be spent on services that drive that efficiency, such as primary sector support services, machinery/ equipment manufacturing, construction services and professional, scientific and technical services.

The 2% per annum improvement is consistent with analysis commissioned by the European Commission [3] which demonstrated that a 2% to 2.5% annual improvement in resource productivity is achievable without impacting on EU GDP. The report to the Club of Rome [1] also uses 2% per year material efficiency improvement assumption.

ASSUMPTION DESCRIPTIONS

x2
INCREASE IN LONG-LIVED PRODUCT LIFE

This assumption examines the effects of doubling the end-user product life for both local and imported long-lived goods such as furniture, clothing, vehicles and buildings[5].

This assumption reflects the importance of keeping tighter resource loops. This provides the greatest mitigation of risk and the highest value recovery to businesses since reuse and remanufacturing preserve much of the value created through manufacturing [4].

The reduced expenditure on long-lived goods is assumed to be spent on services that support enhanced product life: personal services (including repair) and construction services for buildings, renting and leasing, and professional, scientific and technical services (e.g. research, architects, engineers). Regarding buildings, this means that money that would be spent on new builds to replace aging housing is progressively (taking into account the much slower turnover of this good) spent on services that support enhanced product life.

This is a stretch assumption, and will require ambitious policy measures to support new business models such as product-services systems.

50%
VIRGIN MATERIALS SUBSTITUTED WITH SECONDARY MATERIALS

In this assumption, manufacturing sectors[6] substitute 50% of their virgin materials with secondary materials.

The money these manufacturers would have spent on virgin materials, both local and imported, is instead spent on:

- the purchase of secondary materials from local waste services and manufacturing sectors, and
- sectors that support that transition such as transport (reverse logistics), storage, wholesale, retail and services.

Sourcing the necessary amounts of secondary materials for this transition will be a challenge, especially as waste generation should slow with increased product life. It presents opportunities for retaining and transforming more waste commodities within South Australia and may require sourcing of recovered materials from other regions. For simplicity the assumption was applied equally across all manufacturing sectors, however in reality some sectors would probably use higher levels of recovered materials than others.

[5] M2 sectors in Appendix 1
[6] Manufacturing of intermediate and long-lived final demand goods, M1 and M2 sectors in Appendix 1

ASSUMPTION DESCRIPTIONS

30%
OF NATURAL GAS PRODUCTION REPLACED BY BIOGAS

Here the modelling explores an expansion of the biogas industry that replaces approximately 30% of SA natural gas production.

Biogas is produced by the breakdown of organic matter from raw materials such as agricultural waste, manure, municipal waste, plant material (e.g. farmed marine algae), sewage, green waste or food waste in the absence of oxygen. It is considered a key strategy for achieving a circular economy of biological materials, especially when anaerobic digestion can produce high quality fertiliser and energy at the same time.

Replacing 30% of SA's natural gas production with biogas is a stretch assumption, and further studies are needed to investigate the potential feedstock. For simplicity in the modelling half of the biogas comes from municipal waste/sewage treatment works and half from livestock industries.

The emission factors for waste disposal, fugitive emissions and energy production from gas were adjusted to take into account the diversion of methane from being an emission to being an energy source in the gas supply.

1/8
MORE RENEWABLE MATERIALS IN LONG-LIVED PRODUCTS

This assumption explores the effect of an increase in the use of renewable materials in the economy. These materials generally contain less embodied energy than their non-renewable counterparts, and can also help avoid the depletion of non-renewable resources.

The construction sector was used as a simplified example in the model with a 12.5% shift from non-metal mineral production (e.g. concrete products, plasterboard, etc.) and metal products to wood-based products.

In reality such a shift would benefit a range of products (see box) and occur in other sectors too.

Examples of renewable (or bio-based) materials in construction

- Conventional biobased products and materials are biodegradable and made from animal or plant materials. Building material examples include pulp and paper, wood, leathers, wool, and crop based materials such as flax, hemp, bamboo and coconut fibres.
- Wood-based building materials include solid, finger-jointed or laminated timber, medium-density fibreboard, particleboard and hardboard.
- Emerging biobased materials, or biorenewables, are often active subjects of research and development. They are extracted by bio-refining processes or produced from materials with biological origins. For example, sugar beets can be refined to first extract sugar, then lactic acid, and finally polylactic acid (PLA) for use in plastics.

Cross-laminated timber has structural properties comparable with steel and reinforced concrete, enabling the construction of multi-storey wood buildings such as the six-storey International House under construction in Sydney.

15/ Territorial versus consumption-based environmental indicators

In the main report of this study greenhouse gas emissions are reported as consumption-based emissions and energy use is reported on a territorial basis.

The meaning of these terms and why they were applied in this manner is explained in this section.

Since the inception of the ecological footprint in 1995[7], there has been much discussion on the merits of accounting for impacts on a consumption basis or a territorial (or production) basis.

- TERRITORIAL IMPACTS are those which are physically generated within a region under study. In our study this includes jobs created and lost, greenhouse gases emitted and energy produced in South Australia.
- CONSUMPTION IMPACTS are the full supply chain impacts for good and services consumed in the region under study. This includes what is known as “embodied carbon” and “embodied energy”, linked to materials and products imported into, in our case, South Australia. Consumption-based impacts exclude the impacts of exported goods and services and include the impacts of imported goods and services.

Territorial impacts are more relevant when focusing on sustainability of local environments, especially in relation to carrying capacity and pressure state response frameworks used in state of environment reporting.

Consumption-based impacts are more relevant when trying to assess the sustainability of consumption patterns of people and processes. For issues such as global warming, the effects are not restricted to regional borders, and contributions from along the supply chain can be equal to or larger than those contained within territorial borders. For example, Australia imports 23% of clinker (calcined material which is ground to make Portland cement) from China and Japan. Clinker represents over 80% of the greenhouse gas emission impacts of typical concrete manufacture, so a territorial emission based assessment would miss 18% of the global emission impact from concrete [5].

In this study, employment and energy are examined from a territorial basis. Local employment generation is a major policy objective for the South Australian government and for energy use we are interested in local energy self-sufficiency. A consumption basis is used for greenhouse gas emissions to allow consideration of embodied emissions in the consumption patterns within South Australia.

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[7] The ecological footprint was one of the first applications of environmental accounting to focus on impacts within regions.

EFFECT ON RESULTS

Figure 4 shows the balance of territorial, imported and exported greenhouse gas emissions for a circular economy compared with business as usual. It demonstrates that a circular economy reduces territorial emissions, but has little effect on emissions from imported goods coming into South Australia. This is partly because of the assumption that the rest of the world outside South Australia is not undergoing a circular economy transformation. It also represents that the focus of the circular economy model has been on efficiencies in the local supply chain and less on end use consumption behaviour for households.

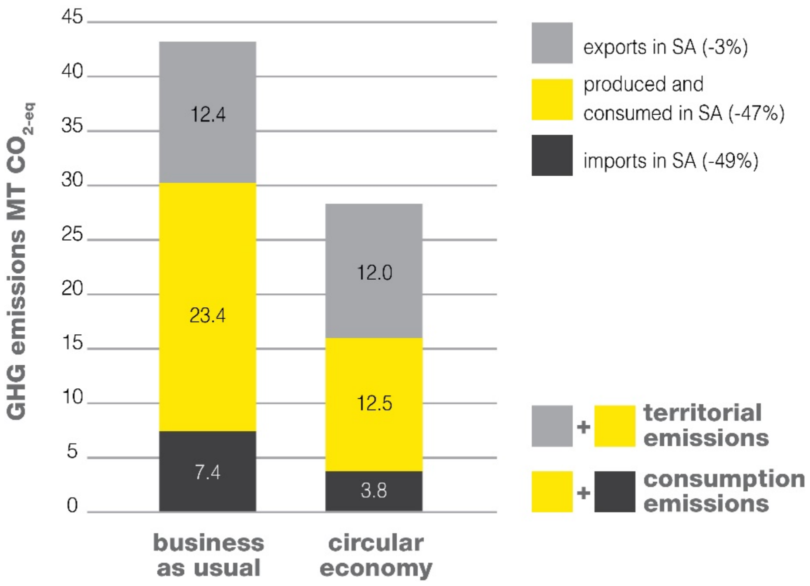


Figure 4 – Territorial and consumption-based greenhouse gas emissions.

appendix 1
sector mapping

The following table shows the mapping between the sectors in the IELab database to the 78 South Australian economic sectors used for the EEIO model, following the Australian and New Zealand Standard Industrial Classification. A further distinction has been made for the modelling and presentation of results based on the following sector groupings:

- Manufacturing - intermediate goods (M1)
- Manufacturing - long-lived final demand goods (M2)
- Manufacturing - short-lived final demand goods (M3)
- Primary industries
- Services

IE Lab, 119 Sectors		South Australia & Regions, 78 Sectors	
1	Sheep	1	Sheep
2	Grains	2	Grains
3	Beef Cattle	3	Beef Cattle
4	Dairy Cattle	4	Dairy Cattle
5	Poultry	5	Poultry
6	Pigs	6	Pigs
7	Other Livestock	7	Other Livestock
8	Winegrapes	8	Winegrapes
9	Vegetables	9	Vegetables
10	Fruit and Nuts	10	Fruit and Nuts
11	Other Agriculture	11	Other Agriculture
12	Aquaculture	12	Aquaculture
13	Forestry and Logging	13	Forestry and Logging
14	Fishing, hunting and trapping	14	Fishing, Hunting and Trapping
15	Agriculture, Forestry and Fishing Support Services	15	Agriculture, Forestry and Fishing Support Services
16	Coal mining	16	Coal Mining
17	Oil and gas extraction	17	Oil and Gas Extraction
18	Iron Ore Mining	18	Iron & Non-ferrous Ore Mining
19	Non Ferrous Metal Ore Mining		
20	Non Metallic Mineral Mining	19	Non Metallic Mineral Mining
21	Exploration and Mining Support Services	20	Exploration and Mining Support Services

IE Lab, 119 Sectors		South Australia & Regions, 78 Sectors	
22	Meat and Meat product Manufacturing	21	Meat and Meat Product Manufacturing
23	Processed Seafood Manufacturing	22	Processed Seafood Manufacturing
24	Dairy Product Manufacturing	23	Dairy Product Manufacturing
25	Fruit and Vegetable Product Manufacturing	24	Fruit and Vegetable Product Manufacturing
26	Oils and Fats Manufacturing	25	Oils and Fats Manufacturing
27	Grain Mill and Cereal Product Manufacturing	26	Grain Mill and Cereal Product Manufacturing
28	Bakery Product Manufacturing	27	Other Food Product Manufacturing
29	Sugar and Confectionary Manufacturing		
30	Other Food Product Manufacturing		
31	Soft Drinks, Cordials and Syrup Manufacturing	28	Other Beverages
32	Beer Manufacturing	29	Beer Manufacturing
33	Wine, Spirits and Tobacco	30	Wine, Spirits and Tobacco Manufacturing
34	Textile Manufacturing	31	Textiles, Clothing and Footwear Manufacturing
35	Tanned Leather, Dressed Fur and Leather Product Manufacturing		
36	Textile Product Manufacturing		
37	Knitted Product Manufacturing		
38	Clothing Manufacturing		
39	Footwear Manufacturing		
40	Sawmill Product Manufacturing	32	Sawmill Product Manufacturing
41	Other Wood Product Manufacturing	33	Other Wood Product Manufacturing
42	Pulp, Paper and Paperboard Manufacturing	34	Pulp, Paper and Paperboard Manufacturing
43	Paper Stationery and Other Converted Paper Product Manufacturing	35	Paper Stationery and Other Converted Paper Product Manufacturing
44	Printing (including the reproduction of recorded media	36	Printing (including the reproduction of recorded media)
45	Petroleum and Coal Product Manufacturing	37	Petroleum and Coal Product Manufacturing
46	Human Pharmaceutical and Medicinal Product Manufacturing	38	Pharmaceutical & Other Chemical Product Manufacturing
47	Veterinary Pharmaceutical and Medicinal Product Manufacturing		
48	Basic Chemical Manufacturing		
49	Cleaning Compounds and Toiletry Preparation Manufacturing		
50	Polymer Product Manufacturing		
51	Natural Rubber Product Manufacturing		
52	Glass and Glass Product Manufacturing	39	Non-metallic Mineral Product Manufacturing
53	Ceramic Product Manufacturing		
54	Cement, Lime and Ready-Mixed Concrete Manufacturing		
55	Plaster and Concrete Product Manufacturing		
56	Other Non-Metallic Mineral Product Manufacturing		
57	Iron and Steel Manufacturing	40	Iron and Steel Manufacturing
58	Basic Non-Ferrous Metal Manufacturing	41	Basic Non-Ferrous Metal Manufacturing
59	Forged Iron and Steel Product Manufacturing	42	Metal Product Manufacturing
60	Structural Metal Product Manufacturing		

IE Lab, 119 Sectors		South Australia & Regions, 78 Sectors	
61	Metal Containers and Other Sheet Metal Product manufacturing		
62	Other Fabricated Metal Product manufacturing		
63	Motor Vehicles and Parts; Other Transport Equipment manufacturing	43	Motor Vehicles and Parts; Other Transport Equipment Manufacturing
64	Ships and Boat Manufacturing	44	Other Machinery & Equipment Manufacturing
65	Railway Rolling Stock Manufacturing		
66	Aircraft Manufacturing		
67	Professional, Scientific, Computer and Electronic Equipment Manufacturing		
68	Electrical Equipment Manufacturing		
69	Domestic Appliance Manufacturing		
70	Specialised and other Machinery and Equipment Manufacturing		
71	Furniture Manufacturing	45	Furniture Manufacturing
72	Other Manufactured Products	46	Other Manufactured Products
73	Electricity Generation	47	Electricity Generation
74	Electricity Transmission, Distribution, On Selling and Electricity Market Operation	48	Electricity Supply
75	Gas Supply	49	Gas Supply
76	Water Supply, Sewerage and Drainage Services	50	Water Supply, Sewerage and Drainage Services
77	Waste Collection, Treatment and Disposal Services	51	Waste Collection, Treatment and Disposal Services
78	Residential Building Construction	52	Residential Building Construction
79	Non-Residential Building Construction	53	Other Construction
80	Heavy and Civil Engineering Construction		
81	Construction Services	54	Construction Services
82	Wholesale Trade	55	Wholesale Trade
83	Retail Trade	56	Retail Trade
84	Accommodation	57	Accommodation
85	Food and Beverage Services	58	Food and Beverage Services
86	Road Transport	59	Road Transport
87	Rail Transport	60	Rail Transport
88	Water, Pipeline and Other Transport	61	Water, Pipeline and Other Transport
89	Air and Space Transport	62	Air and Space Transport
90	Postal and Courier Pick-up and Delivery Service	63	Transport Support Services and Storage
91	Transport Support services and storage		
92	Publishing (except Internet and Music Publishing)	64	Publishing (except Internet and Music Publishing)
93	Motion Picture and Sound Recording	65	Communication Services
94	Broadcasting (except Internet)		
95	Internet Publishing and Broadcasting and Services Providers, Websearch Portals and Data Processing Services		
96	Telecommunication Services		
97	Library and Other Information Services		
98	Finance	66	Finance
99	Insurance and Superannuation Funds	67	Insurance & Other Financial Services

IE Lab, 119 Sectors		South Australia & Regions, 78 Sectors	
100	Auxiliary Finance and Insurance Services		
101	Rental and Hiring Services (except Real Estate)	68	Rental, Hiring and Real Estate Services
102	Ownership of Dwellings	69	Ownership of Dwellings
103	Non-Residential Property Operators and Real Estate Services	68	Rental, Hiring and Real Estate Services (cont.)
104	Professional, Scientific and Technical Services	70	Professional, Scientific and Technical Services
105	Computer Systems Design and Related Services		
106	Building Cleaning, Pest Control, Administrative and Other Support Services	71	Administrative and Support Services
107	Public Administration and Regulatory Services	72	Public Administration and Regulatory Services
108	Defence	73	Defence
109	Public Order and Safety	74	Public Order and Safety
110	Education and Training	75	Education and Training
111	Health Care Services	76	Health & Community Services
112	Residential Care and Social Assistance Services		
113	Heritage, Creative and Performing Arts	77	Cultural & Recreational Services
114	Sports and Recreation		
115	Gambling		
116	Automotive Repair and Maintenance	78	Personal & Other Services
117	Other Repair and Maintenance		
118	Personal Services		
119	Other Services		

appendix 2
literature review

Report	Geographical Representation	Indicators	Modelling Methodology	Key results
Towards the circular economy Economic, Volume 1, Ellen MacArthur Foundation, 2012 [6]	European Union	Net material cost savings	Detailed modelling of eight key sectors, upscaled to the rest of the economy. Figures represent the overall annual potential, not attached to a particular year of achieving this.	Opportunity of up to USD 380 billion in a transition scenario and of up to USD 630 billion in an advanced scenario.
Opportunities for a circular economy in the Netherlands, Organisation for Applied Scientific Research (TNO), 2013 [7]	The Netherlands	$CO_{2\text{-eq}}$ emissions Use of freshwater Land use (ecological footprint) Raw Material Equivalent (RME) Change in market value (€ '000) Share of labour costs in value added No. of new jobs created	Analysis of metals and electrical sectors, and the use of biotic waste streams, extrapolated to the Dutch economy. Figures represent the overall annual potential, not attached to a particular year of achieving this. Base year= 2010	Opportunities of €7.3 billion a year (1.4% of 2013 GDP) and 54,000 jobs. Reduction of 17,150 kt $CO_{2\text{-eq}}$, (national $CO_{2\text{-eq}}$ emissions in 2010 were 214,000 kt) Reduction in land use of 2,180 km2, (2.5% of the Dutch ecological footprint). 0.7 billion m^3 of avoided fresh water use (current use ~16 billion m^3/year) 100,400 kt of avoided use of raw materials (more than 25% of the total imports of goods by weight in the Netherlands each year)
Study on modelling of the economic and environmental impacts of raw material consumption, European Union, 2014 [3]	European Union	Raw material consumption (RMC) Resource productivity (GDP per unit of RMC)	Macro-econometric E3ME model (www.e3me.com). Baseline scenario compared to scenarios based around different resource productivity targets for the EU28, from a modest improvement in RP (1% pa) to ambitious improvements (3% pa).	RP improvements of around 2% to 2.5% pa can be achieved with net positive impacts on EU28 GDP (benefits of higher efficiency levels outweigh the costs of making the improvements to efficiency)

Report	Geographical Representation	Indicators	Modelling Methodology	Key results
The Carbon Impacts of the circular economy Technical Report, Zero Waste Scotland, 2015 [8]	Scotland	$CO_{2\text{-eq}}$ (using territorial and consumption carbon footprinting)	Carbon accounting of 4 scenarios to 2050: BAU: all developments in line with relevant projections Resource efficiency: -25% material consumption Limited growth: economic growth of 0.2% (2-2.2% in other scenarios) Circular economy: -50% material consumption	Material consumption is responsible for over two thirds of Scotland's carbon emissions. A more circular economy could reduce $CO_{2\text{-eq}}$ emissions by 11 million tonnes per year Nearly 1 in every 5 tonnes of material flowing through the Scottish economy is waste.
Employment and the circular economy Job creation in a more resource efficient Britain, WRAP and Green Alliance, 2015 [9]	UK	Gross jobs growth Net job creation Unemployment rate fall % offset of predicted decline in skilled employment	Input-output modelling of 3 scenarios to 2030: **No new initiatives:** 55% recycling, 1% remanufacturing, slight growth of reuse. **More of the same:** 70% recycling, 5% remanufacturing, slight growth in reuse, modest growth in servitisation, biorefining expands from fuel to bioplastics & biomaterials **Transformation:** 85% recycling, 12-13 % remanufacturing, substantial growth in reuse, widespread servitisation, biorefining spreads to high value pharmaceuticals and specialist chemicals	Circular economy could create of 102,000 jobs (net) or a reduction in unemployment by 0.28% and the potential to offset around 18 per cent of the expected loss in skilled jobs.
The circular economy and Benefits for Society, Anders Wijkman and Kristian Skånberg for the Club of Rome, 2015 [1]	Finland, France, the Netherlands, Spain and Sweden	$CO_{2\text{-eq}}$ Emission reduction Jobs GDP	Input-output modelling of 3 scenarios to 2030: Enhancing energy efficiency by +25% Renewable energy: 50% fossil fuel substituted by renewables Circular economy: +5% material efficiency, 50% virgin materials replaced by secondary materials, product life of long-lived consumer products doubled	Carbon emission reduction and job creation were significant in all scenatios: emission reductions were stronger for energy scenarios and job creation stronger in material efficiency. The improvement in the trade balance would be around 1,5% of GDP for a circular economy. Unemployment rates could be cut by a quarter to a half depending on the country.
Growth Within, a circular economy vision for a competitive Europe the Ellen MacArthur Foundation, 2015 [10]	European Union	$CO_{2\text{-eq}}$ emissions, primary material consumption Economic benefits (resource benefit economies, non-resource and externality benefits, GDP increase)	Detailed analysis of the mobility, food and building sectors, and computable general equilibrium (CGE) analysis to extend across the economy.	Annual benefits of up to €1.8 trillion by 2030. $CO_{2\text{-eq}}$ emissions would drop as much as 48% by 2030 (31% on the current development path) and 83% by 2050 (61% on the current development path), compared with 2012 levels
Unemployment and the circular economy in Europe, Green Alliance, 2015 [11]	Italy, Poland and Germany	Jobs (gross and net) % of jobs which are future-proof Unemployment cost savings	Input-output modelling of increased circular economy activities (recycling, remanufacturing, servitisation, reuse and biorefining)	An ambitious circular economy strategy for Europe could bring at least 270,000 unemployed people in Italy, Poland, and Germany back into work, saving at least €3 billion in unemployment costs.

Report	Geographical Representation	Indicators	Modelling Methodology	Key results
Economic Growth Potential of More Circular Economies, WRAP, 2015 [12]	UK	Jobs	I-O modelling approach exploring the interaction with CE and the labour market in Europe to quantify the economic impact of transition to a more circular economy by 2030	1.By 2030, expansion in circular economy in Europe has the potential to create 1.2 to 3 million jobs and reduce unemployment by around 250,000 to 520,000 2.CE creates economic value through using more labour and fewer resources 3.The European economy has become more resource efficient as its circularity has increased but it is currently not very circular 4.3.4 million people currently employed in circular economy activities in Europe 5.A growing circular economy in Europe can potentially create (net) jobs by reducing regional mismatches in unemployment
Job creation through resource efficiency in London, WRAP, 2015 [13]	London, UK	Jobs	Input-output modelling of 3 scenarios to 2030: **No new initiatives:** 55% recycling, 10% growth of reuse, 5% growth servitisation. **More of the same:** 70% recycling, remanufacturing = 20% of UK manufacturing, 10% growth in reuse, 30% growth in servitisation **Transformation:** 85% recycling, remanufacturing = 50% of UK manufacturing, 25% growth in reuse, 100% growth in servitisation	1.Currently around 46,700 people are employed in circular economy activities in London. 2.In a 'transformative' scenario, an extensive expansion of the circular economy could provide more than 40,000 new circular economy jobs (gross), reducing unemployment in London by around 12,000 jobs (or 0.26 percentage points), by 2030 or 12.5% of excess employment (at the time of the study) 3.With the right investment and policy interventions, lasting reductions in unemployment, especially in low-skilled to mid-skilled occupations are obtainable whilst simultaneously driving resource efficiency.

Other relevant studies:

- Vijay Gill, J.K. Opportunities for Ontario's waste: Economic impacts of waste diversion in North America. in The Conference Board of Canada. 2014.
- Jane Beasly, R.G., Advancing resource efficiency in europe: Indicators and waste policy scenarios to deliver a resource efficient and sustainable Europe. 2014, European Environmental Bureau: Brussels. p. 50.
- Jyri Arponen, A.G., Mari Pantsar-Kallio, Martin Stuchtey, Antti Törmänen, Helga Vanthournout The opportunities of a circular economy for Finland, in Sitra Studies. 2015, Sitra: Erweko, Helsinki.

appendix 3
waste sector modelling methodology

The input-output model used throughout this project uses statistical data at a broad geographical level (state, nation, or multi-regional), to calculate environmental or social coefficient per dollar of transaction. In practice, this coefficient could for instance represent the mass of greenhouse gas emissions associated with one dollar of purchase in the mining sector. Input-output analysis works really well for high level assessment of broad modifications of the economy, which is exactly the purpose of the project.

To better understand how the scenarios considered in this study impact the waste sector, we have opted for the use of a process model.

The waste sector has the particularity of covering the management of a wide variety of material – inert and degradable. This is particularly significant when looking at landfill, where degradable materials would generate significant quantities of greenhouse gases. Therefore, an input-output coefficient would not have the ability to inform the study on the results of changing practices in the sector, and the potential greenhouse gas emissions reductions associated with our scenarios.

The main difference between input-output and process approaches is that a process model is based on the use of data specific to the process under study. In our case, we used data representative of a number of waste management systems – including variations based on the material types and whether the material was sent for disposal in landfill or reprocessed. All data was derived from the Australian Life Cycle Inventory database (AusLCI) and is therefore representative of the processes actually taking place in South Australia.

Green Industries SA's waste data for 2014 were scaled up to the business as usual and material efficiency scenarios. Note that the Efficient and Renewable Energy scenario was assumed to have no specific impact on the waste sector, hence no modification was implemented.

As for the overall modelling scenario assumptions, the waste-specific assumptions presented in Table 1 have been derived from literature review, a scenario planning workshop held with the client and discussions held with international colleagues who have modelled potential circular economies.

Table 1 – Waste model scenario assumptions.

BaU	Efficient & Renewable Energy	Material Efficiency	Circular
Material use efficiency			
Based on historical trends	As per BAU	Material use improvement over BAU: All sectors 35%	Material use improvement over BAU: All sectors 35%
Material reprocessing (Incorporated into the main model as the Material Reuse assumption)			
Based on historical trends	As per BAU	90% recycling rate throughout all material types	90% recycling rate throughout all material types
Material reprocessing- organic waste (Incorporated into the main model as the Biogas Production assumption)			
Based on historical trends	As per BAU	90% organic waste used to produce biogas and compost at Anaerobic Digestion facilities	90% organic waste used to produce biogas and compost at Anaerobic Digestion facilities

The results reported in Figure 5 and Figure 6 show the variations in physical waste quantities flowing from the South Australian economy. Clearly apparent on the two figures is the impact of higher material use efficiency, resulting in lower quantities of waste produced. Secondly, the quantity of material disposed in landfill is significantly reduced. Finally, material losses are significantly lower under the material efficiency scenario, primarily because of the switch from open air composting to anaerobic digestion.

Figure 5 – Business as usual scenario: physical waste streams.

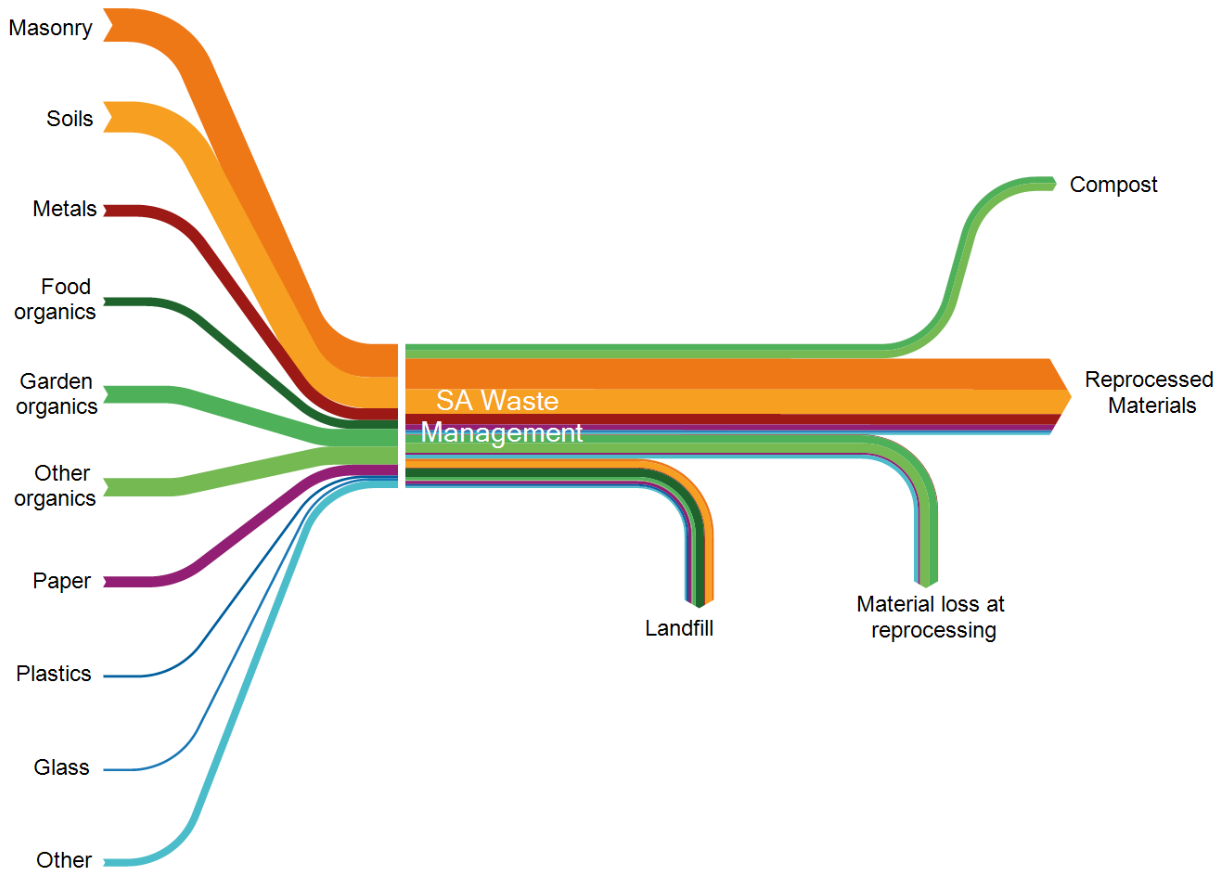
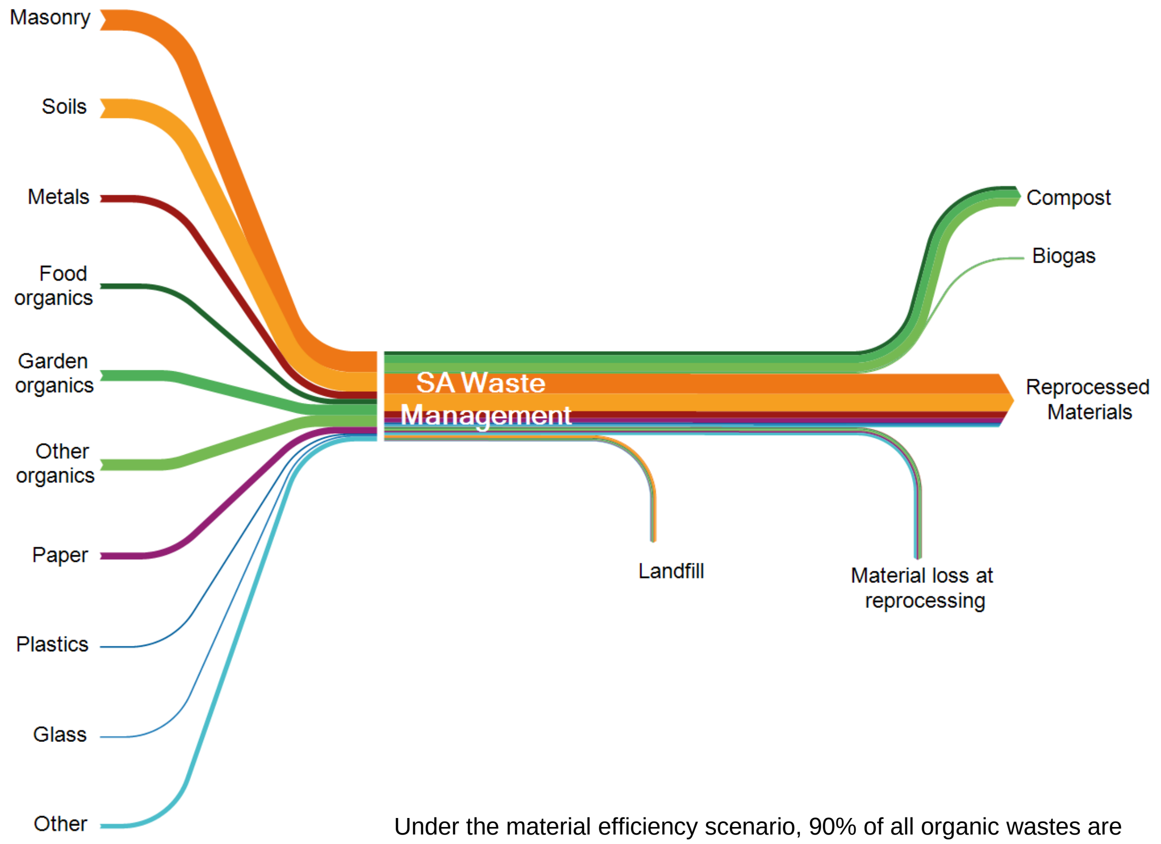


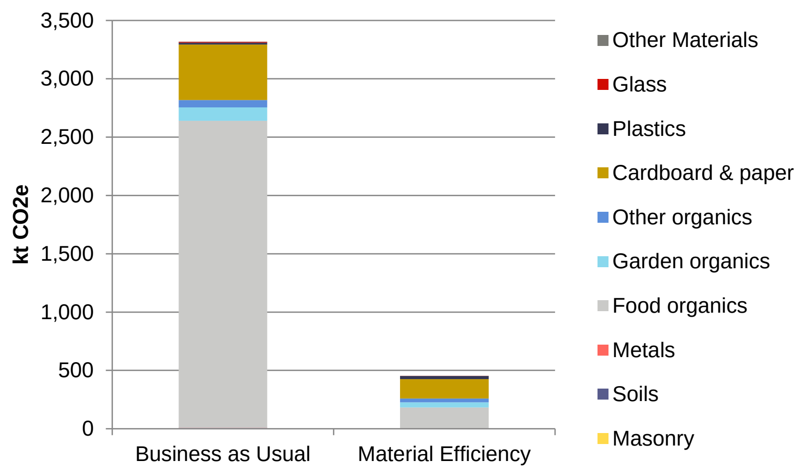
Figure 6 – Material efficiency scenario: physical waste streams.

Greenhouse gas emissions associated with the waste management sector for business as usual and the material efficiency scenario have been calculated and are reported in Figure 7. This clearly shows the value of the material efficiency scenario when compared to business as usual. The significant drop observed between the two scenarios can almost entirely be attributed to variations in the management of organic waste – particularly food waste. Business as usual is founded on current trends, and almost all food waste is assumed to end up in landfill.



Under the material efficiency scenario, 90% of all organic wastes are reprocessed through anaerobic digestion. Additionally, the recycling rate of cardboard and paper products are also raised to 90%. This in itself has the potential to reduce greenhouse gas emissions by 2.8 Mt $CO_{2\text{-eq}}$.

Figure 7 – Variation of greenhouse gas emissions for the scenario analysed.



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