Environmental benefits of recycling

Appendix 4 – Organics

Timber pallets, food and garden organics

NSW GOVERNMENT

Environment, Climate Change & Water

Published by
Department of Environment, Climate Change and Water NSW
59–61 Goulburn Street
PO Box A290
Sydney South 1232
Ph: (02) 9995 5000 (switchboard)
Ph: 131 555 (environment information and publications requests)
Ph: 1300 361 967 (national parks information and publications requests)
Fax: (02) 9995 5999
TTY: (02) 9211 4723
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

DECCW 2010/58
ISBN 978 1 74232 530 9
June 2010

Table of Contents

List of tables and figures

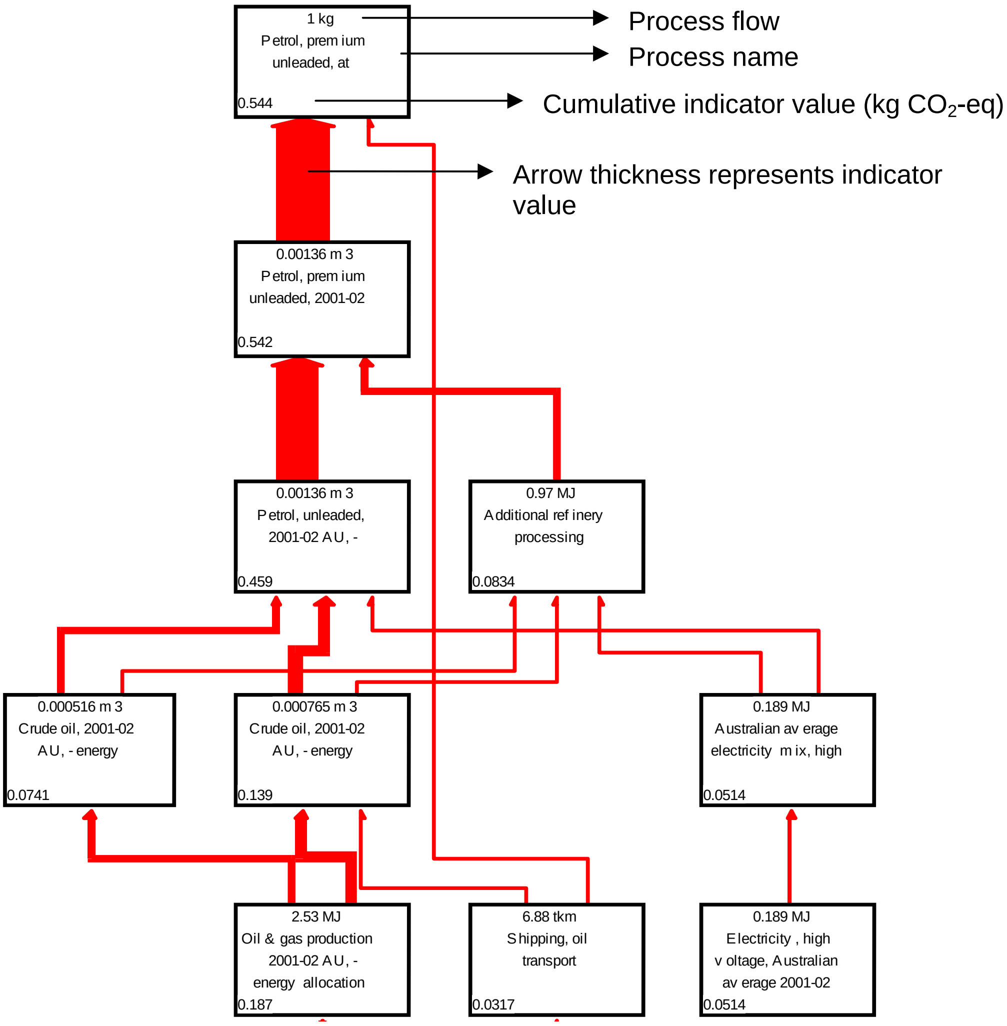
Understanding network diagrams

This appendix presents the data sources and assumptions used in modelling the life cycle stages. Most of the data is contained and modelled in LCA software and consists of hundreds of individual unit process processes. To help provide transparency on the inventories used for the background processes, process network diagrams are presented.

To interpret the process network, start at the top of the tree representing the functional output of the process (e.g. petrol premium unleaded, shown in Figure 1). The amount and unit of the process is shown in the upper number in the unit process box (1kg). The lower number (in the bottom left hand corner) represents an indicator value which, in this case, is set to show cumulative greenhouse gas contributions in kilograms of equivalent carbon dioxide (CO_2 eq). The arrow thickness represents the indicator value (the thicker the arrow the more impact that process is contributing). Note that minor processes may not be physically shown in the process network if the indicator value falls below a specific cut-off level, though their contribution to the overall functional unit (the top box in the diagram) is still included. The network diagram may also be truncated at the bottom to improve readability of the networks. Finally, some diagrams may not show the process flows for confidentiality reasons.

Some network diagrams will include green process flow arrows. These arrows represent beneficial flows (negative impacts) and are common when viewing recycling processes. In recycling processes, negative cumulative indicator values (lower left hand corner) will typically be associated with avoided processes, such as avoided primary material production and avoided landfill.

Figure 1: Sample network diagram.



Timber Pallets

Process description

Pallets are commonly used for the transport of goods. They can be constructed using many different materials but, they mainly are made of wood. The recovered wooden pallets can be used as a substitute for virgin structural pine.

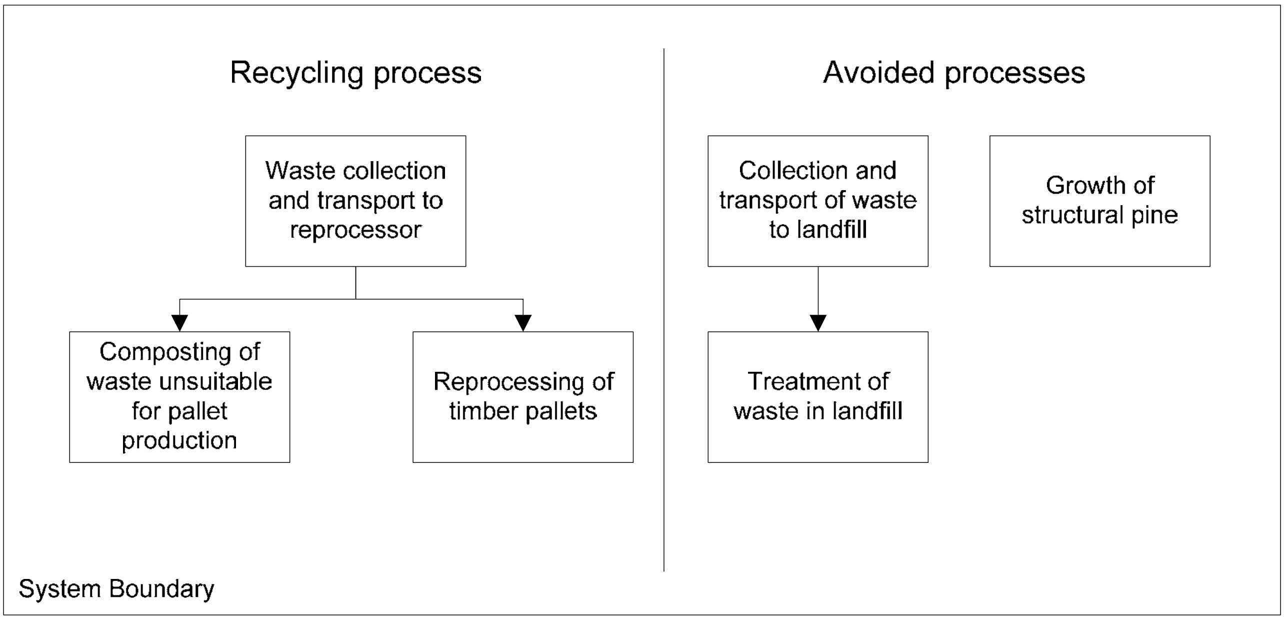
The pallet reprocessing process accepts waste pallets or pallet timber that has been collected and sorts the timber according to size and type. Pallets received that are suitable for reuse without repair/resizing are on-sold, while those requiring only simple repairs may have boards replaced with recycled or first-use boards. Pallets that cannot be repaired are broken into bearers and deck-board components either by cutting or pulling apart. Deck-boards are resized according to the required size of new pallets, and pallets are rebuilt using a combination of new, recycled and first-use bearers and deck-boards. Waste timber from off-cuts and reject bearers/deck-boards are shredded or sent to timber recyclers. All other material goes to be shredded, where ferrous contamination is removed, and the shredded timber is used in a variety of ways, such as in landscaping as course mulch. The processing of pallets was split, 60 per cent to new pallets and 35 per cent to wood composting. 5 per cent of the total material is assumed to be waste (Grant, 2005).

Only one collection system for waste timber pallets was considered in the model:

i) C&I, C&D collection — the segregated waste collected is sent directly to the reprocessing site without any further sorting process, or associated losses. The model developed takes into account transportation impacts incurred to bring the material from C&I and C&D sources to the material reprocessing facility. Once at the reprocessing facility, the model considers the impacts of material reprocessing. Losses associated with this process are included in the analysis.

Figure 2 illustrates the processes considered in determining the overall impact of asphalt recycling from C&I and C&D sources (shown to the left of the vertical line), and the processes considered in determining the impact of the processes avoided when recycling asphalt (shown to the right of the vertical line).

Figure 2: Processes considered in determining the net impacts of the recycling process from C&I and C&D sources.



Results

Considering both the recycling process flows and the avoided process flows, described in Figure 2, an inventory of environmental flows was developed. This inventory was then assessed using the Australian Impact Assessment Method, with results described in Figure 1.

Table 1: Benefits and impacts of recycling and landfill of timber pallets from C&I and C&D sources (per 1 tonne of timber pallets collected). Benefits are shown negative, impacts are shown positive.

Impact category	Unit	Recycling process impacts (Figure 76 - left hand side)	Avoided process impacts (Figure 76 - right hand side)			Net benefits of recycling
		Collection and reprocessing	Collection and landfill	Primary material production	Total avoided impacts	
Green house gases	t CO_2	-0.16	-0.96	-0.23	-1.18	-1.35
Cumulative energy demand	GJ LHV	-0.33	-2.27	-8.12	-10.39	-10.73
Water use	kL H_2O	-0.05	0.33	-0.23	0.09	0.04
Solid waste	tonnes	-0.15	-0.64	-0.01	-0.65	-0.80

Network diagrams detailing key processes that influence the impact listed in Table 1 are shown in Figure 3 to Figure 6. For further information regarding interpretation of network diagrams, refer to Understanding Network Diagrams (Figure 1).

Key assumptions

Table 2 describes the key processes and data sources used to determine the benefits and impacts associated with the collection, recycling and reprocessing of 1 tonne of timber pallets. The table also includes the products and processes avoided when 1 tonne of timber pallets are recycled.

Table 2: Inventory for recycling timber pallets from C&I and C&D sources (1 tonne)

Item	Flow	Unit	Comment
Process flows (Figure 2 — left hand side)			
Waste collection and transport to reprocessor	20	km	20km distance estimate based on a simplified transport analysis for Sydney; refer appendices for discussion on transport. Emissions from transport based on a trucking model developed by the Centre for Design, incorporating trucking data from Apelbaum (2001), Truck backhaul ratio assumed to be 1:2.
Reprocessing of timber pallets	600	kg	Average amount of energy to reprocess timber estimate from Grant (2005) Amount of diesel used per MJ, and emissions from this used recorded by Pre Consultants from Boeijink (1993). Data on diesel density from ABARE (2008) Impacts from natural gas combustion based on National Greenhouse Gas Inventory (NGGI) data (2002-2006). Impact from the production of electricity high voltage in Australia based on ESAA, 2003 and other sources.
Composting of waste unsuitable for pallet production	350	kg	Inputs from Grant (2005) Emission from composting from Eunomia (2002), and AEA Technology Environment (2001) Transport to composting facility consistent with C&I and C&D assumptions waste transport. Energy input from Grant (2005) Refer ‘Organics’ section in this report.
Avoided process (Figure 2 — right hand side)			
Collection and transport of waste to landfill	20	km	20km distance to reprocessing plant estimate based on a simplified transport analysis for Sydney. Refer appendices for discussion on transport. Emissions from transport based on a trucking model developed by the Centre for Design, incorporating trucking data from Apelbaum (2001), Truck backhaul ratio assumed to be 1:2.
Treatment of waste in landfill	1	tonne	Operation to the landfill from a personal communication with S. Middleton, Pacific Waste, NSW, 1998 Methane generated in landfill from NGGIC (2007). Capture of methane assumed to be 36% Hyder (2006), ‘Mid 2020’ scenario.
Growth and production of structural pine	0.95	tonne	Data collected from 2 Tasmanian mills by J.Todd, University of Tasmania. Inventory is based on a cubic metre of pine log input.

Data Quality

Table 3 presents a summary of the data quality for the main processes considered. It shows the data sources used; if they are general data or specific to a company; the age of the data; the geographic location that the data were based on; and, the nature of the technology considered.

Table 3: Data quality for life cycle inventory data modelled for recycling and landfilling of timber pallets, from C&I and C&D source (1 tonne)

	Primary data source	Geography	Data Age	Technology	Representativeness
Recycling collection and transport	Apelbaum consulting group (2001)	Australia	2001	Average	Average from all suppliers
Transportation distances	Estimate	Sydney	2009	Average	Estimate based on simple radial transport model
Reprocessing timber pallets	Grant (2005) and other sources	Australia	2005	Average	Mixed data
Avoided structural pine manufacturing	RMIT CfD, University of Tasmania	Australia	1995–1999	Mixed data	Data from a specific process and company
Avoided landfill impacts	Grant (2005) NGGIC	Australia	1998–2004	Average	Mixed data

References

ABARE (2008), Energy in Australia 2008, Australian Government Department of Resources, Energy and Tourism

Apelbaum Consulting Group (2001), Australian Transport facts 2001 Tables in Excel Format, Blackburn, Victoria.

Australian Greenhouse Office, Factors and Methods Workbook, November 2008, Department of Environment & Heritage.

Electricity Supply Association of Australia (2003), Electricity Australia 2003

Eunomia (2002). Economic Analysis of Options for Managing Biodegradable Municipal Waste. Final Report, Eunomia Research and Consulting for the European Commission.

Grant and James (2005), Life Cycle Impact Data for resource recovery from C&I and C&D waste in Victoria final report, Melbourne, Victoria, Centre for Design at RMIT university (www.cfd.rmit.edu.au)

Grant, T., James, K., Lundie, S., Sonneveld, K., (2001), Life Cycle Assessment for Paper and Packaging Waste Management Scenarios in Victoria, EcoRecycle, Melbourne

Grant T., and Todd J. (1998), Hardwood & Softwood timber production in Australia report, RMIT Centre for Design and University of Tasmania

Hyder Consulting Group, (2007), Review of Methane recovery and flaring from landfills, Australian Greenhouse Office, Department of Environment and Water Resources

National Greenhouse Gas Inventory Committee (2007), Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006 - Waste, Environment Australia, Canberra Australia

National Greenhouse Gas Inventory (2002 through 2006), Department of Climate Change, Canberra

Swiss Centre for Life Cycle Inventories. (2004). "EcoInvent Database version 1.01." from http://www.ecoinvent.ch/en/index.htm.

U.S Greenhouse Gas Emissions and sinks inventory (2006), United States Environmental Protection Agency, http://www.epa.gov/methane/sources.html

Network diagrams — C&I and C&D collection

Figure 3: Recycling process network diagram — Green house gases indicator. Processes contributing less than 2 per cent to total are not shown. Major processes from results table above are shown shaded.

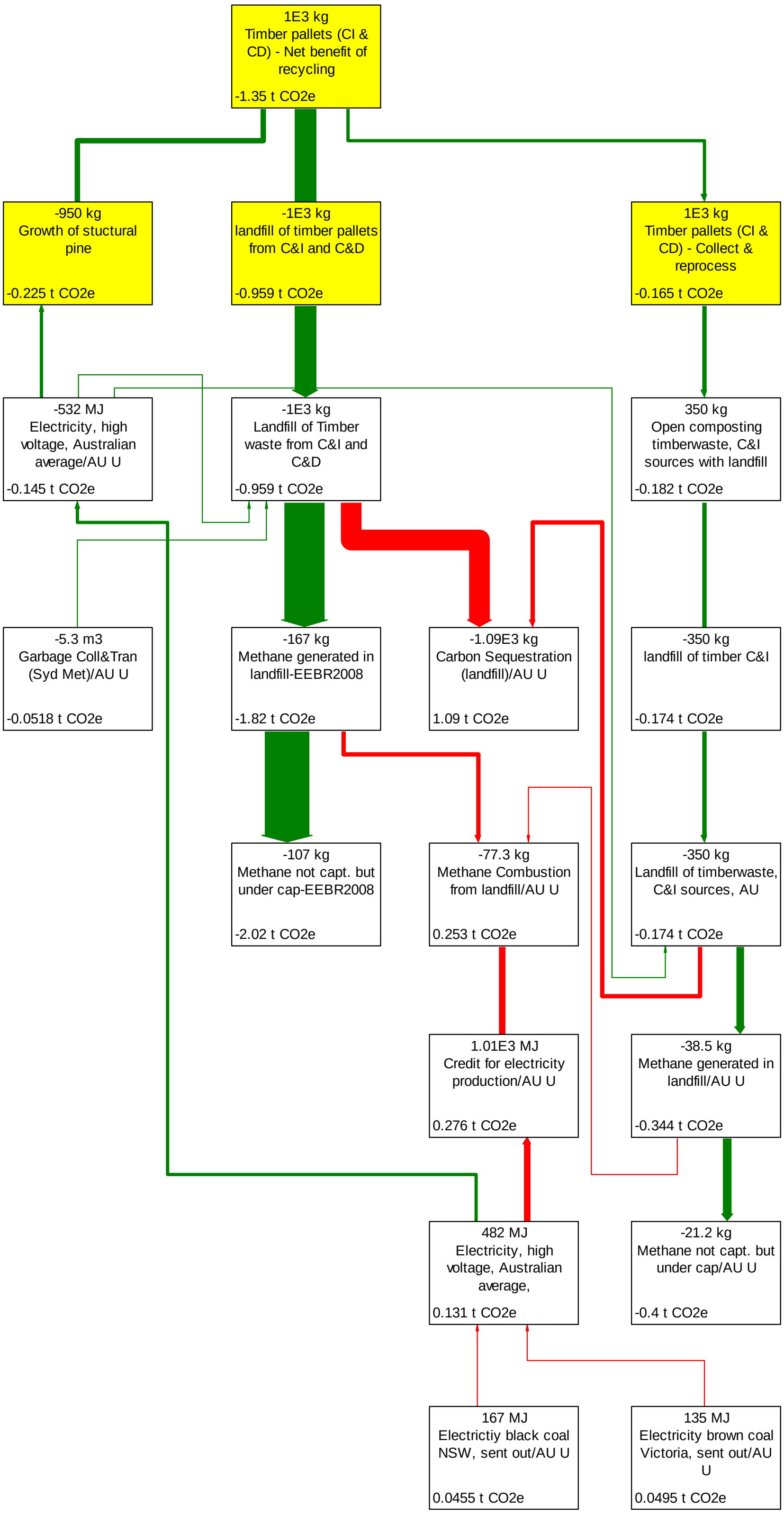


Figure 4: Recycling process network diagram — Cumulative energy demand indicator. Processes contributing less than 5 per cent to total are not shown. Major processes from results table above are shown shaded.

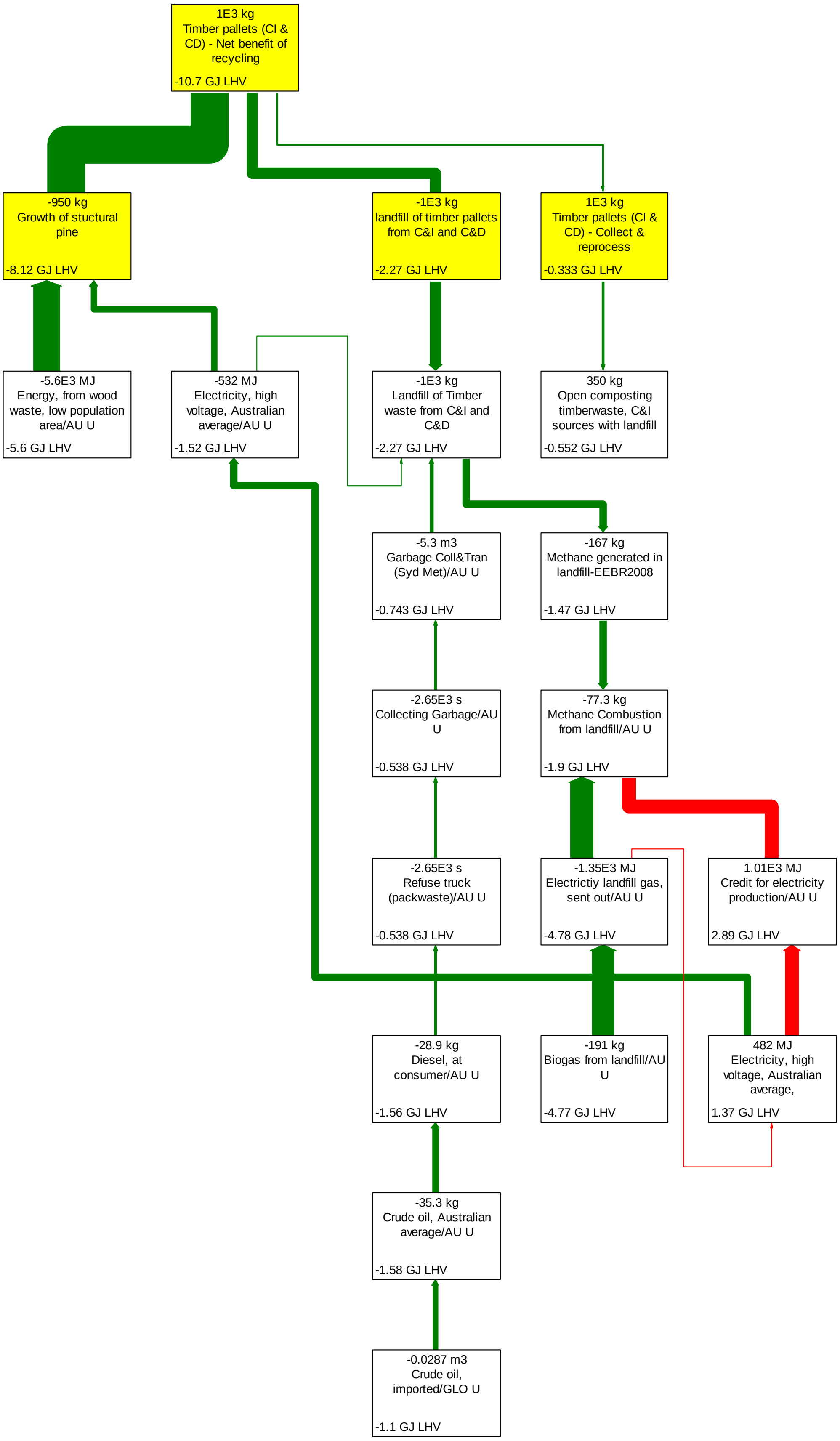


Figure 5: Water indicator. Processes contributing less than 7 per cent to total are not shown. Major processes from results table above are shown shaded.

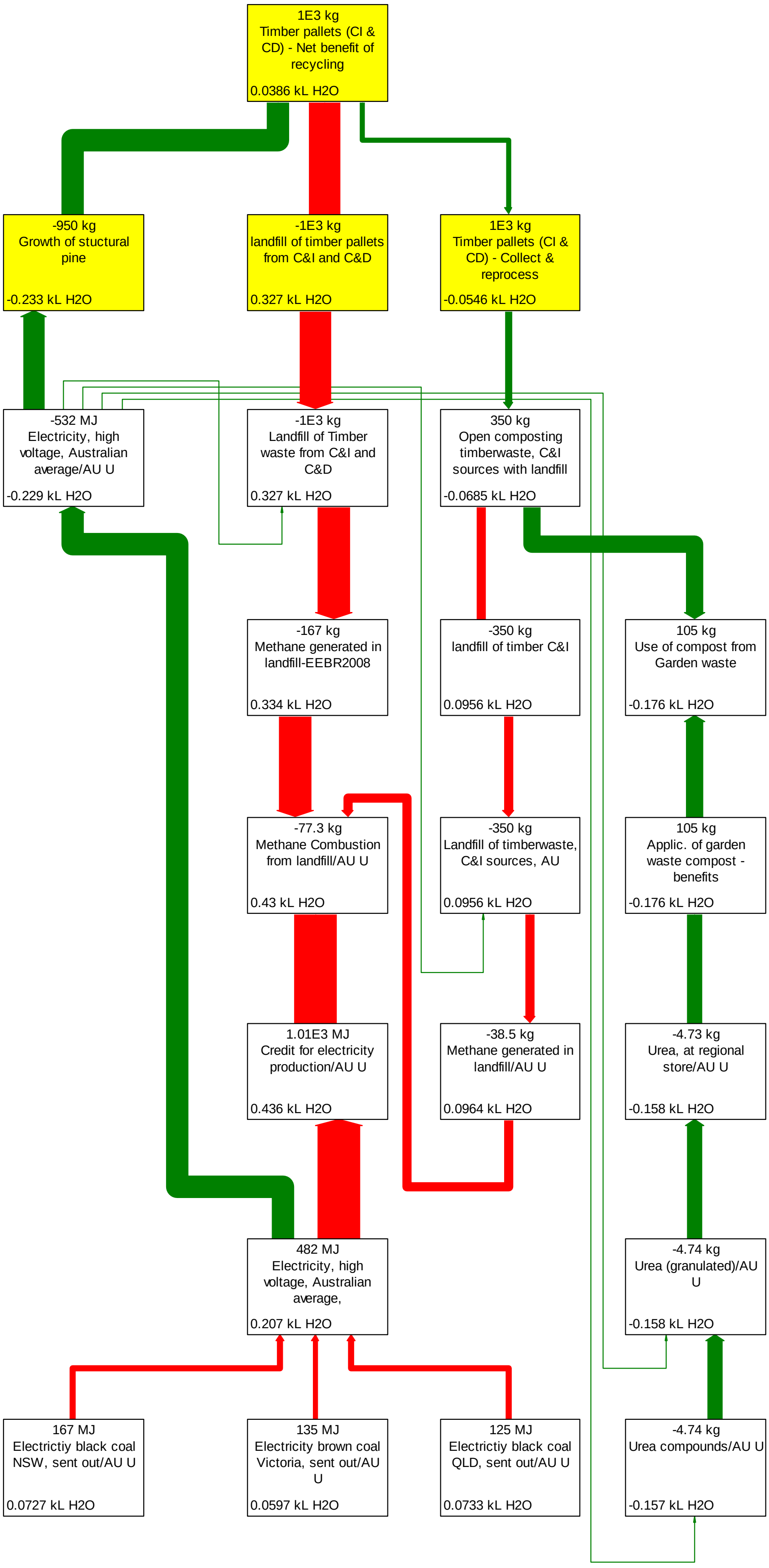
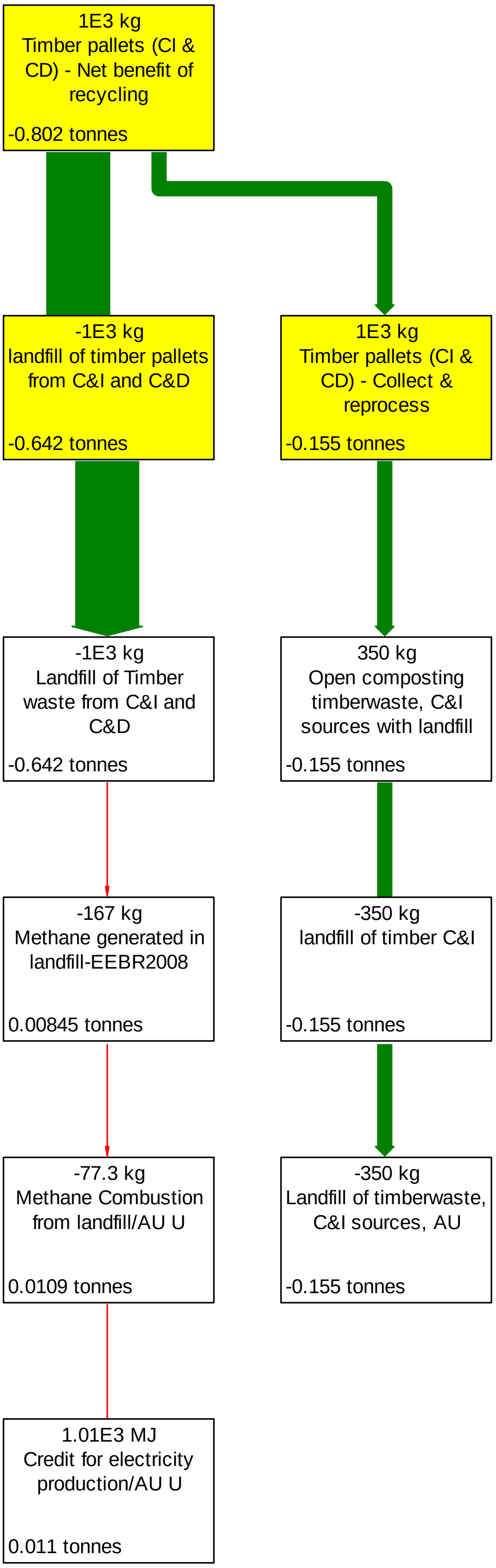


Figure 6: Solid waste indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.



Centralised composting of food and garden waste

Process description

Organic waste such as food scraps and garden clippings is collected separately by some municipalities. This process model considers kerbside collection of these materials and subsequent treatment in a centralised composting process.

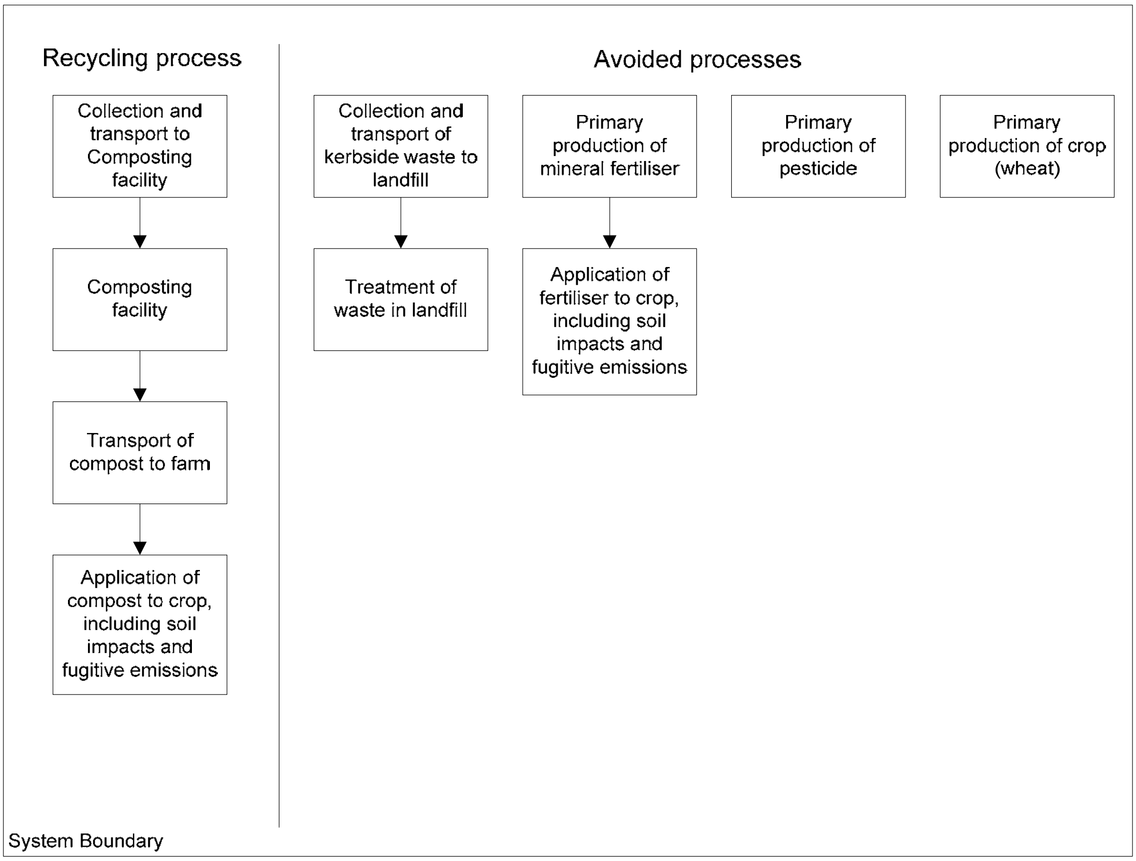
The model developed takes into account transportation impacts incurred to bring the material from the kerbside to the composting facility. Once at the composting facility, the model considers the impacts of the composting of material required to convert the waste material into compost. Losses associated with this process are included in the analysis. The model also takes into account the benefits associated with the use of compost in agriculture, and the avoided material production resulting from this use.

Two mixes of input materials are considered in the model, reflecting common collection practices.

1) Food (68 per cent) and Garden waste (32 per cent) — ratio from Grant et. al.(2003),
2) Garden waste only.

Figure 7 illustrates the processes considered in determining the overall impact of organic waste composting from kerbside sources. Processes considered include the collection of commingled green and food waste, which passes through a process assumed to be similar to the collection of recyclable materials from kerbside. Composting then takes place in a centralised facility with associated material losses. Compost generated is then transported to an agricultural application, where it is applied, generating N_2O emissions (a green house gases emission driver) and contributing to carbon sequestration in the soil. Material flows are shown for reference.

Figure 7: Processes considered in determining composting impacts



In order to determine the benefit or impact of composting organic waste, it is necessary to consider the processes avoided when composting is undertaken, as well as the processes associated with composting.

The processes that are avoided through the use of a composting process include:

i) disposal and treatment of organic waste in landfill — organic waste would otherwise be transported to and processed in a municipal landfill

ii) primary production and application of mineral fertiliser — compost is applied to a crop, reducing its need for mineral fertiliser. Reduced use of mineral fertiliser also reduces N2O formation associated with fertiliser application

iii) primary production of pesticides are reduced — compost reduces the amount of pesticide required by a crop

iv) yields associated with the crop to which the fertiliser is applied are also increased, thereby avoiding additional resources typically required to produce this additional yield (in this case the crop is assumed to be wheat)

Results

Considering both the composting process flows and the avoided process flows, described in Figure 7, an inventory of environmental flows was developed. This inventory was then assessed using the Australian Impact Assessment Method, with results described in Table 4 for mixed garden and food waste, and Table 5 for garden waste only.

Table 4: Benefits and impacts of composting and landfill of mixed food and garden waste from kerbside sources (per 1 tonne of food and garden organics collected). Benefits are shown negative, impacts are shown positive.

Impact category	**Unit**	**Recycling process impacts (Figure 81 - left side)**	**Avoided process impacts (Figure 81 - right side)**			**Net benefits of recycling**
		Collection, sorting and reprocessing	Collection and landfill	Primary material production	Total avoided impacts	
Green house gases	t CO_2	0.17	-0.31	-0.11	-0.42	-0.25
Cumulative energy demand	GJ LHV	1.07	-0.92	-0.33	-1.25	-0.18
Water use	kL H_2O	0.09	0.10	-0.63	-0.53	-0.44
Solid waste	tonnes	0.00	-0.35	0.00	-0.35	-0.35

Network diagrams detailing key processes that influence the impact listed in Table 4 are shown in Figure 8 to Figure 11. For further information regarding interpretation of network diagrams, refer to Understanding Network Diagrams (Figure 1).

Table 5: Benefits and impacts of composting and landfill of garden waste from kerbside sources (per 1 tonne of organics collected). Benefits are shown negative, impacts are shown positive.

Impact category	Unit	Recycling process impacts (Figure 81 - left side)	Avoided process impacts (Figure 81 - right side)			Net benefits of recycling
		Collection, sorting and reprocessing	Collection and landfill	Primary material production	Total avoided impacts	
Green house gases	t CO_2	0.17	-0.36	-0.14	-0.50	-0.32
Cumulative energy demand	GJ LHV	1.07	-1.26	-0.28	-1.53	-0.47
Water use	kL H_2O	0.09	0.11	-0.68	-0.57	-0.48
Solid waste	tonnes	0.00	-0.61	0.00	-0.61	-0.61

Network diagrams detailing key processes that influence the impact listed in Table 5 are shown in Figure 12 to Figure 15. For further information regarding interpretation of network diagrams, refer to Understanding Network Diagrams (Figure 1).

Key assumptions

Table 6 describes the key processes and data sources used to determine the benefits and impacts associated with the collection and composting of 1 tonne of mixed garden and food waste.

Table 7 describes benefits and impacts associated with the collection and composting of 1 tonne of garden waste only. Both tables also described avoided processes for each.

Table 6: Inventory for composting garden and food waste (1 tonne)

Item	Flow	Unit	Comment
Composting process flow (Figure 7 — left hand side)			
Collection of garden and food waste	3.056	m^3	Assumption of a bulk density of garden waste of 5.3 m^3/t and food waste 2 m^3/t, with a fraction of 32% garden waste and 68% food wastes, from (Warren, M., 1997) Default waste split (68/32) from Eunomia (2002) Transport model for kerbside collection based on Grant (2001), refer appendices for discussion on transport. Emission of the truck from Apelbaum (2001), NGGIC (1997) and other sources.
Composting facility operation (Diesel machinery)	1	L	Fuel consumption from Eunomia (2002) Emissions from combustion by Pre Consultants from Boeijink (1993). Data on diesel density from ABARE (2008).
Composting facility operation (electricity consumption)	50	kWh	Estimated electricity consumption from Eunomia (2002) Impacts from the production of electricity high voltage in Australia are based on ESAA, 2003 and other sources.
Composting facility operation (fugitive emissions) Methane N2O and others	3.81 11	kg g	Methane emissions for composting from Dept. of Climate Change (2008). N20 emissions from Eunomia (2002)
Compost yield per tonne of waste	350	kg	Eunomia (2002), states 1 tonne waste yields 350kg compost at 60% dry matter content (210kg dry matter). Eunomia discission infers that this output is associated with a mix of garden and foodwaste at approximately 35% dry matter content, which is consistent with a 68/32 food/garden waste split.
Truck compost to place of use. 15 tonne on 30 tonne capacity truck.	200	km	Assume compost used in wheat crop 200km from Sydney. Emissions from transport based on a trucking model developed by the Centre for Design, incorporating trucking data from Apelbaum (2001) and other sources. Truck backhaul ratio assumed to be 1:2.
Compost application			
Fugitive Emissions of N$_2$O from compost on ground.	87	g (N$_2$O)	Compost contains 2.25%N, of which 0.7% of is emitted as N$_2$O (350*2.25%*0.7%*44/28=0.087kg) Eunomia (2002) adapted and employed in Grant et. al.(2003)
Sequestration of carbon from compost to soil	16.3	Kg carbon	Evidence exists that addition of compost increases the carbon content of soils. In this study, soil is assumed to accept 10% of the carbon content of compost applied. In line with Grant et. al.(2003), compost carbon content estimated as follows: 1 tonne x 68% food x (1-75% moisture) x 48% carbon (dry basis) x 10% sequestration = 8.2kg Carbon Plus 1 tonne x 32% garden x (1-45% moisture) x 46% carbon (dry basis) x 10% sequestration = 8.1kg Carbon
Avoided process flows (Figure 7 — right hand side)			
Collection and transport of waste to landfill	3.056	m^3	Waste collection avoided by sending material to composting. Transport model for kerbside collection based on Grant (2001b); refer appendices for discussion on transport. Emission of the truck from Apelbaum (2001), NGGIC (1997) and other sources.

Item	Flow	Unit	Comment
Landfill of garden waste	320	kg	Avoided process includes operation of the landfill, fugitive emissions from material breakdown and energy generated from collection of methane. Operation to the landfill from a personal communication with S. Middleton, Pacific Waste, NSW, 1998 Methane generated in landfill from NGGIC (2007) - assumes degradable organic carbon fraction of 0.2. Capture of methane assumed to be 36% Hyder (2006), 'Mid 2020' scenario.
Landfill of food waste	680	kg	Avoided process includes operation of the landfill, fugitive emissions from material breakdown and energy generated from collection of methane. Operation to the landfill from a personal communication with S. Middleton, Pacific Waste, NSW, 1998 Methane generated in landfill from NGGIC (2007) – assumes degradable organic carbon fraction of 0.15. Capture of methane assumed to be 36% Hyder (2006), 'Mid 2020' scenario.
Avoided fertiliser addition — Urea (for crop nitrogen requirements)	17.5	kg	Substitution assumes crop requires more nutrient than is supplied by the compost applied, therefore substituting for the application of mineral fertiliser) Compost contains 2.25% N at 75% availability (350*2.25%*75%=5.91kg per tonne waste processed). Urea contains 45% N at 75% availability (1*45%*75%=0.338kg per kg urea), therefore 350kg compost substitutes for 17.5kg urea (5.91/0.338). Adapted and employed in Grant et. al.(2003)
Avoided fertiliser addition — Diammonium phosphate (for crop phosphorous requirements)	7	kg	Substitution assumes crop requires more nutrient than is supplied by the compost applied, therefore substituting for the application of mineral fertiliser) Compost contains 0.4% P (350*0.4%=1.4kg per tonne waste processed). Diammonium phosphate contains 20% P (1*20%=0.2kg per kg diammonium phosphate), therefore 350kg compost substitutes for 7kg diammonium phosphate. Adapted and employed in Grant et. al.(2003)
Avoided fertiliser addition — Potassium chloride (for crop potassium requirements)	2.8	kg	Substitution assumes crop requires more nutrient than is supplied by the compost applied, therefore substituting for the application of mineral fertiliser) Compost contains 0.4% K (350*0.4%=1.4kg per tonne waste processed). Potassium chloride contains 50% K (1*50%=0.5kg per kg potassium chloride), therefore 350kg compost substitutes for kg potassium chloride. Substitution rates from Eunomia(2002) Adapted and employed in Grant et. al.(2003)
Emissions of N_2O from mineral fertiliser application (fugitive emissions avoided by not having to apply mineral fertiliser)	344	g (N_2O)	1.25% of N in urea (45%N) emitted as N_2O. Urea avoided by the use of compost is 17.5kg (per 350kg application) (17.5*1.25%*44/28=0.344kg) Eunomia (2002) adapted and employed in Grant et. al.(2003)
Pesticides avoided	14	g	Substitution assumes crop requires more pesticide than is avoided by the compost applied, therefore substituting for the application of fossil fuel derived pesticide) Application of compost: 10tonne/Ha Pesticide applied at 2kg/Ha.

Item	Flow	Unit	Comment
			Compost saves 20% of pesticide. Therefore savings per tonne compost: 2*0.2/10=0.04g/kg compost. 350*0.04=14g pesticide saved per 350kg compost applied. Substitution rates from Eunomia (2002) Adapted and employed in Grant et. al.(2003)
Production of wheat (production avoided by increased crop yield)	2.6	kg (wheat)	Wheat production yield increases by 2.5%/Ha due to compost application (in place of mineral fertlisers only). Assuming 10t/Ha application of compost, and a typical crop yield of 3t/Ha, the compost contributes to a yield increase of 0.0075kg/kg compost (2.5%*3/10=0.0075). Therefore 350kg of compost equates to 2.6kg of wheat yield increase. Australian compost experience used in Grant et. al.(2003).

Table 7: Inventory for composting garden waste only (1 tonne)

Item	Flow	Unit	Comment
Composting process flow (Figure 7 — left hand side)			
Collection of garden and food waste	5.3	m^3	Assumption of a bulk density of garden waste of 5.3 m^3/t from (Warren, M., 1997) Transport model for kerbside collection based on Grant (2001), refer appendices for discussion on transport. Emission of the truck from Apelbaum (2001), NGGIC (1997) and other sources.
Composting facility operation (Diesel machinery)	1	L	Fuel consumption from Eunomia (2002) Emissions from combustion by Pre Consultants from Boeijink (1993). Data on diesel density from ABARE (2008).
Composting facility operation (electricity consumption)	50	kWh	Estimated electricity consumption from Eunomia (2002) Impacts from the production of electricity high voltage in Australia are based on ESAA, 2003 and other sources.
Composting facility operation (fugitive emissions) Methane N2O and others	3.81 11	kg g	Methane emissions for composting from Dept. of Climate Change (2008). N20 emissions from Eunomia (2002)
Compost yield per tonne of waste	550	kg	Eunomia (2002), states 1 tonne waste yields 350kg compost at 60% dry matter content (210kg dry matter). Eunomia discission infers that this output is associated with a mix of garden and foodwaste at approximately 35% dry matter content, which is consistent with a 68/32 food/garden waste split. Assume increased dry matter content of garden waste translates to proportionate increase in compost yield. 35% (mix food and garden) dry matter increased to 55%. Grant et. al.(2003) use 600kg in similar application.
Truck compost to place of use. 15 tonne on 30tonne capacity truck.	200	km	Assume compost used in wheat crop 200km from Sydney. Emissions from transport based on a trucking model developed by the Centre for Design, incorporating trucking data from Apelbaum (2001) and other sources. Truck backhaul ratio assumed to be 1:2.
Compost application			
Fugitive Emissions of N_2O from compost on ground.	91	g (N_2O)	Compost contains 1.5%N, of which 0.7% of is emitted as N_2O (550*1.5%*0.7%*44/28=0.091kg) Eunomia (2002) adapted and employed in Grant et. al.(2003)
Sequestration of carbon from compost to soil	25.3	Kg carbon	Evidence exists that addition of compost increases the carbon content of soils. In this study, soil is assumed to accept 10% of the carbon content of compost applied. In line with Grant et al.(2003), compost carbon content estimated as follows: 1 tonne x (1-45% moisture) x 46% carbon (dry basis) x 10% sequestration = 25.3kg Carbon
Avoided process flows (Figure 7 — right hand side)			
Collection and transport of waste to landfill	5.3	m^3	Waste collection avoided by sending material to composting above. Transport model for kerbside collection based on Grant (2001b); refer appendices for discussion on transport. Emission of the truck from Apelbaum (2001), NGGIC (1997) and other sources.

Item	Flow	Unit	Comment
Landfill of garden waste	1000	kg	Avoided process includes operation of the landfill, fugitive emissions from material breakdown and energy generated from collection of methane. Operation to the landfill from a personal communication with S. Middleton, Pacific Waste, NSW, 1998 Methane generated in landfill from NGGIC (2007) — assumes degradable organic carbon fraction of 0.2. Capture of methane assumed to be 36% Hyder (2006), 'Mid 2020' scenario.
Avoided fertiliser addition — Urea (for crop nitrogen requirements)	18.3	kg	Substitution assumes crop requires more nutrient than is supplied by the compost applied, therefore substituting for the application of mineral fertiliser) Compost contains 1.5% N at 75% availability (550*1.5%*75%=6.2kg per tonne waste processed). Urea contains 45% N at 75% availability (1*45%*75%=0.338kg per kg urea). Therefore 550kg compost substitutes for 18.3kg urea (6.2/0.338). Adapted and employed in Grant et. al.(2003)
Avoided fertiliser addition – Diammonium phosphate (for crop phosphorous requirements)	11	kg	Substitution assumes crop requires more nutrient than is supplied by the compost applied, therefore substituting for the application of mineral fertiliser) Compost contains 0.4% P (550*0.4%=2.2kg per tonne waste processed). Diammonium phosphate contains 20% P (1*20%=0.2kg per kg diammonium phosphate). Therefore 550kg compost substitutes for 11kg diammonium phosphate. Adapted and employed in Grant et. al.(2003)
Avoided fertiliser addition — Potassium chloride (for crop potassium requirements)	4.4	kg	Substitution assumes crop requires more nutrient than is supplied by the compost applied, therefore substituting for the application of mineral fertiliser) Compost contains 0.4% K (550*0.4%=2.2kg per tonne waste processed). Potassium chloride contains 50% K (1*50%=0.5kg per kg potassium chloride). Therefore 550kg compost substitutes for 4.4kg potassium chloride. Substitution rates from Eunomia(2002) Adapted and employed in Grant et. al.(2003)
Emissions of N_2O from mineral fertiliser application (fugitive emissions avoided by not having to apply mineral fertiliser)	359	g (N_2O)	1.25% of N in urea (45%N) emitted as N_2O. Urea avoided by the use of compost is 18.3kg (per 550kg application) (18.3*1.25%*44/28=0.359kg) Eunomia (2002) adapted and employed in Grant et. al.(2003)
Pesticides avoided	22	g	Substitution assumes crop requires more pesticide than is avoided by compost applied, therefore substituting for the application of fossil fuel-derived pesticide. Application of compost: 10tonne/Ha Pesticide applied at 2kg/Ha. Compost saves 20% of pesticide, therefore savings per tonne compost: 2*0.2/10=0.04g/kg compost. 550*0.04=22g pesticide saved per 550kg compost applied. Substitution rates from Eunomia (2002) Adapted and employed in Grant et. al.(2003)

Item	Flow	Unit	Comment
Production of wheat (production avoided by increased crop yield)	4.1	kg (wheat)	Wheat production yield increases by 2.5%/Ha due to compost application (in place of mineral fertlisers only). Assuming 10t/Ha application of compost, and a typical crop yield of 3t/Ha, the compost contributes to a yield increase of 0.0075kg/kg compost (2.5%*3/10=0.0075). Therefore 550kg of compost equates to 4.1kg of wheat yield increase. Australian compost experience used in Grant et. al.(2003).

Data Quality

Table 8 presents a summary of the data quality for the main processes considered. It shows the data sources used; if they are general data or specific to a company; the age of the data; the geographic location that the data were based on; and, the nature of the technology considered.

In this case, composting impacts have been determined from a variety of sources and across a range of time-frames. In general, data quality is poor, as no single study assessed quantifies composting benefits across the range of processes considered.

A particular issue is the conversion of specific waste material into compost outputs. Studies assessed utilise a variety of conversion rates, and many employ aggregated data that does not link directly to specific material inputs.

It is acknowledged that further work could be undertaken to improve the composting model developed, as specific empirical studies are completed.

Table 8: Data quality for life cycle inventory data modelled for composting and landfilling of garden waste

	Primary data source	Geography	Data A
Impact of transportation mode	Grant, NGGIC (1997)	European data adapted to Australian conditions and Australian data	1997–2
Composting process	Grant (2003) Eunomia (2002)	Australia/Europe	2002
Avoided products	Grant (2003) Eunomia (2002)	Australia/Europe	2002
Landfill impacts	NGGIC (2007) Hyder (2007)	US data adapted to Australian conditions	2006

References

Eunomia (2002). Economic Analysis of Options for Managing Biodegradable Municipal Waste. Final Report, Eunomia Research and Consulting for the European Commission.

Grant, T., James, K., Partl, H.,(2003), Life Cycle Assessment of Waste and Resource Recovery Options (including energy from waste). Melbourne, Victoria, Centre for Design at RMIT & Nolan ITU

Grant, T., James, K., (2005), Life Cycle Impact Data for Resource Recovery from Commercial and Industrial and Construction and Demolition Waste in Victoria – Final report for EcoRecycle Victoria. Melbourne, Victoria, Centre for Design at RMIT

Grant, T., James, K.L., Lundie, S., Sonneveld, K., Beavis, P. (2001), Report for Life Cycle Assessment for Paper and Packaging Waste Management Scenarios in New South Wales, NSW Environment Protection Authority, Sydney

Hyder Consulting Group, (2007), Review of Methane recovery and flaring from landfills, Australian Greenhouse Office, Department of Environment and Water Resources

National Greenhouse Gas Inventory Committee (2007), Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2006 - Waste, Environment Australia, Canberra Australia

National Greenhouse Gas Inventory Committee (1997), National Greenhouse Gas Inventory 1995 with Methodology Supplement, Environment Australia, Canberra Australia

US EPA (2006). Solid Waste Management and Greenhouse Gases. A Life-Cycle Assessment of Emissions and Sinks, 3rd Edition.

Warren, M., 1997, Australian Waste and Recycling Cost Model (WRCM). Sydney, Software developed for the CRC for Waste Management and Pollution Control, June

Network diagrams — Mixed garden and food waste

Figure 8: Recycling process network diagram — Green house gases indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.

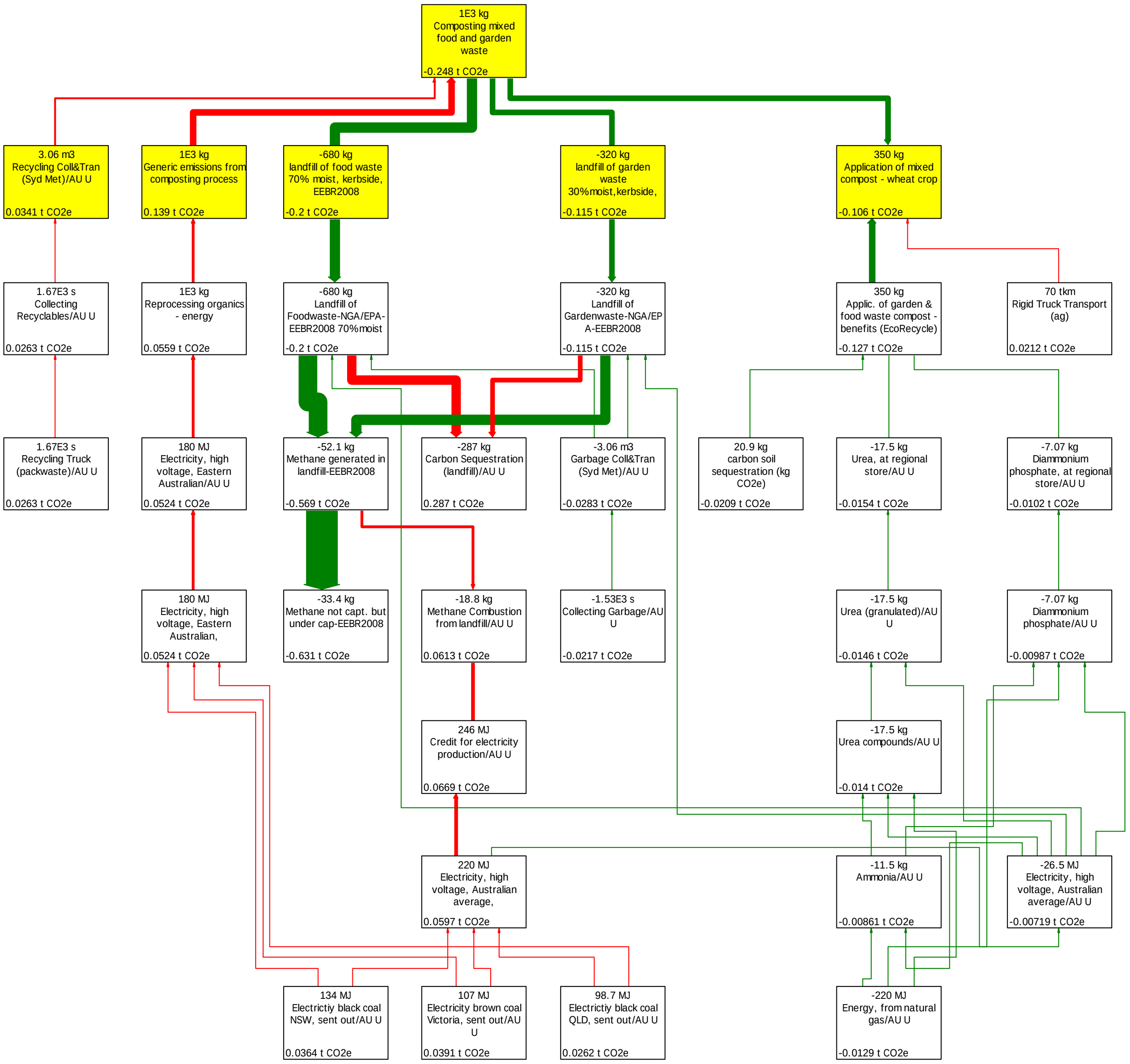


Figure 9: Recycling process network diagram — Cumulative energy demand indicator. Processes contributing less than 5 per cent to total are not shown. Major processes from results table above are shown shaded.

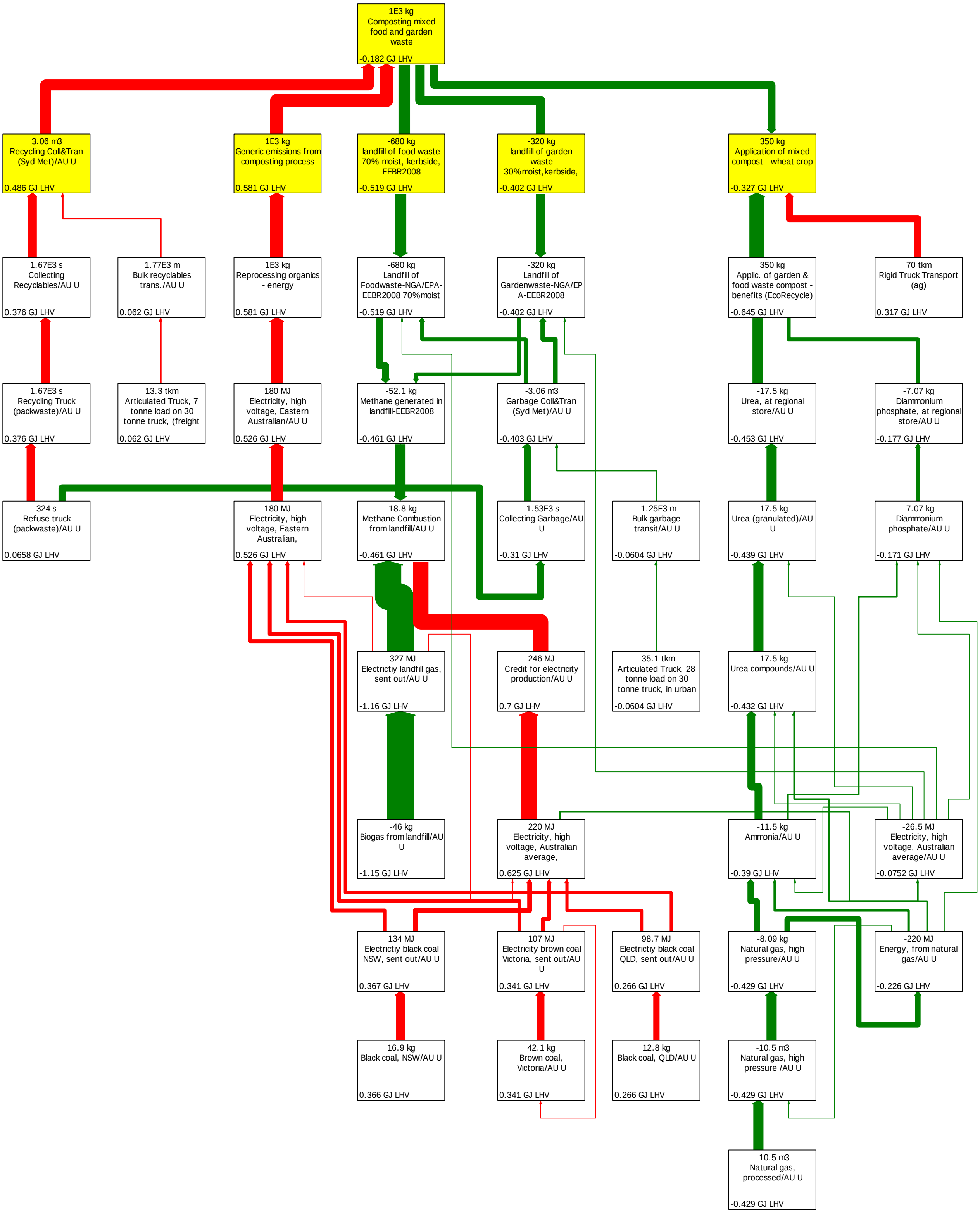


Figure 10: Recycling process network diagram — Water indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.

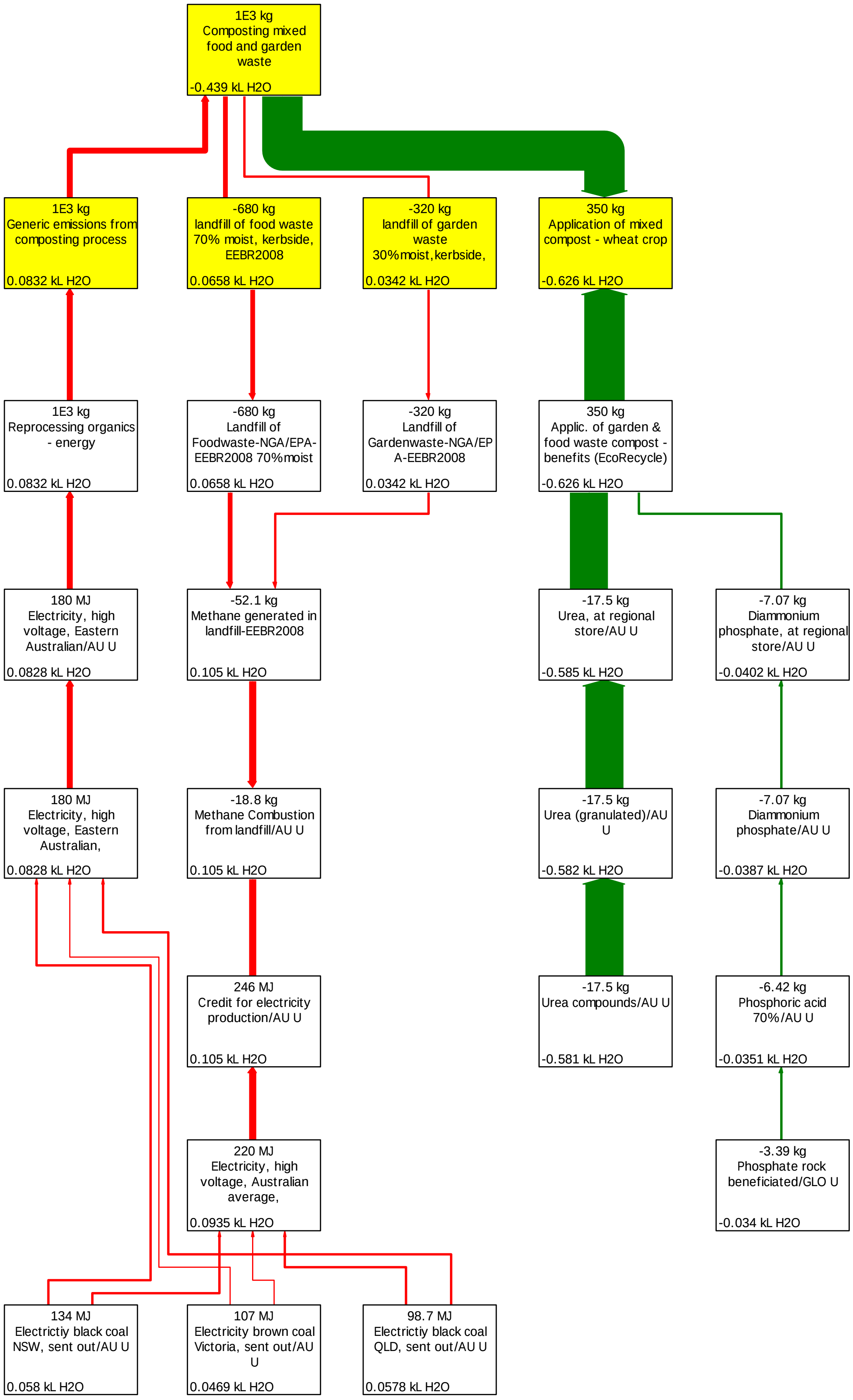
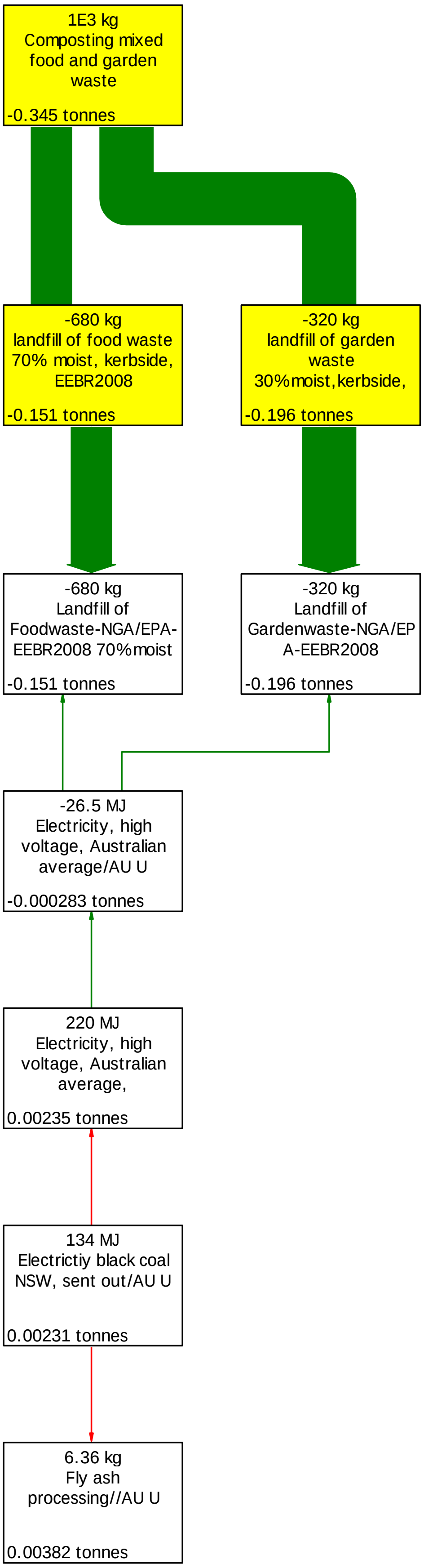


Figure 11: Recycling process network diagram — Solid waste indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.



Network diagrams — Garden waste only

Figure 12: Recycling process network diagram — Green house gases indicator. Processes contributing less than 2 per cent to total are not shown. Major processes from results table above are shown shaded.

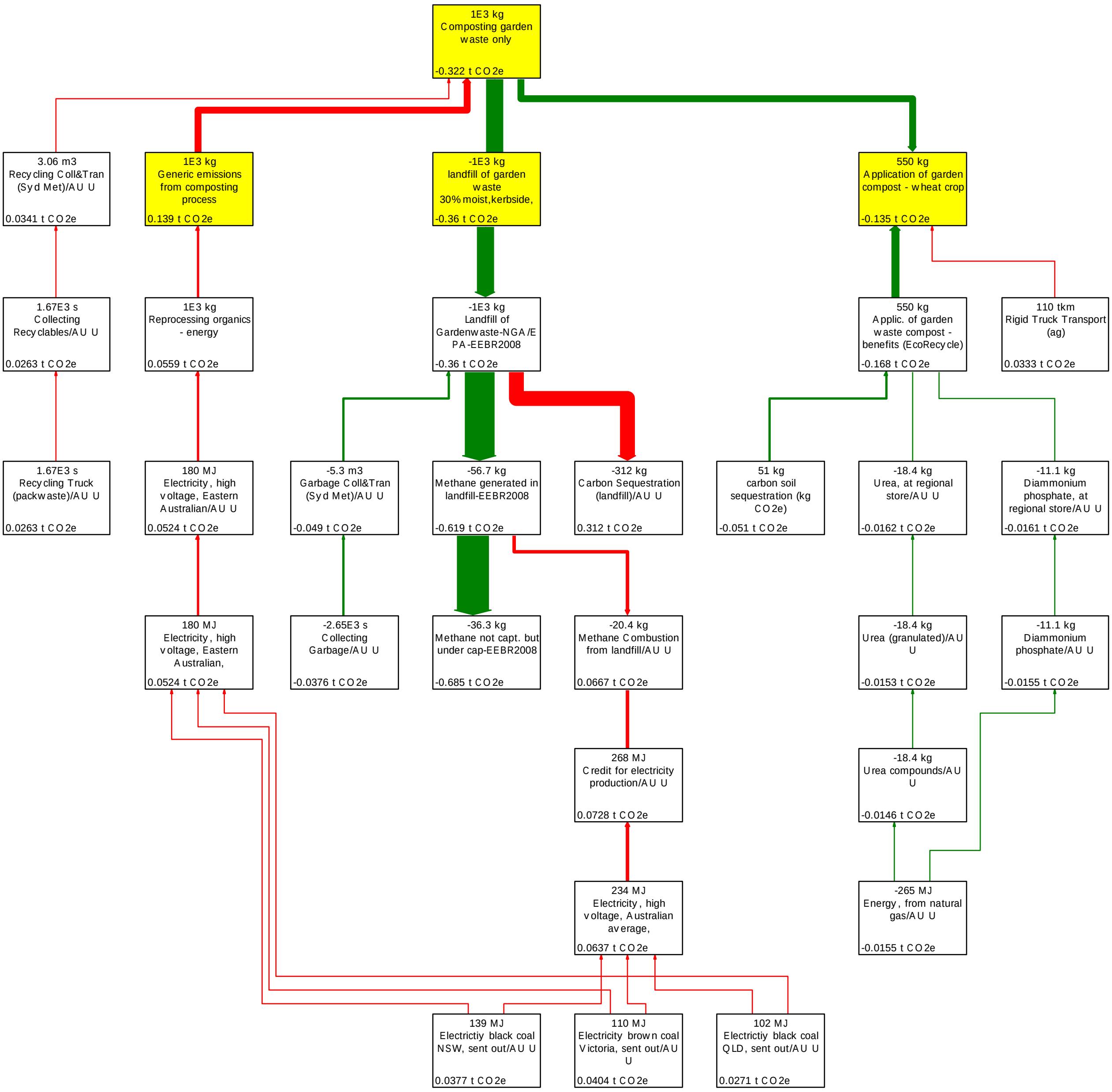


Figure 13: Recycling process network diagram — Cumulative energy demand indicator. Processes contributing less than 15 per cent to total are not shown. Major processes from results table above are shown shaded.

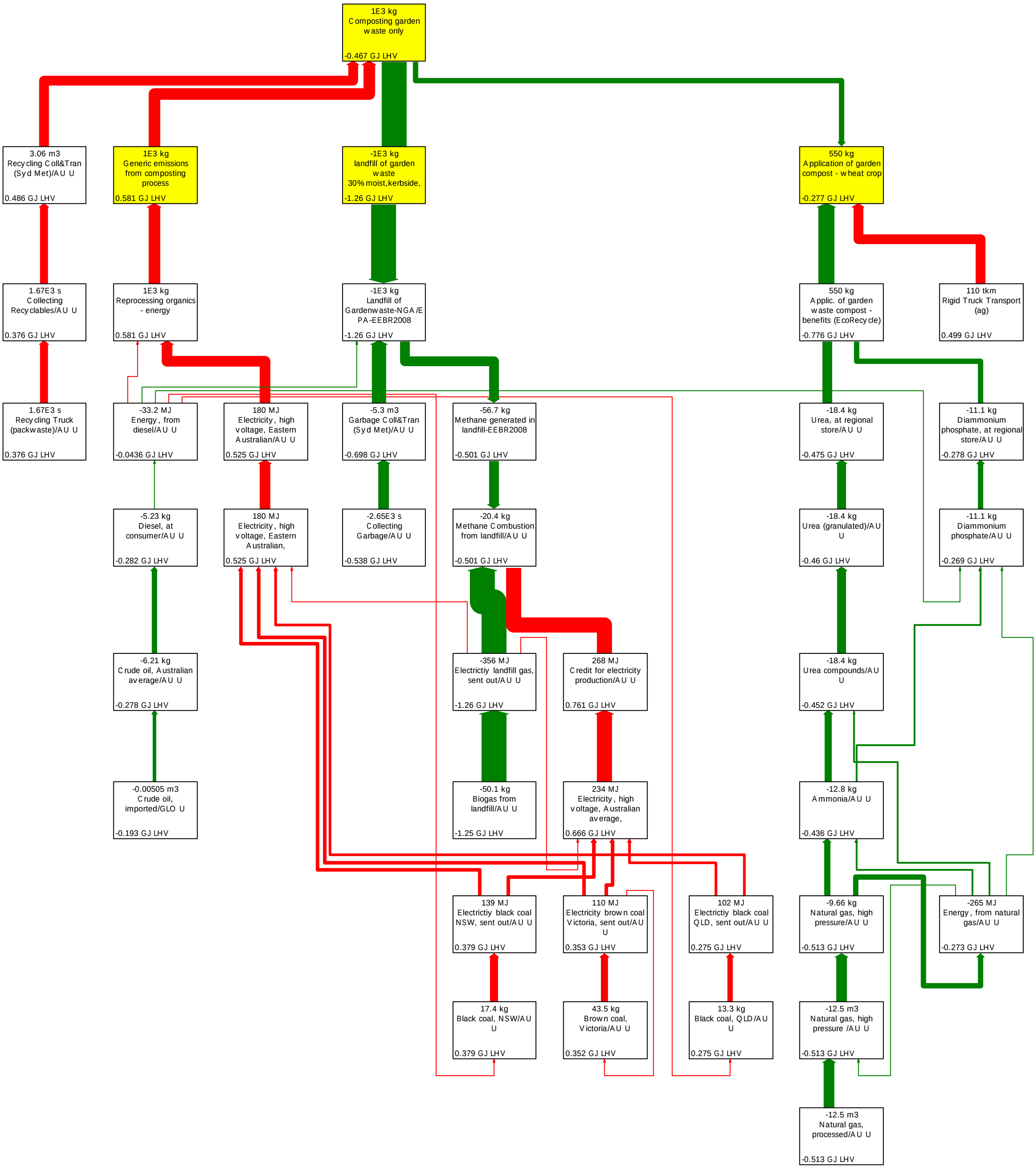


Figure 14: Recycling process network diagram — Water indicator. Processes contributing less than 2 per cent to total are not shown. Major processes from results table above are shown shaded.

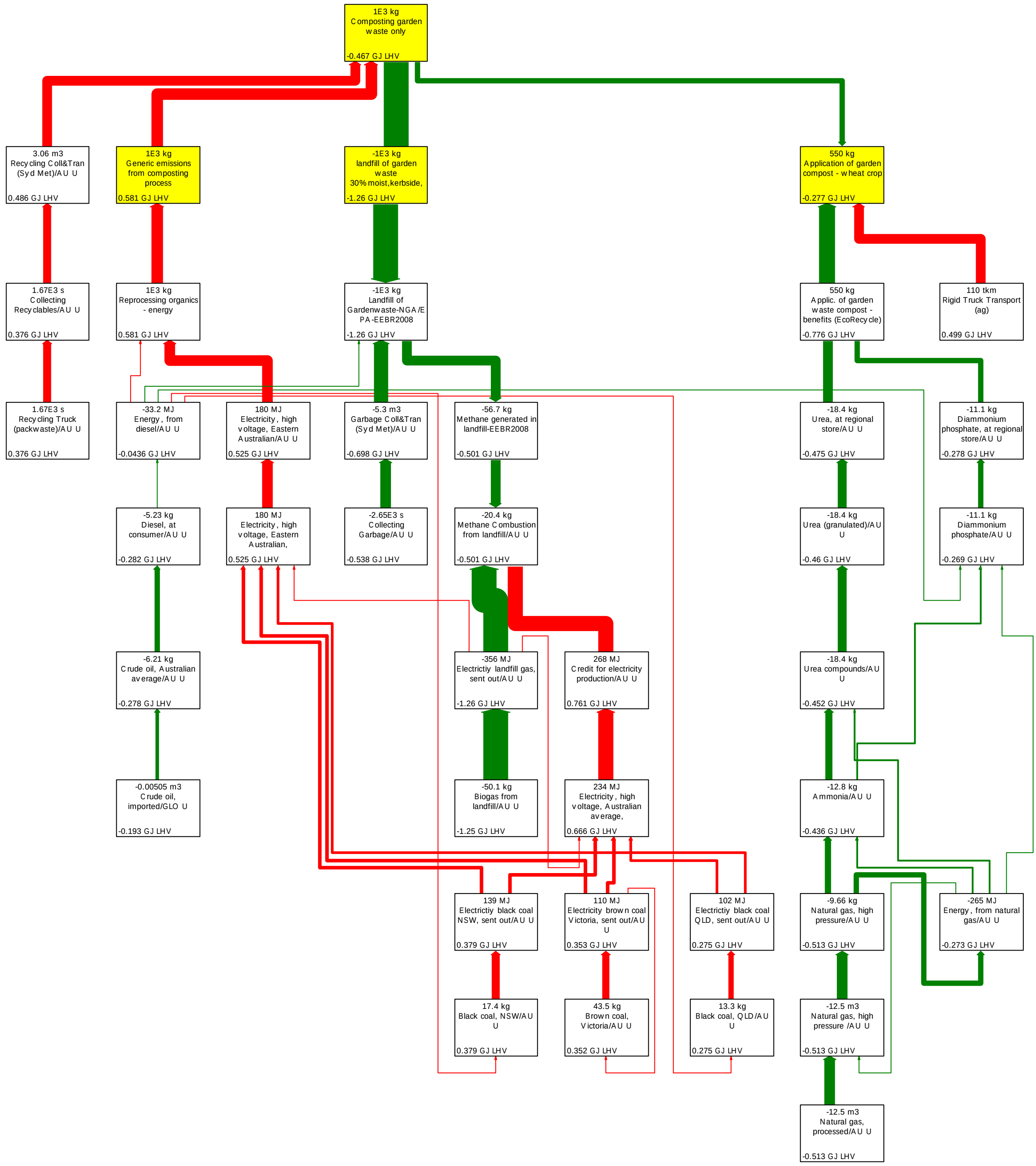


Figure 15: Recycling process network diagram — Solid waste indicator. Processes contributing less than 0.5 per cent to total are not shown. Major processes from results table above are shown shaded.