Environmental benefits of recycling

Appendix 2 – Building materials

Concrete, brick, asphalt and plasterboard

NSW GOVERNMENT

Environment, Climate Change & Water

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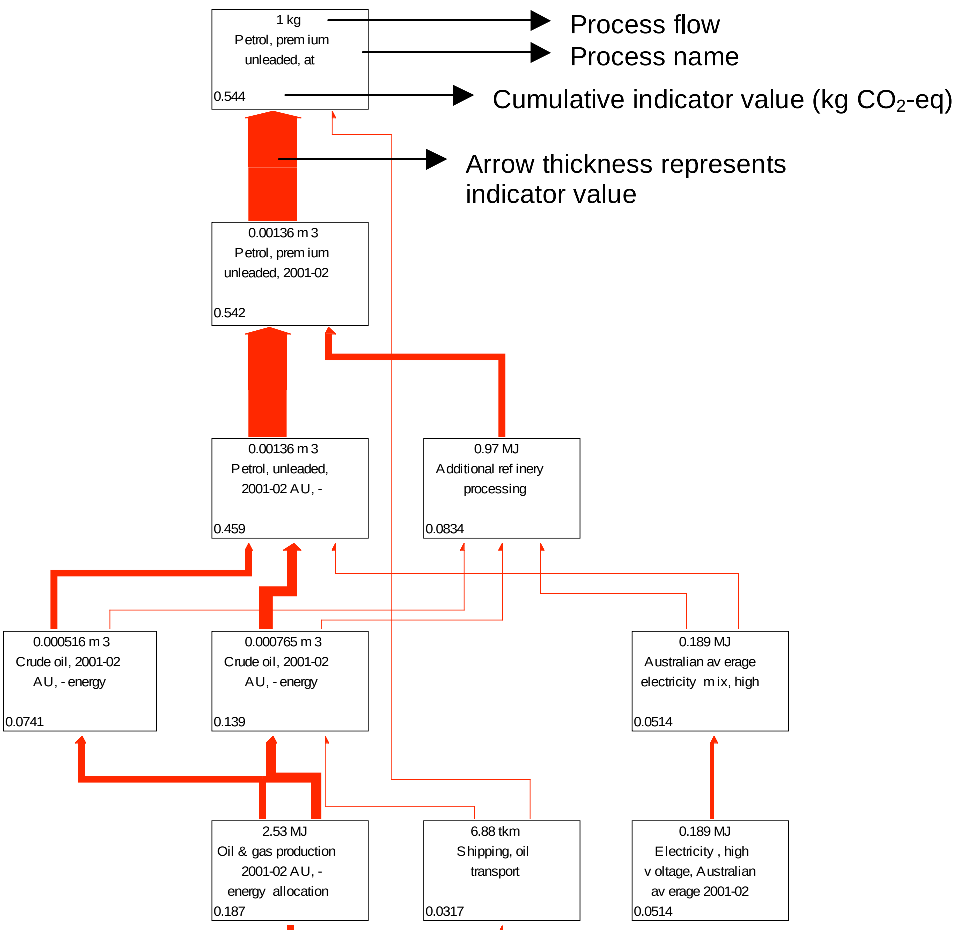
Understanding network diagrams

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.



Asphalt

Process description

Asphalt is a composite material, usually made of bitumen and aggregate, commonly used for the construction of pavement. After collection for recycling and reprocessing, it can be used as an aggregate in road base and other construction activities or in recycled asphalt products, where the bituminous content of the asphalt is also reused. The recycling process is relatively simple, with asphalt being crushed either onsite where road repair is being undertaken, or offsite, and it is then re-blended with additional bitumen and other additives as necessary to produce an appropriate quality of asphalt ready for laying. Re-blending rates up to approximately 20 per cent are typically achieved.

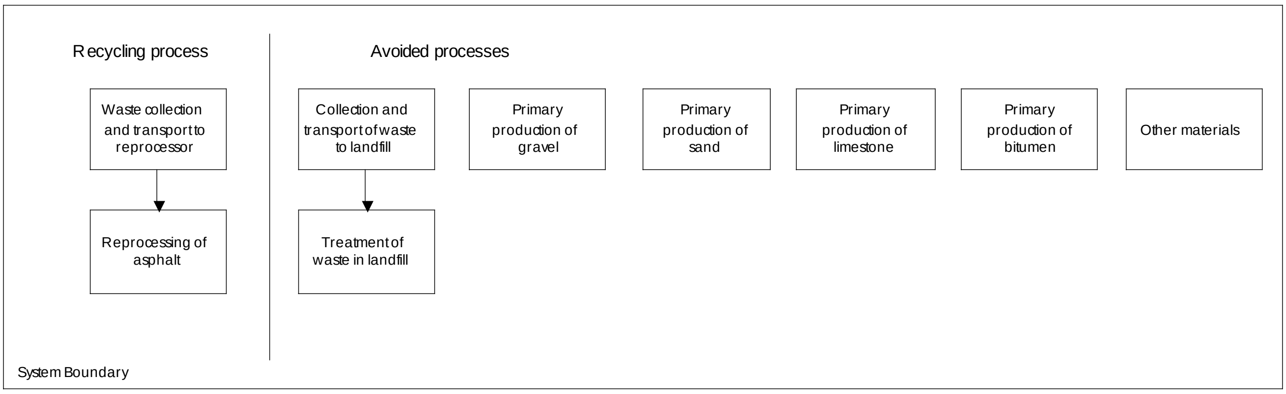
Only one collection system for waste asphalt was considered in the model:

> C&I and 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 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).

Recycled asphalt is assumed to be used as a '1 for 1' substitute for virgin asphalt at up to a maximum of 20 per cent of final asphalt production mix. This model assumes that up to this quantity, recycled asphalt displaces virgin asphalt on a '1 to 1' basis. This means that production of typical typical component materials are avoided, as described in Figure 2. Notably, the model assumes the model assumes that sufficient capacity exists within NSW to accept an incremental unit of recycled asphalt, even though it can only represent a maximum of 20 per cent of final asphalt production. In this sense, the model developed reflects a marginal benefit associated with recycling in an unconstrained material demand situation. In future, asphalt recycling may increase such that recycled material exceeds that which can be accepted by local production (at a 20 per cent maximum usage), negating benefits of recycling.

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 Table 1.

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

Impact category	Unit	Recycling process impacts (Figure 24 - left hand side)	Avoided process impacts (Figure 24 - 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	0.02	-0.04	-0.01	-0.05	-0.03
Cumulative energy demand	GJ LHV	0.22	-2.46	-0.13	-2.60	-2.38
Water use	kL H_2O	0.02	-0.90	0.00	-0.90	-0.88
Solid w aste	tonnes	0.00	-0.06	-1.00	-1.06	-1.06

Network diagrams detailing key processes that influence the impact listed in Figure 2 are shown in 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 asphalt. The table also includes the products and processes avoided when 1 tonne of asphalt is recycled.

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

Item	Flow	Unit	Comment
Recycling process flows (Figure 2 — left hand side)			
Waste collection and transport to reprocessor	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.
Reprocessing of asphalt	1	tonne	Energy inputs from asphalt reprocessing extracted from a Swedish LCI (Stripple, 2005). 57.6 MJ of diesel and 41 MJ of electricity consumed during the process Impacts from the production of electricity high voltage in Australia are based on ESAA, 2003 and other sources. Emissions from consumption of diesel recorded by Pre Consultants, from Boeijink (1993). Data on diesel density from ABARE (2008)
Avoided process flows (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.
Landfill of asphalt	1	tonne	Emission factors adapted from EcoInvent database to Australian conditions; energy and transport data have been changed to Australian data. Operation to the landfill from a personal communication with S. Middleton, Pacific Waste, NSW, 1998.
Primary production of gravel	0.64	tonne	Quantity used in the asphalt mix from Stripple (2000). Gravel production impacts from EcoInvent database, adjusted for Australian conditions (energy and materials data have been changed to Australian data). Distance from quarries to Sydney regional store (127 km) estimated from NPI emissions database.
Primary production of sand	0.16	tonne	Quantity used in the asphalt mix from Stripple (2000). Sand production impacts adapted for Australian conditions from IVAM database. Distance from quarries to Sydney regional store (127 km) estimated from NPI emissions database.
Primary production of bitumen	0.05	tonne	Quantity used in the asphalt mix from Stripple (2000). Bitumen production impacts developed from data provided in 2002 National Pollutant Inventory (NPI) (2004).
Primary production of limestone	0.03	tonne	Quantity used in the asphalt mix from Stripple (2000). Limestone production impacts based on past discussions with ACI Minerals. Distance from quarries to Sydney regional store (180 km) estimated from NPI emissions database.
Other materials	0.12	tonne	Amount used in the asphalt mix from Stripple (2000). Refers to Recycled Asphalt Pavement (RAP) and dust. Production impacts assumed to be negligible.

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 asphalt, from C&I and C&D source (1 tonne)

	Primary Data Source	Geography	Data Age	Technology	Representativeness
Impacts of transportation modes	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 asphalt	Grant and James (2005)	Australia	2006	Average	Mixed data
Avoided Materials production	Eco-Invent, IVAM, NPI and conversations with material reprocessors	Australia and Europe	2000-2006	Average	Mixed Data
Avoided landfill impacts	Ecoinvent	European data adapted to Australian consitions	2004	Unspecified	Unspecified
Impacts from reprocessing energy	NGGI, NPI and other sources	Australia	2002–2006	Average	Representative of energy consumption in Australia

References

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

DEH (2004), National Pollutant Inventory Data for year 2002, Department of Environment, Canberra.

DEH (2009), National Pollutant Inventory Data for year 2006, Department of Environment, Canberra, http://www.npi.gov.au

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)

IVAM 4.0 Database (2004), IVAM Environmental Research, Amsterdam, Netherlands, from www.ivam.nl/index.php?id=164&L=1

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

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

Stripple (2000), Life Cycle Inventory of Asphalt Pavements, IVL Swedish Environmental Research Institute Ltd for European Asphalt Pavement Association and Eurobitume

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

Network diagrams — C&I and C&D collection

Figure 3: Recycling process network diagram — Green house gases indicator. Processes contributing less than 5 per cent to total are not shown. Major processes from results table above are shown shaded.

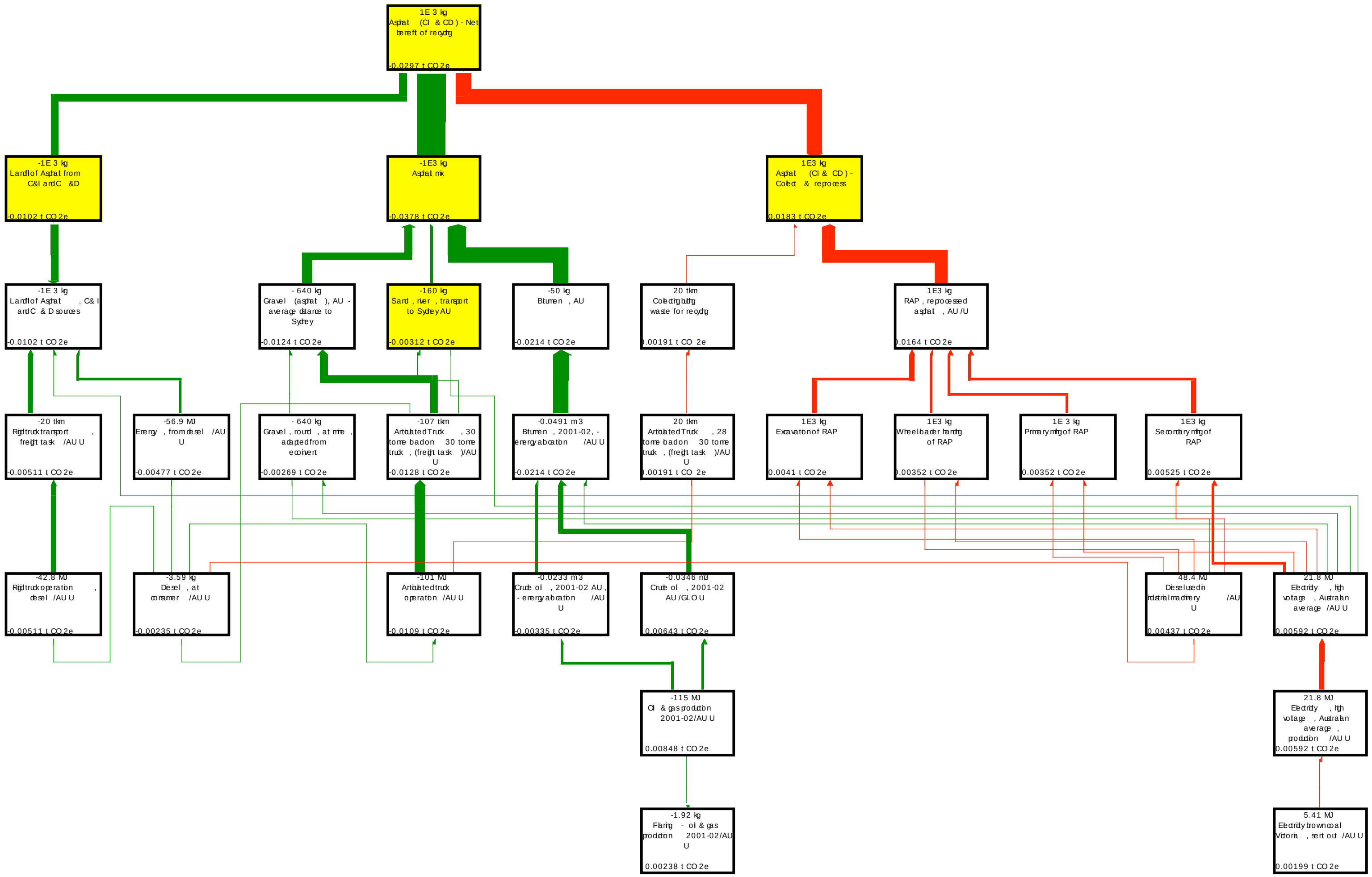


Figure 4: Recycling process network diagram — Cumulative energy demand indicator. Processes contributing less than 2 per cent to total are not shown. Major processes from results table above are shown shaded.

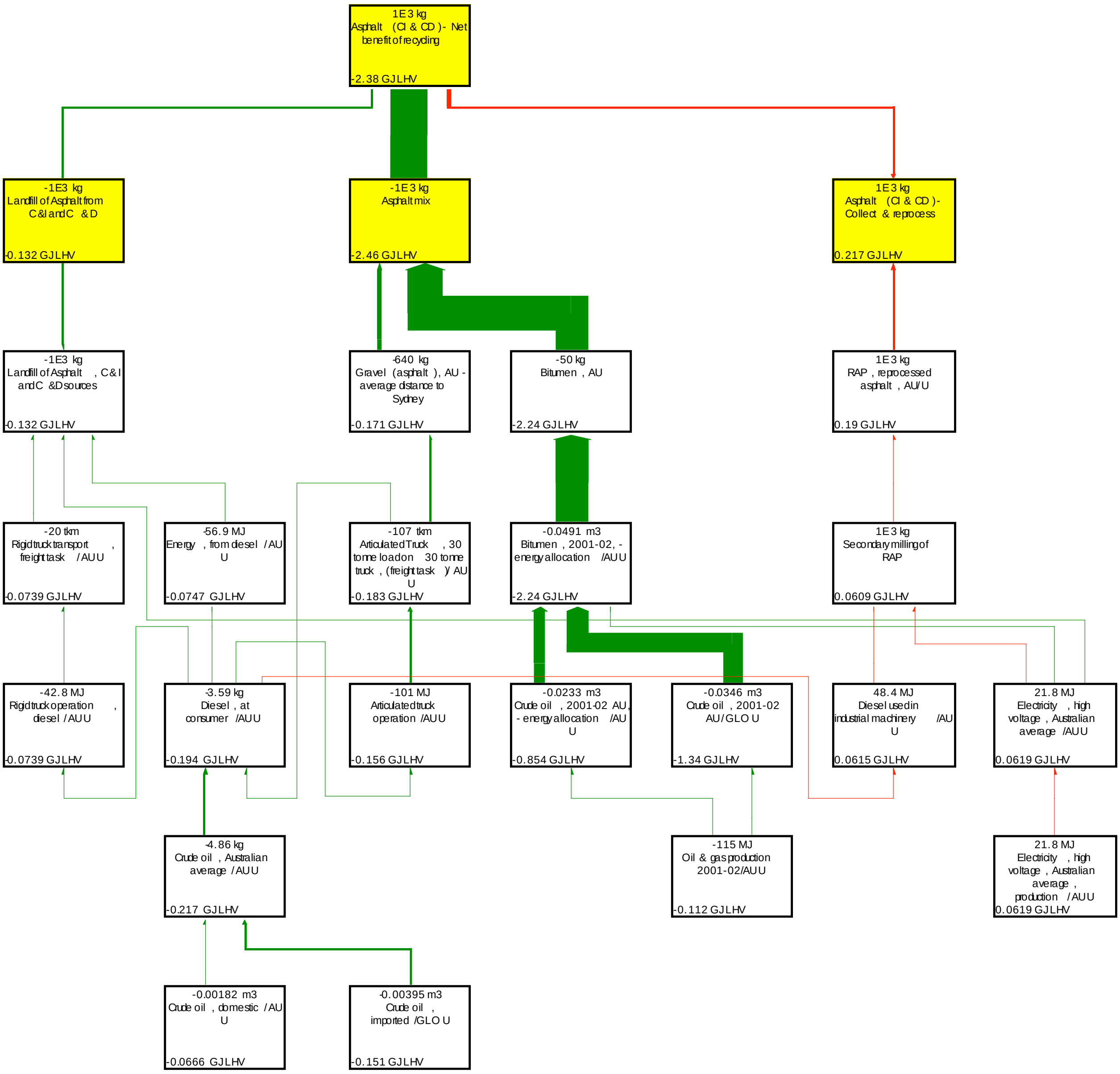


Figure 5: Recycling process network diagram — Water indicator. Processes contributing less than 2 per cent to total are not shown. Major processes from results table above are shown shaded.

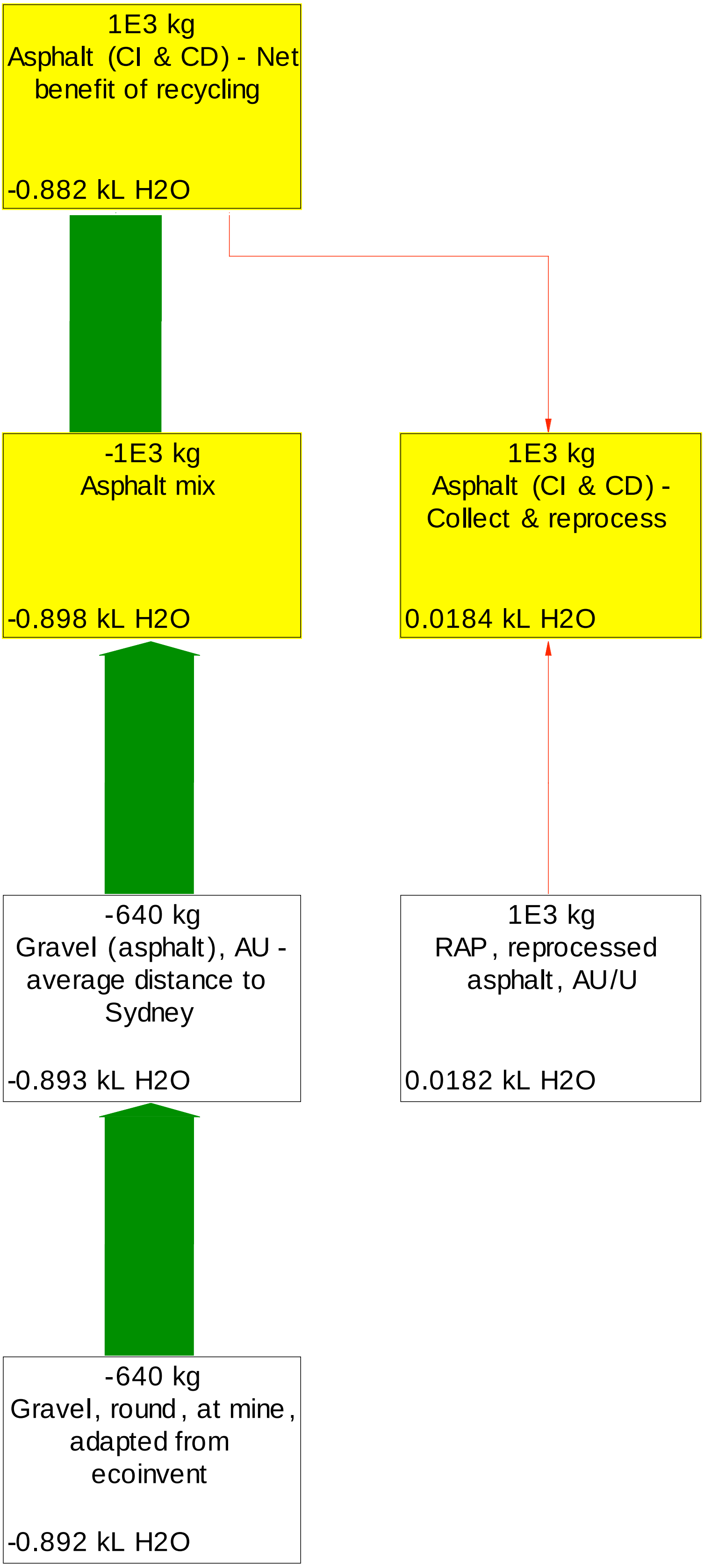
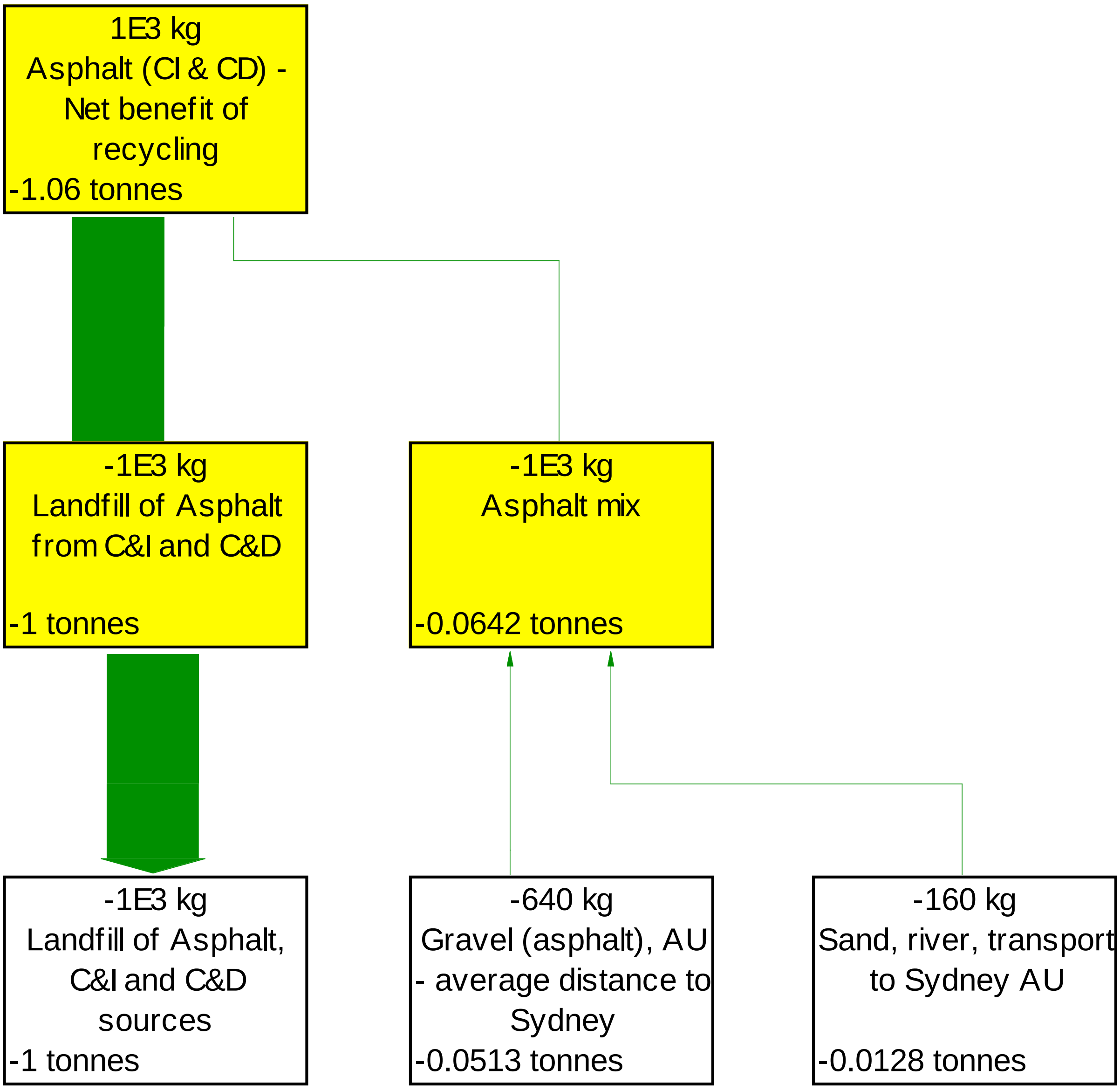


Figure 6: Recycling process network diagram — Solid waste indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.



Brick and Tile

Process Description

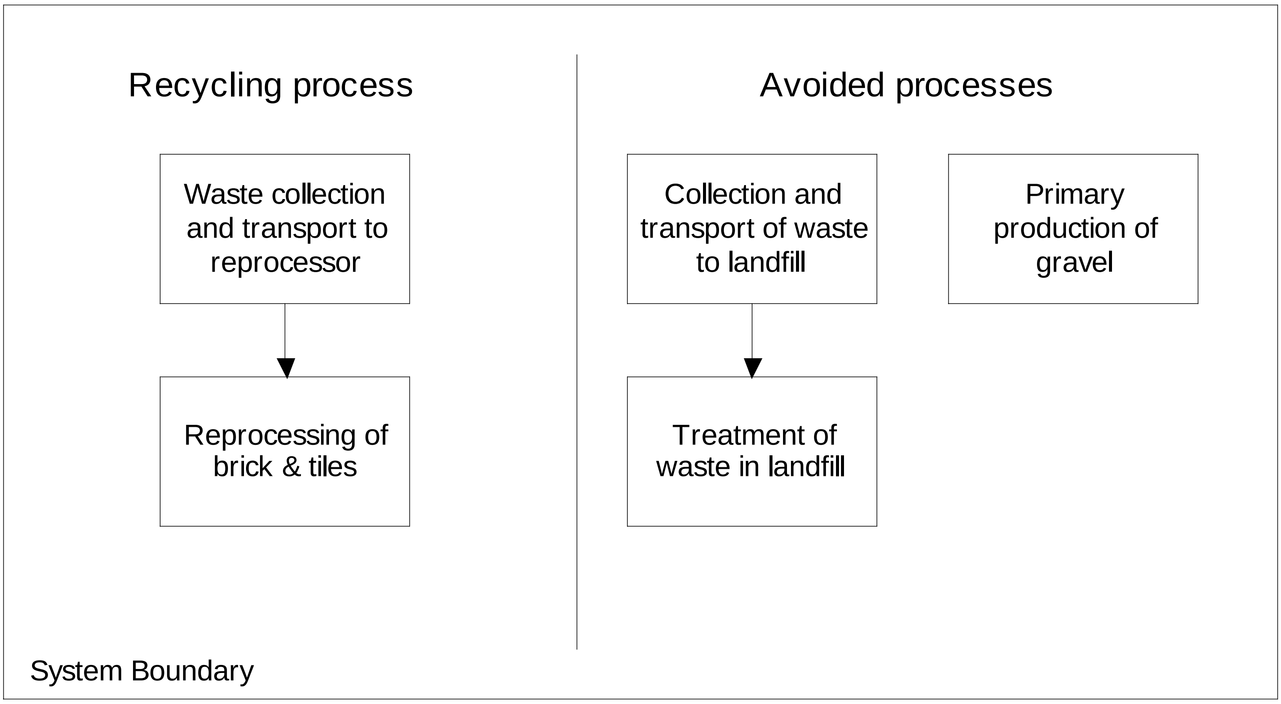
Bricks and tiles are materials commonly used for building construction. Waste from the use of these materials is collected from various construction sites and can often be part of a larger volume of co-mingled debris. The reprocessing process modelled for brick and tile is straight forward. The brick and tile waste is crushed several times in order to progressively reduce the size of the crushed product generated. It is then screened and can be reused as aggregate in different processes, i.e. road construction.

Only one collection system for brick and tile waste was considered in the model:

> C&I and 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.

Figure 7 illustrates the processes considered in determining the overall impact of brick and tile recycling from C&I and C&D sources (shown to the left of the vertical line), and the processes avoided when recycling brick and tile (shown to the right of the vertical line).

Figure 7: 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 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.

Table 4: Benefits and impacts of recycling brick and tile from C&I and C&D sources (per tonne). Benefits are shown negative, impacts are shown positive.

Impact category	Unit	Recycling process impacts (Figure 29 - left hand side)	Avoided process impacts (Figure 29 - 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	0.01	-0.01	-0.02	-0.03	-0.02
Cumulative energy demand	GJ LHV	0.09	-0.13	-0.24	-0.37	-0.28
Water use	kL H_2O	0.00	0.00	-1.26	-1.26	-1.26
Solid w aste	tonnes	0.00	-1.00	-0.07	-1.07	-1.07

Network diagrams detailing key processes that influence the impact listed in Figure 7 are shown in Figure 8 to Figure 11. For further information regarding interpretation of network diagrams, refer to Understanding Network Diagrams (Figure 1).

Process data

Table 5 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 brick and tile waste. The table also includes the products and processes avoided when 1 tonne of brick and tile waste is recycled.

Table 5: Inventory for recycling brick and tile (1 tonne)

Item	Flow	Unit	Comment
Avoided products (Figure 7 — left hand side)			
Waste collection and transport to reprocessor	20	km	20km distance estimate based on a simplified transport analysis for Sydney. Refer transport discussion below. 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.
Reprocessing of brick and tile waste	48.3	MJ	Energy inputs from Grant (2005). Amount of diesel used per MJ, and emissions from Pre Consultants from Boeijink (1993). Data on diesel density from ABARE (2008)
Avoided process (Figure 7 — right hand side)			
Collection and transport of waste to landfill	20	km	20km distance estimate based on a simplified transport analysis for Sydney. Refer appendices for transport model details. 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.
Treatment of waste in landfill	1	tonne	Emission factors for brick and tile from Tellus Study (1992), energy and transport data adapted to Australian conditions.
Primary production of gravel	0.9	tonne	Gravel production impacts from Ecoinvent database, adjusted for Australian conditions (energy and materials data have been changed to Australian data) Distance from quarries to Sydney regional store (127 km) estimated from NPI emissions database.

Data Quality table and comment

Table 6 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 6: Data quality for life cycle inventory data modelled for recycling and landfilling of brick and tile 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 brick and tile	Grant and James (2005)	Australia	2006	Average	Mixed data
Avoided gravel production	EcoInvent and IVAM	Australia and Europe	2000-2006	Average	Mixed Data
Avoided landfill impacts	Tellus Packaging Study, 1992	Australia	1999	Unspecified	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.

Boeijink, Miedema (1993), Inzameling vormvaste kunststof verpakkingen, Ecolyse Nederland, Aduart, Arnhem, The Netherlands

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

Tellus Institute (1992), Tellus Packaging Study, for the Council of State Governments, US EPA and New Jersey Department of Environmental Protection and Energy

Network diagrams — C&I and C&D collection

Figure 8: 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.

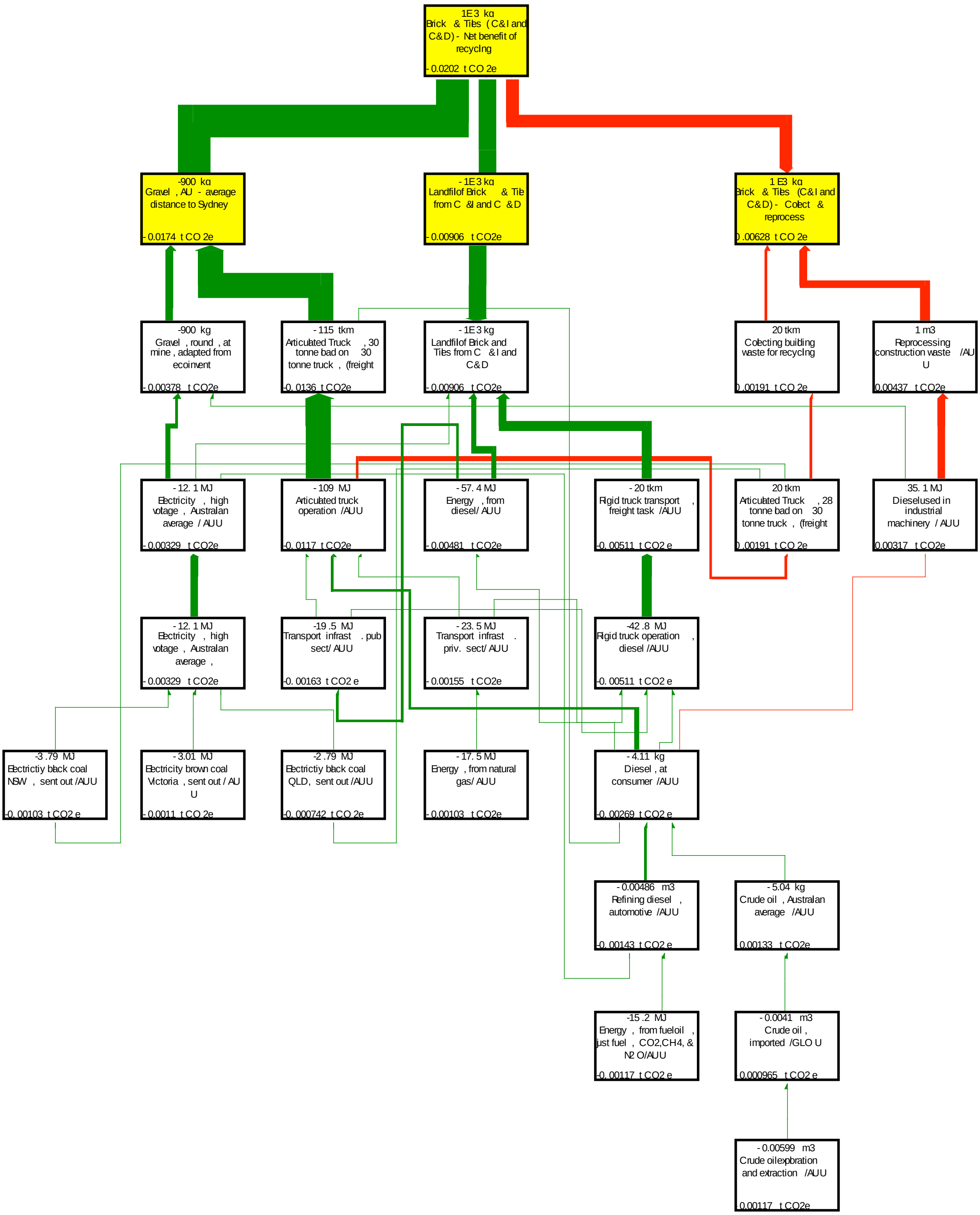


Figure 9: Recycling process network diagram — Cumulative energy demand indicator. Processes contributing less than 4 per cent to total are not shown. Major processes from results table above are shown shaded.

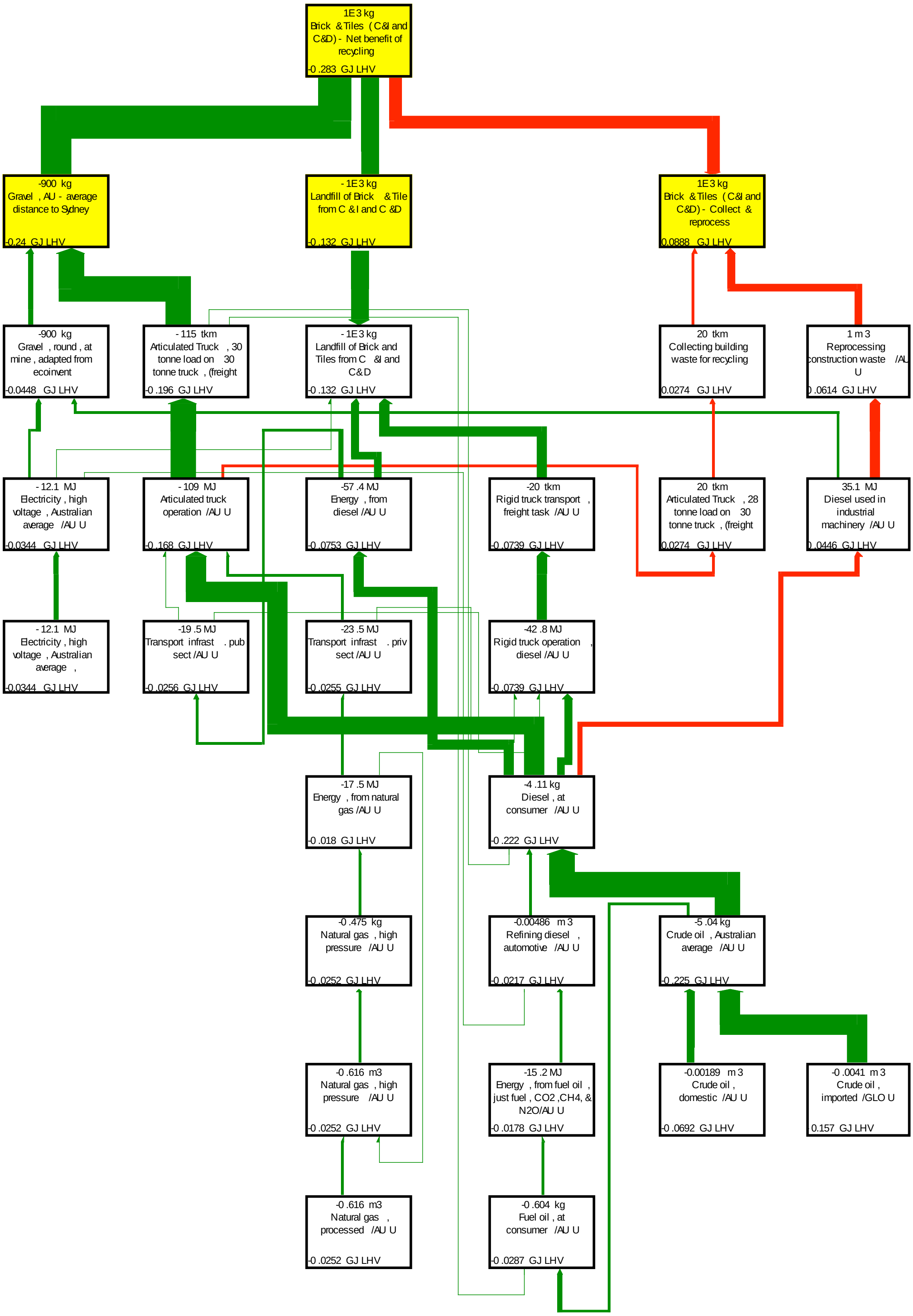


Figure 10: Recycling process network diagram — Water indicator. Processes contributing less than 0.5 per cent to total are not shown. Major processes from results table above are shown shaded.

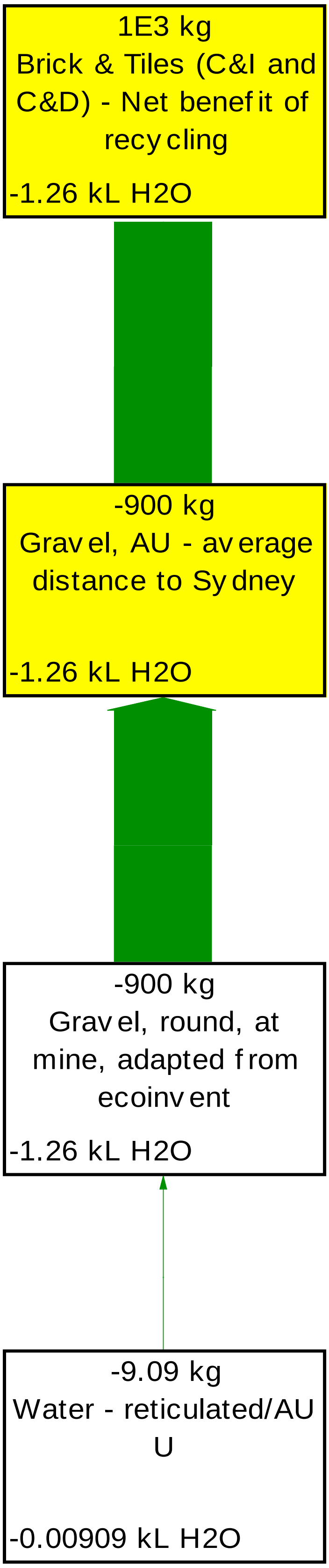
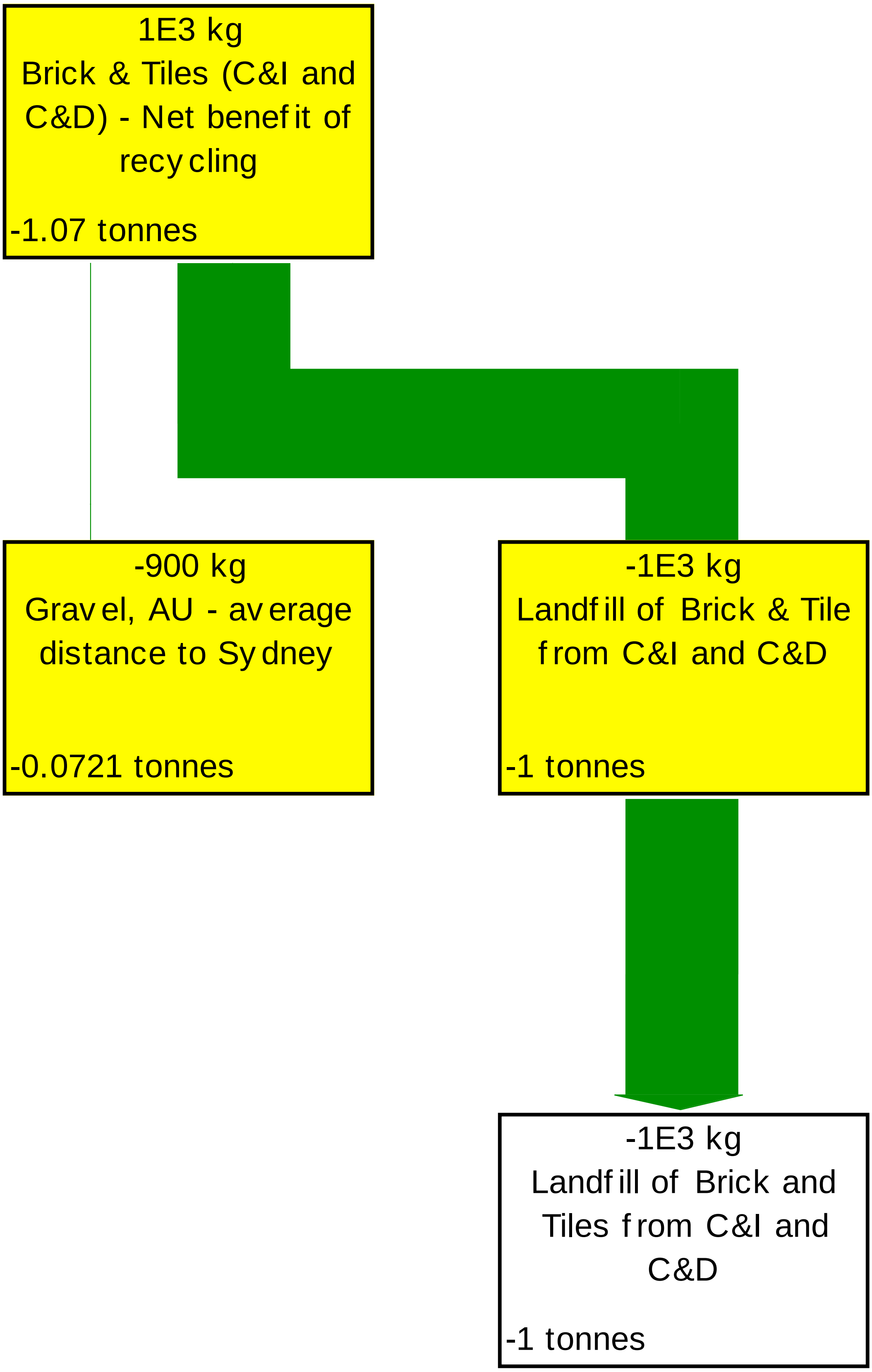


Figure 11: Recycling process network diagram — Solid waste indicator. Processes contributing less than 0.5 per cent to total are not shown. Major processes from results table above are shown shaded.



Concrete

Process description

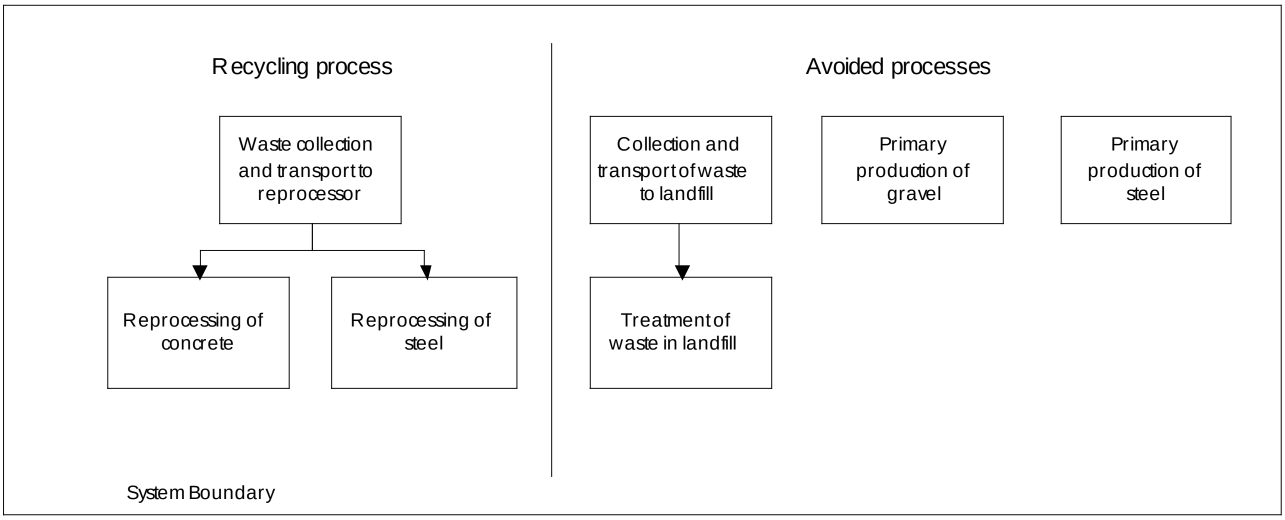
Concrete is a composite construction material composed of cement as well as fly ash, slag cement, aggregate (a combination of gravel, limestone and sand), water and chemicals. It is a very commonly used material, and construction sites can produce a large amount of concrete waste. Concrete is collected from building sites and crushed and screened into different grades for re-use, along with asphalt, bricks, dirt and rocks. It goes with other materials through a variety of different machines depending on the size of the matter, including a rubble crusher, side discharge conveyor, screening plant, and a return conveyor from the screen to the crusher inlet for reprocessing oversize materials. It can then be reused as road base, gravel etc. Some other materials like steel can be recovered from reprocessing of concrete. Steel will usually be sent to reprocessing, as it has a high economic value.

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

> 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 12 illustrates the processes considered in determining the overall impact of concrete 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 concrete (shown to the right of the vertical line).

Figure 12: 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 12, an inventory of environmental flows was developed. This inventory was then assessed using the Australian Impact Assessment Method, with results described in Table 7.

Table 7: Benefits and impacts of recycling concrete from C&D and C&I sources (per tonne). Benefits are shown negative, impacts are shown positive.

Impact category	Unit	Recycling process impacts (Figure 34 - left hand side)	Avoided process impacts (Figure 34 - 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	0.00	0.00	-0.02	-0.02	-0.02
Cumulative energy demand	GJ LHV	-0.02	-0.06	-0.26	-0.32	-0.35
Water use	kL H_2O	0.09	0.00	-1.38	-1.38	-1.28
Solid w aste	tonnes	-0.01	-1.00	-0.08	-1.08	-1.09

Network diagrams detailing key processes that influence the impact listed in Figure 12 are shown in Figure 13 to Figure 16. For further information regarding interpretation of network diagrams, refer to Understanding Network Diagrams (Figure 1).

Key assumptions

Table 8 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 concrete. The table also includes the products and processes avoided when 1 tonne of concrete is recycled.

Table 8: Inventory for recycling concrete from C&I and C&D sources (1 tonne)

Item	Flow	Unit	Comment
Recycling process flows (Figure 12 — 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 transport discussion. 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 concrete, diesel use	77.2	MJ/tonne	Data provided by Concrete Recyclers (B.Lawson) (2008) Amount of diesel used per MJ, and emissions from recorded by Pre Consultants from Boeijink (1993). Data on diesel density from ABARE (2008)
Reprocessing of concrete, reticulated water use	15	kg/tonne	Data provided by Concrete Recyclers (B.Lawson) (2008)
Reprocessing of steel	10	kg	Assumption of 1 per cent steel recovery from concrete crushing.
Avoided process flows (Figure 12 — right hand side)			
Collection and transport of waste to landfill	20	km	20km distance estimate based on a simplified transport analysis for Sydney. Refer appendices for transport discussion. 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	Emission factors for concrete from Tellus Study (1992), energy and transport data adapted for Australian conditions.
Primary production of gravel	0.996	tonne	Gravel production impacts from EcoInvent database, adjusted for Australian conditions (energy and materials data have been changed to Australian data). Distance from quarries to Sydney regional store (127 km) estimated from NPI emissions database.
Primary production of steel	10	kg	Assumes 1 per cent of waste concrete is steel that can be recovered. Steel inventory based on input data from BHP (2000), and other sources Emission data from NGGIC (1995) and NPI (2002-2003)

Data Quality

Table 9 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 9: Data quality for life cycle inventory data modelled for recycling and landfilling of concrete from C&I and C&D (1 tonne)

	Primary Data Source	Geography	Data Age	Technology	Representativeness
Impacts of transportation modes	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 concrete	Grant and James (2005), Concrete Recyclers	Australia	2004–2006	Average	Mixed data
Avoided gravel production	Eco-Invent, and IVAM	Australia and Europe	2000–2006	Average	Mixed Data
Avoided landfill impacts	Tellus Packaging Study	Australia	1999	Unspecified	Mixed Data

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Tellus Institute (1992), Tellus Packaging Study, for the Council of State Governments, US EPA and New Jersey Department of Environmental Protection and Energy

Network diagrams — C&I and C&D collection

Figure 13: Recycling process network diagram - Green house gases indicator. Processes contributing less than 7 per cent to total are not shown. Major processes from results table above are shown shaded.

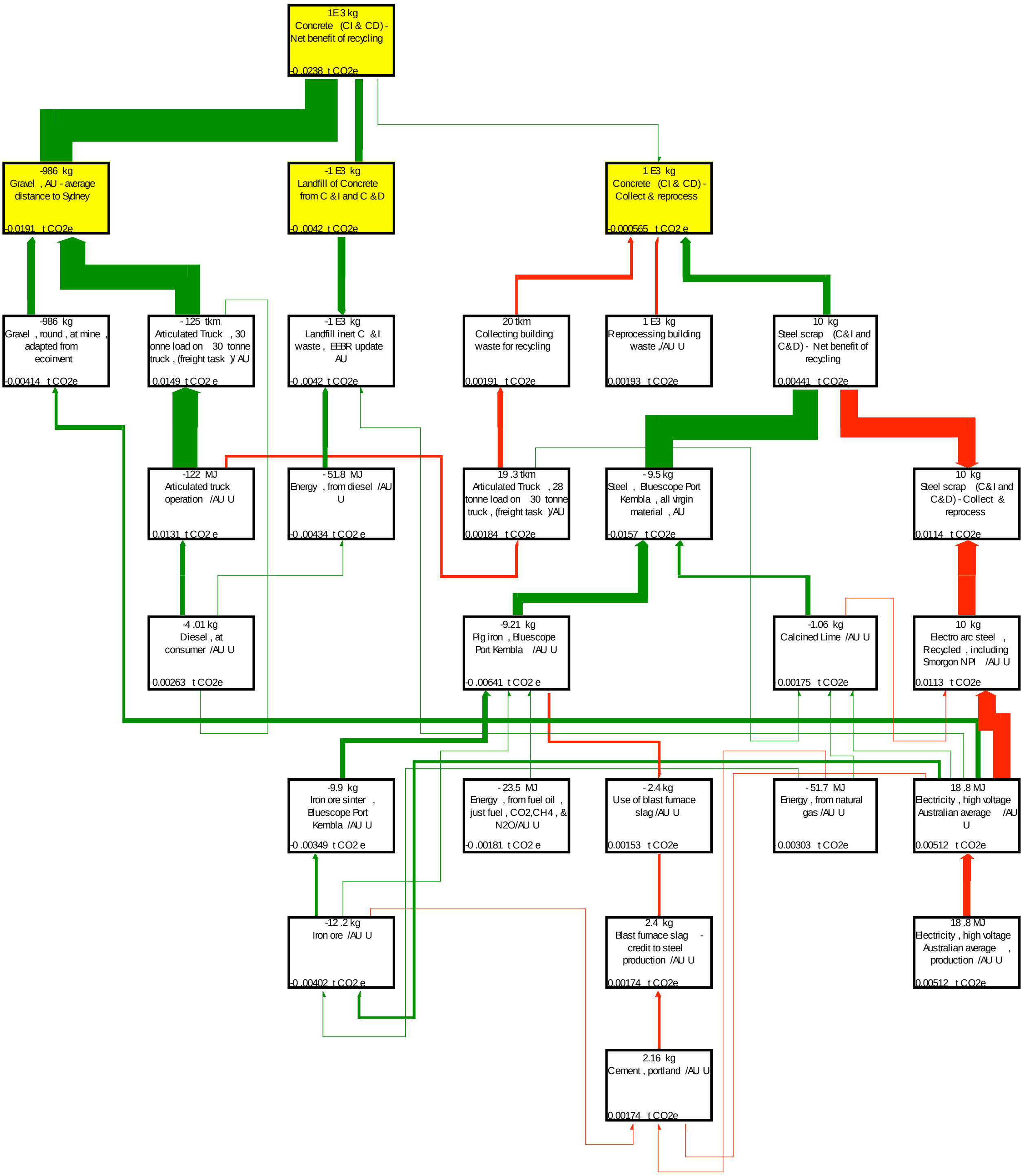


Figure 14: Recycling process network diagram — Cumulative energy demand indicator. Processes contributing less than 5 per cent to total are not shown. Major processes from results table above are shown shaded.

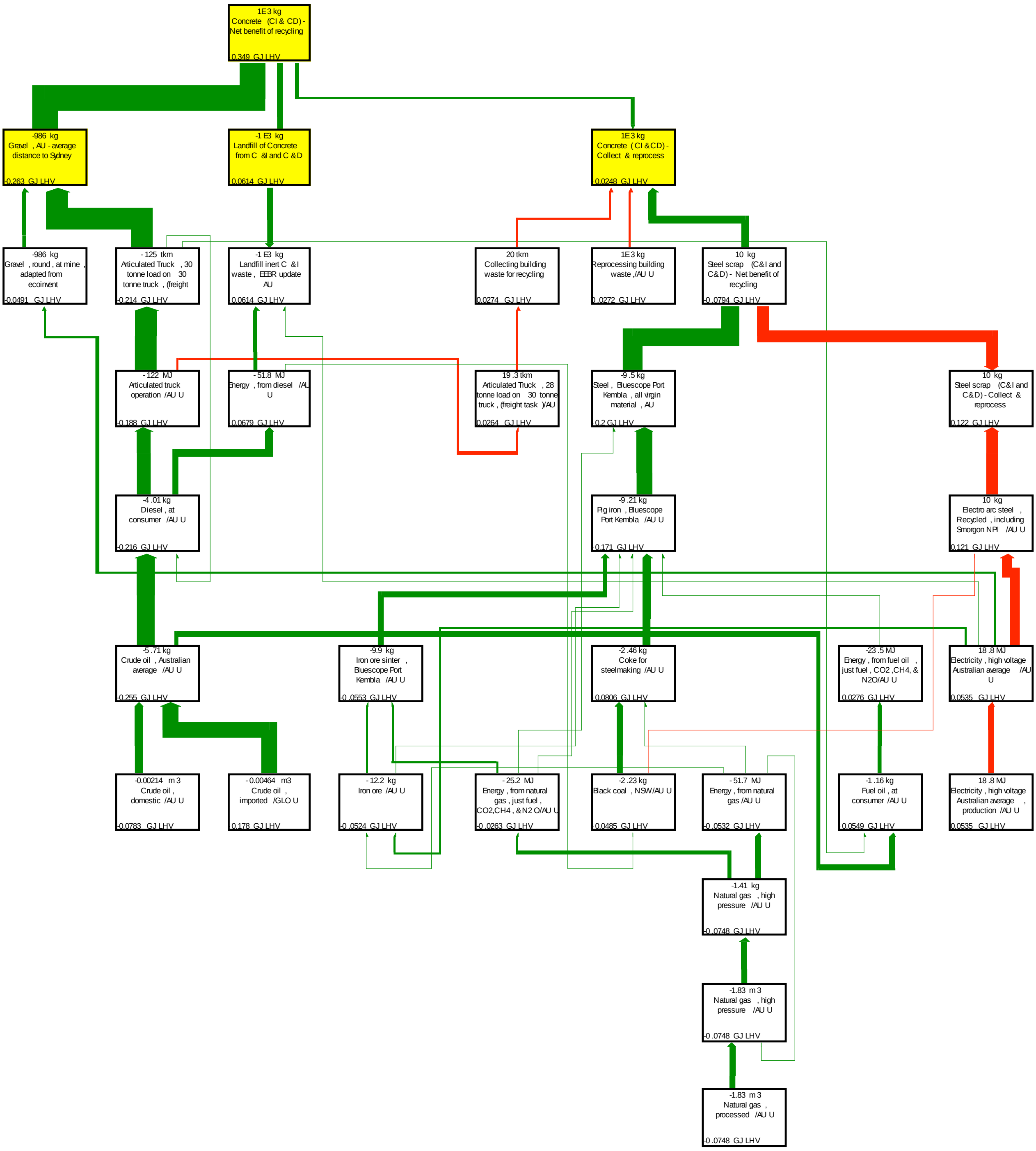


Figure 15: Recycling process network diagram — Water indicator. Processes contributing less than 0.5 per cent to total are not shown. Major processes from results table above are shown shaded.

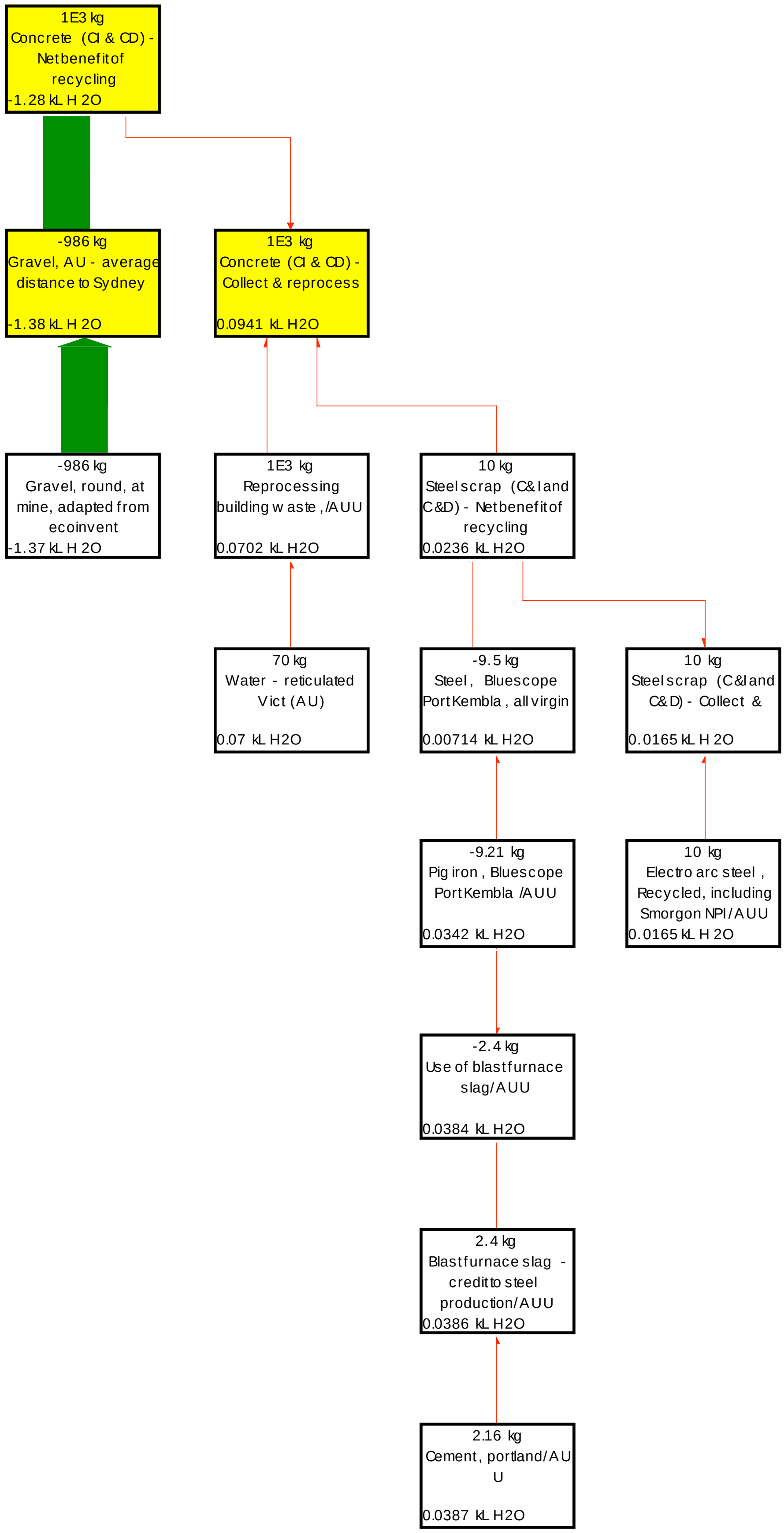
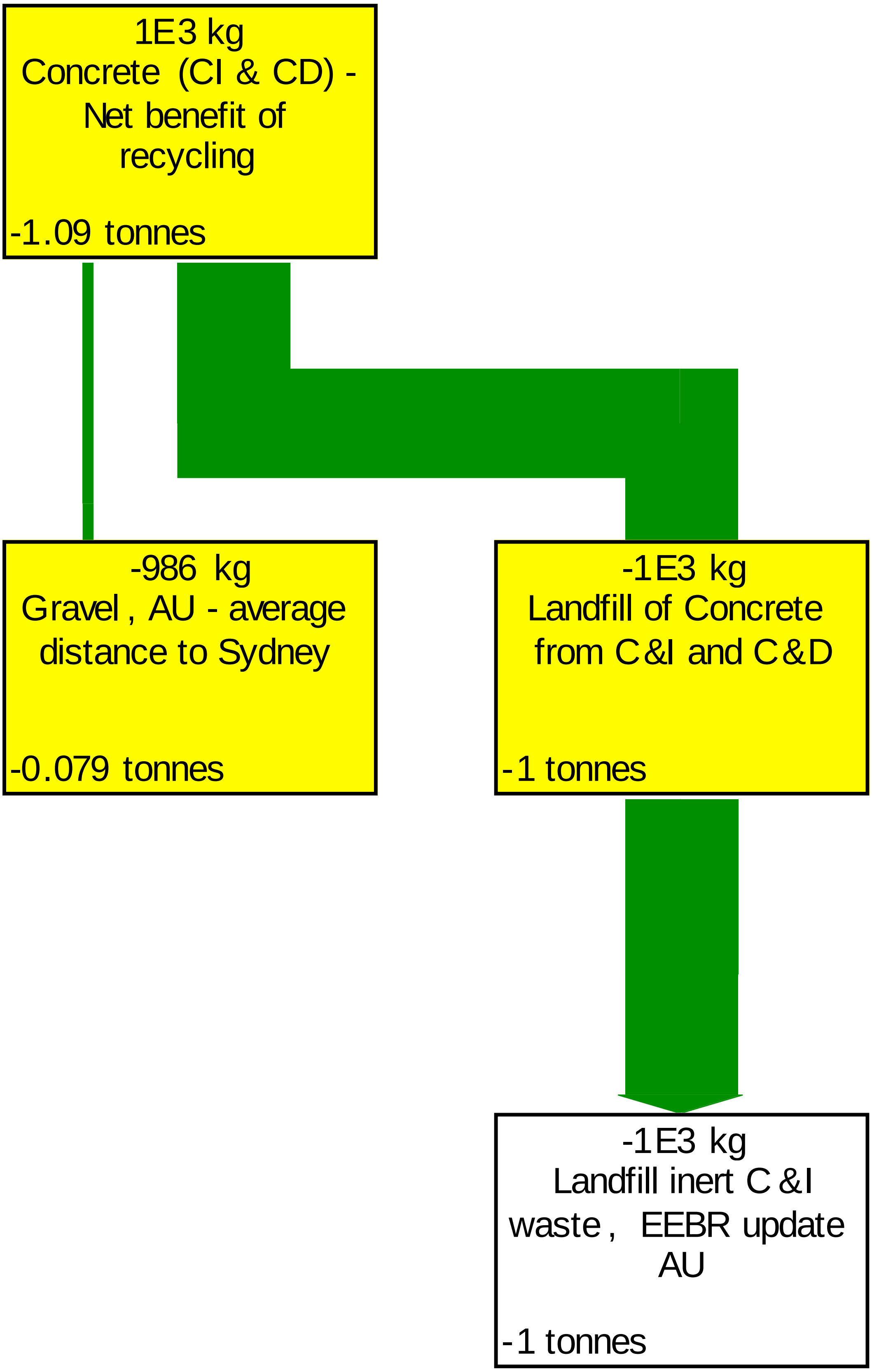


Figure 16: Recycling process network diagram — Solid waste indicator. Processes contributing less than 0.5 per cent to total are not shown. Major processes from results table above are shown shaded.



Plasterboard

Process description

Plasterboard is generally made of a layer of gypsum plaster pressed between two thick sheets of paper and then dried. It is usually used for the finish construction of interior walls and ceilings.

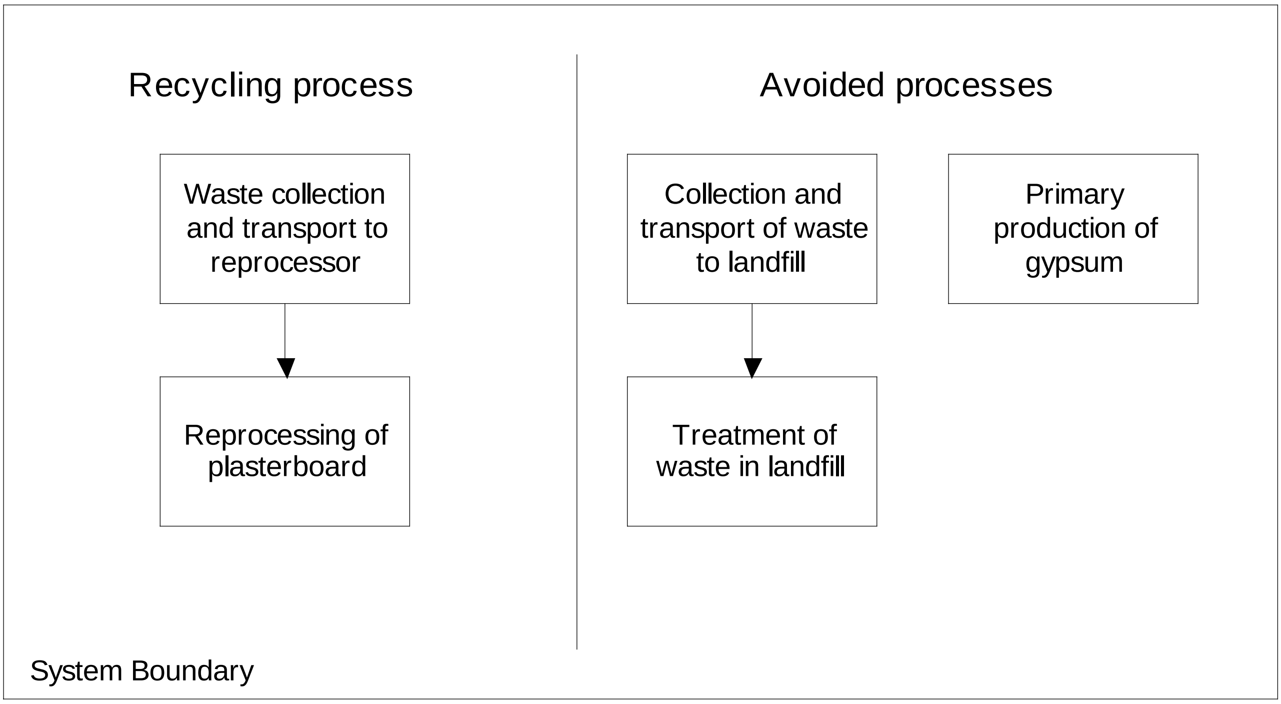
Waste plasterboard is generated as a post-industrial waste during plasterboard manufacture and as a result of C&D works. The post-industrial material is either remanufactured into billets for the packing and transportation of plasterboard sheets, or is crushed and the cardboard sent to composting and the gypsum used as a soil improver. In the case of C&D waste, the plasterboard is generally allowed to compost with other organic and soil waste after initial screening, where it breaks down almost entirely and ends up as a soil improver in manufactured topsoil and composts. No specific data was returned via the survey on plasterboard recycling; however a generic model was developed assuming the recycled plasterboard substitutes gypsum mining from natural sources. Most Australian gypsum produced for domestic use comes from South Australia, so transport via rail is assumed from South Australia to Sydney.

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

> 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 17 illustrates the processes considered in determining the overall impact of plasterboard 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 17: Processes considered in determining impacts of the recycling



Results

Considering both the recycling process flows and the avoided process flows, described in Figure 17, an inventory of environmental flows was developed. This inventory was then assessed using the Australian Impact Assessment Method, with results described in Table 10.

Table 10: Benefits and impacts of recycling and landfill of plasterboard from C&I and C&D source (per tonne). Benefits are shown negative, impacts are shown positive.

Impact category	Unit	Recycling process impacts (Figure 39 - left hand side)	Avoided process impacts (Figure 39 - 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	0.01	-0.01	-0.02	-0.03	-0.03
Cumulative energy demand	GJ LHV	0.07	-0.32	-0.30	-0.63	-0.55
Water use	kL H_2O	0.00	0.04	-0.01	0.03	0.03
Solid w aste	tonnes	0.00	-0.98	0.00	-0.98	-0.98

Network diagrams detailing key processes that influence the impact listed in Figure 17 are shown in Figure 18 to Figure 21. For further information regarding interpretation of network diagrams, refer to Understanding Network Diagrams (Figure 1).

Key assumptions

Table 11 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 plasterboard. The table also includes the products and processes avoided when 1 tonne of plasterboard is recycled.

Table 11: Inventory for recycling plasterboard from C&I and C&D (1 tonne)

Item	Flow	Unit	Comment
Process flows (Figure 17 — left hand side)			
Waste collection and transport to reprocessor	20	km	20km distance estimate based on a simplified transport analysis for Sydney. Refer transport discussion below. 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 plasterboard	36	MJ	Average diesel consumed to reprocess plasterboard. Estimate from Grant and James (2005) Impacts from diesel pre-combustion based on EcoInvent database adjusted for Australian conditions
Avoided process (Figure 17 — 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	Emission factors for plasterboard from Tellus (1992). Energy data adapted for Australian conditions.
Primary production of gypsum	0.9	tonne	Gypsum production impacts from EcoInvent database, adjusted for Australian conditions

Data Quality table and comment

Table 12 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 12: Data quality for life cycle inventory data modelled for recycling and landfilling of plasterboard

	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 plasterboard	Grant and James (2005)	Australia	2006	Average	Mixed data
Avoided gypsum production	EcoInvent and IVAM	Australia and Europe	2000–2006	Average	Mixed Data
Avoided landfill impacts	Tellus Packaging Study, 1992	Australia	1999	Unspecified	Mixed Data

References

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Boeijink, Miedema (1993), Inzameling vormvaste kunststof verpakkingen, Ecolyse Nederland, Aduart, Arnhem, The Netherlands

DEH (2009), National Pollutant Inventory Data for year 2006, Department of Environment, Canberra, http://www.npi.gov.au

Grant, T., James, K., (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

IVAM 4.0 Database (2004), IVAM Environmental Research, Amsterdam, Netherlands, from www.ivam.nl/index.php?id=164&L=1

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

Tellus Institute (1992), Tellus Packaging Study, for the Council of State Governments, US EPA and New Jersey Department of Environmental Protection and Energy

Network diagrams — C&I and C&D collection

Figure 18: Recycling process network diagram — Green house gases indicator. Processes contributing less than 4 per cent to total are not shown. Major processes from results table above are shown shaded.

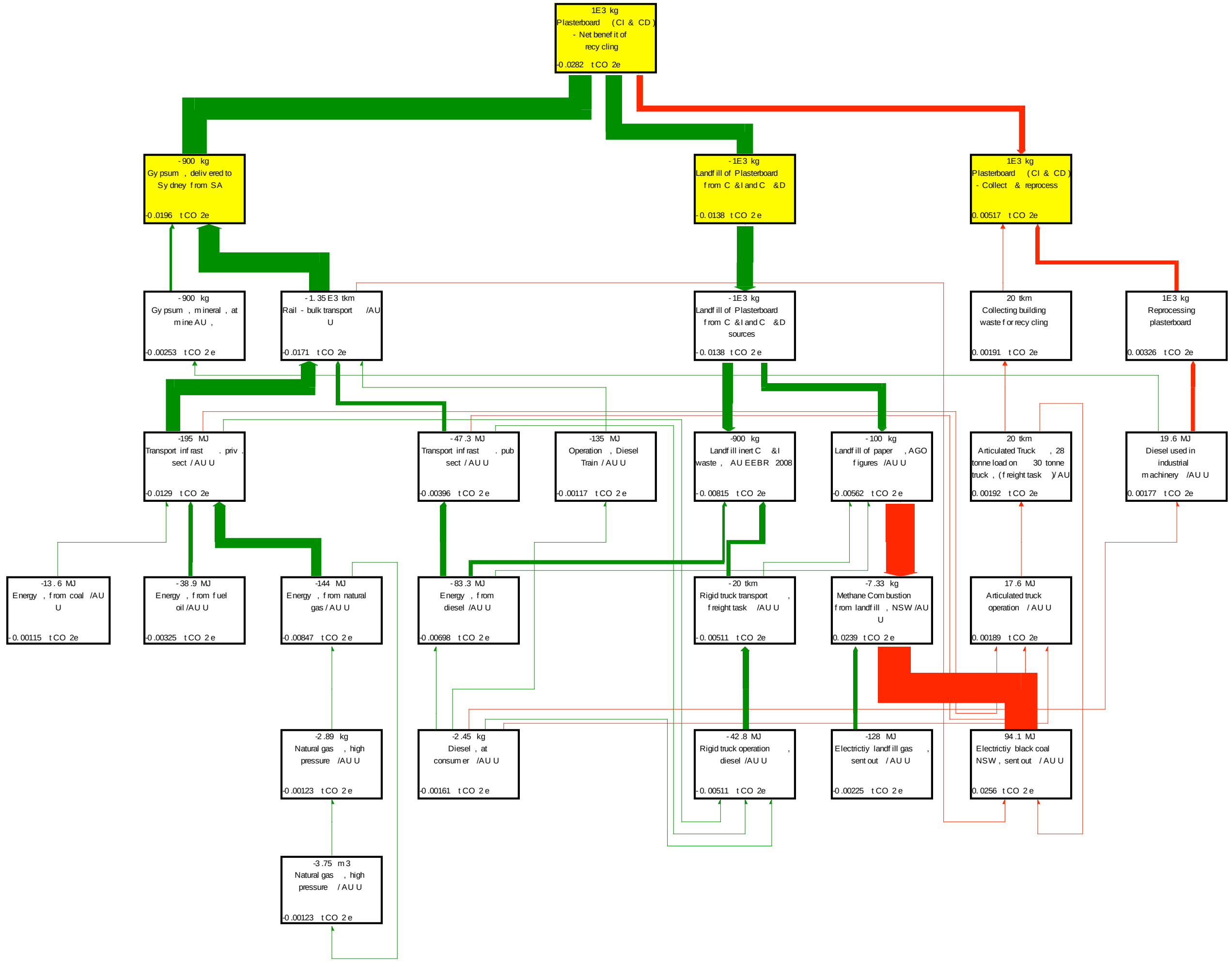

Figure 19: Recycling process network diagram — Cumulative energy demand indicator. Processes contributing less than 4 per cent to total are not shown. Major processes from results table above are shown shaded.

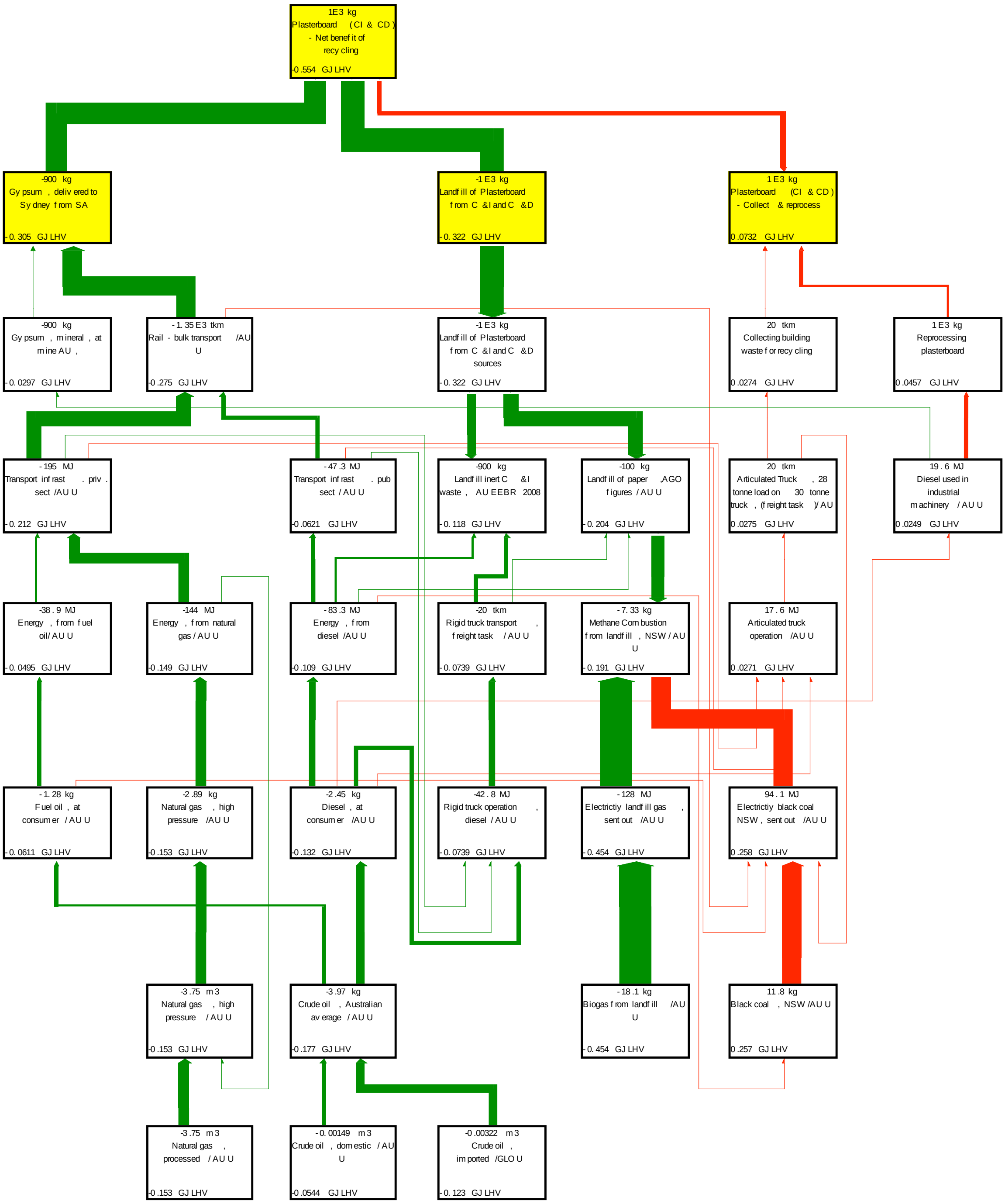

Figure 20: Recycling process network diagram — Water indicator. Processes contributing less than 3 per cent to total are not shown. Major processes from results table above are shown shaded.

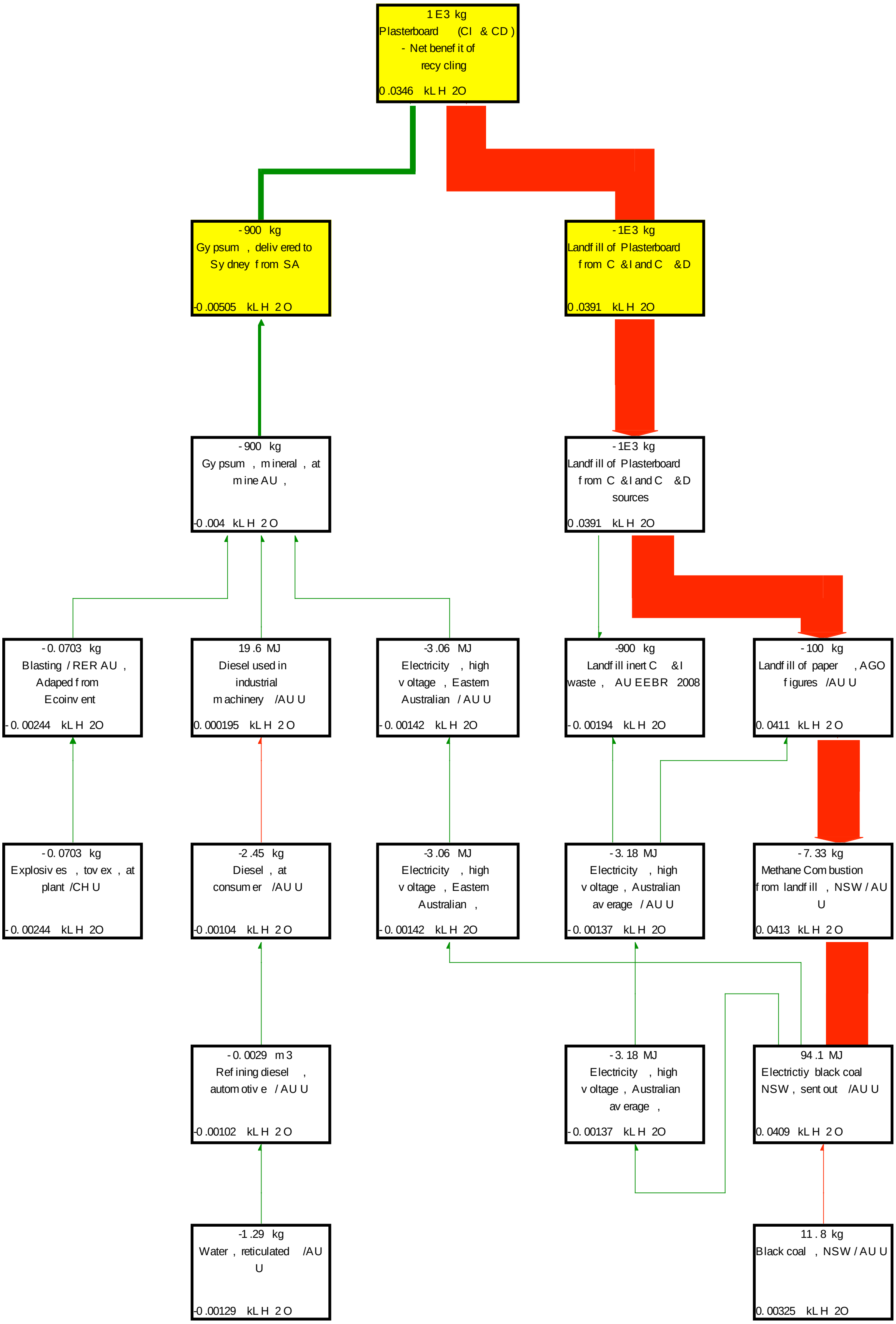

Figure 21: Recycling process network diagram — Solid waste indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.