Environmental benefits of recycling

Appendix 3 – Paper

Packaging paper and board, newsprint, liquid paper board and office paper

NSW GOVERNMENT

Environment, Climate Change & Water

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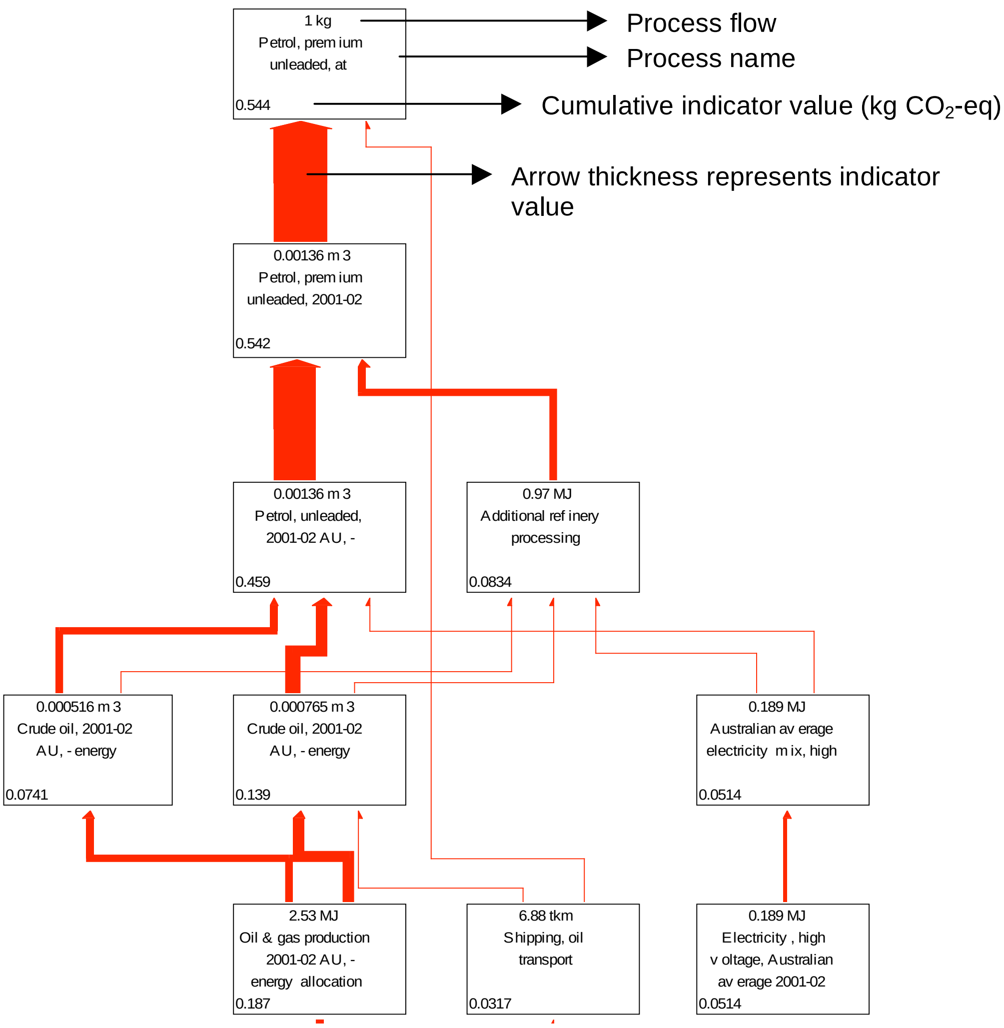
Understanding network diagrams

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.



Packaging paper and board

Process description

Corrugated board and packaging papers are generally recycled back into corrugated boards and papers by Visy Recycling and Amcor. The process involves sorting waste paper and board into basic commodity grades. These are then mixed with water to create a wet pulp, which is then screened through a series of turbo-separators to remove impurities. The pulp is then pumped at high speeds across a series of moving mesh filters (paper former), which drains the bulk of the water out of the pulp. A series of presses and heated dryers subsequently removes excess moisture from the fibre to form a single, continuous sheet of paper. In its final stage, the 100 per cent recycled paper is wound onto a jumbo reel. Paper is then rewound into smaller, more manageable paper reels for customer use. The avoided product is unbleached Kraft pulp (Grant, 2001a).

Two collection systems for waste paper and board were considered in the model:

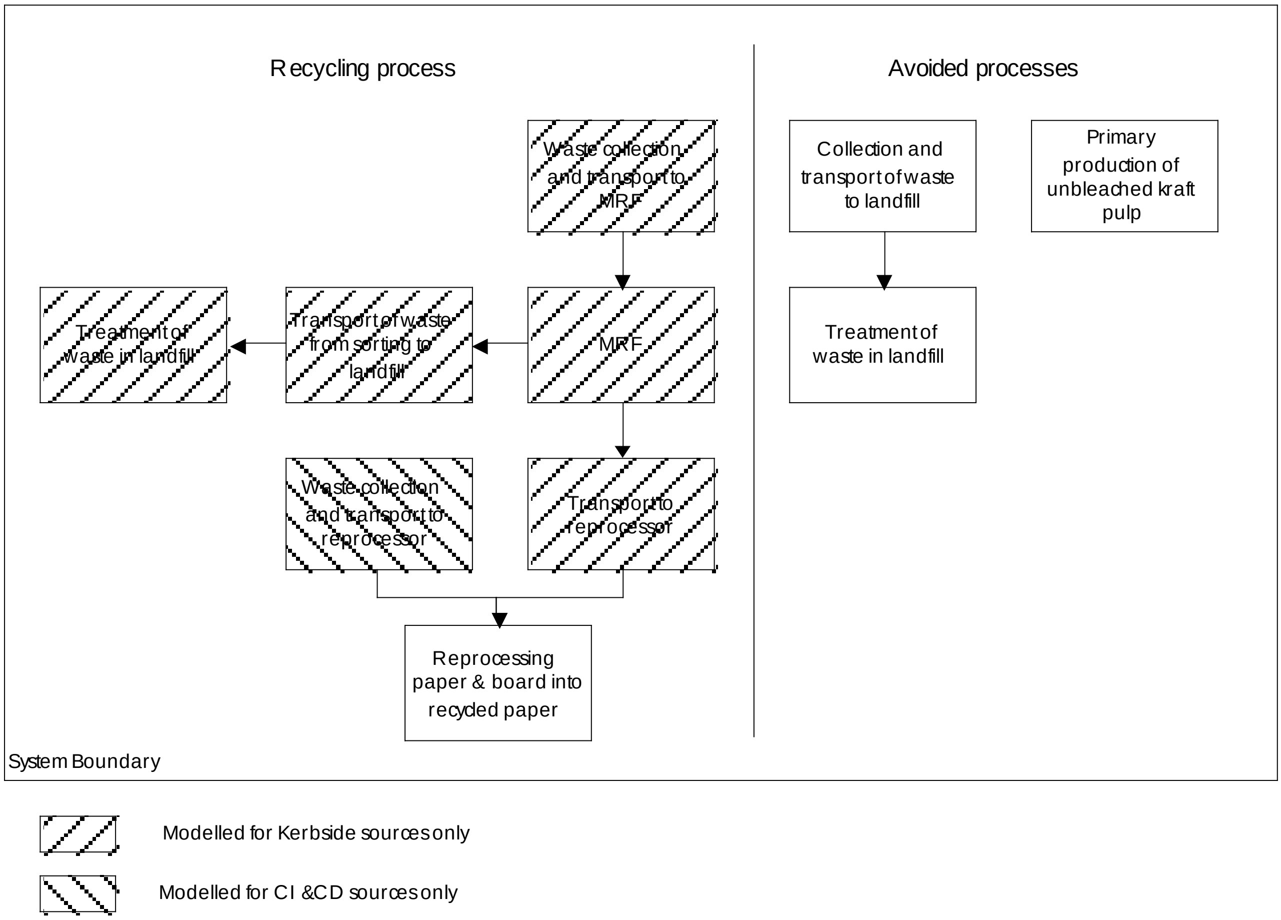
A) Kerbside collection — municipal collection from households, and processing through a Materials Recovery Facility

B) C&I, C&D collection — direct transfer of segregated waste from point of waste generation to a reprocessing facility

The unique nature of each collection system drives differences in the impacts associated with paper and board recycling. For this reason the recycling processes considered and impacts generated have been described separately in the following sections, according to the collection method used.

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

Figure 2: Processes considered in determining the net impacts of the recycling process from kerbside and CI&CD sources.



A) Kerbside collection system

Processes considered

The kerbside collection system involves collection of waste for recycling from the kerbside and transport to a Materials Recovery Facility (MRF), which sorts the commingled materials in the recycling stream. The model developed takes into account transportation impacts as well as sorting impacts incurred to bring the material from the kerbside to the material reprocessing facility. During sorting, waste material is generated and transported to landfill.

Once at the reprocessing facility, the model considers the impacts of material reprocessing required to convert the waste material into secondary products. Losses associated with this process are included in the analysis. The kerbside treatment system is illustrated in Figure 2 (process unique to kerbside collection are shaded accordingly).

In order to determine the benefit or impact of recycling a material, it is also necessary to consider the processes avoided when recycling is undertaken. Figure 2 also illustrates the processes that would be avoided if waste paper and board are reprocessed (shown to the right of the vertical line). Two main processes are considered, the collection and disposal to landfill of waste paper and board from the kerbside, and the primary manufacture of unbleached kraft pulp from virgin resources.

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 of paper and board from kerbside sources (per tonne). Benefits are shown negative, impacts are shown positive.

Impact category	Unit	Recycling process impacts (Figure 44 - left side)	Avoided process impacts (Figure 44 - 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	0.25	-0.78	-0.07	-0.85	-0.60
Cumulative energy demand	GJ LHV	3.34	-2.01	-10.65	-12.66	-9.32
Water use	kL H_2O	4.80	0.26	-30.47	-30.21	-25.41
Solid w aste	tonnes	0.10	-0.74	0.00	-0.74	-0.64

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 paper and board. The table also includes the products and processes avoided when 1 tonne of paper and board is recycled.

Table 2: Inventory for recycling 1 tonne of paper and board from a kerbside source (1 tonne)

Item	Flow	Unit	Comment
Recycling process flows (Figure 2 — left hand side)			
Waste collection and transport to MRF	8.0	m^3	Density from Grant (2001a) Transport model for kerbside collection based on collection model developed in Grant (2001b). Emission of the truck from Apelbaum (2001), NGGIC (1997) and other sources.
Sorting of paper and board at Material Recovery Facility (MRF)	8.0	m^3	10 per cent of the waste material is lost during sorting at MRF Energy inputs from Nishtala (1997) and estimated from equipment specifications
Transport to reprocessor	65	km	65km transport to reprocessor in Sydney metro area. Emissions from transport based on a trucking model developed from data provided by Apelbaum (2001)
Reprocessing paper and board into recycled paper	900	kg	Assumption of 25% loss (especially due to fibre losses), so reprocessing 980kg of waste ends up with 735kg of reprocessed paper outputs. Energy requirement to reprocess one tonne of waste paper. Estimate from Grant and James (2005): 0.311 GJ of electricity, 0.23 GJ from coal, 0.685 GJ from natural gas, 0.017 GJ from fuel, 0.17 GJ from steam (cogeneration), and 0.062 MJ from woodwaste consumed for the reprocessing of 1 tonne of waste. Visy environment report 2003/2004 for water, electricity and energy data. Impact from the production of electricity high voltage in Australia based on ESAA, 2003 and other sources. This is the main inventory which is an integrated grid for QLD, NSW, ACT, SA and Victoria.
Transport of waste from sorting to landfill	20	km	Emissions from transport based on an articulated truck, 28 tonne load on 30 tonne truck. Trucking model developed from data provided by Apelbaum (2001).
Treatment of waste in landfill	100	kg	During the sorting process, 10 per cent of waste assumed to be discarded at MRF, and treated in landfill. 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 per cent Hyder (2006), 'Mid 2020' scenario.
Avoided process flows (Figure 2 — right hand side)			
Collection and transport of waste to landfill	8.0	m^3	Waste collection avoided by sending material to MRF 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.
Landfill of mixed paper	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.
Unbleached kraft pulp	675	kg	For 900kg reprocessed 675kg of paper is produced thereby avoiding 675kg of virgin unbleached kraft pulp production.. Data from IVAM Environmental Research, University of Amsterdam 13.5 MJ of energy from woodwaste, plus the energy necessary to produce the pulp wood supply, consumed for the processing of 1 tonne of unbleached kraft pulp.

Data quality table and comment

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 paper and board, kerbside source

	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 waste paper	Grant and James (2005), Visy Industries	Australia	2003–2005	Average	Mixed data
Avoided unbleached kraft pulp	IVAM	Europe	2005	Unspecified	Unspecified
Avoided landfill impacts	Grant and James (2005)	Australia	1998–2004	Average	Mixed data

B) C&I and C&D collection system

Processes considered

In the case of the C&I and C&D collection system, it has been assumed that segregated waste collected from such sources is directly sent 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 required to convert the waste material into recycled paper. Losses associated with this process are included in the analysis. The model also illustrates the processes considered in determining the impact of the processes avoided when recycling paper and board from C&I and C&D sources. Three main processes are considered, the collection of waste paper and board and landfill treatment, and the primary manufacture of unbleached kraft pulp from virgin resources. The system is also described in Figure 2 (processes unique to C&I, C&D collection are shown shaded accordingly).

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 4.

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

Impact category	Unit	Recycling process impacts (Figure 44 - left side)	Avoided process impacts (Figure 44 - 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	0.18	-0.73	-0.08	-0.81	-0.63
Cumulative energy demand	GJ LHV	2.37	-1.31	-11.83	-13.14	-10.76
Water use	kL H_2O	5.31	0.27	-33.86	-33.59	-28.28
Solid w aste	tonnes	0.00	-0.74	0.00	-0.75	-0.74

Network diagrams detailing key processes that influence the impact listed in Table 4 are shown in Figure 7 to Figure 10. For further information regarding interpretation of network diagrams, refer to Understanding Network Diagrams (Figure 1).

Key assumptions 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 paper and board. The table also includes the products and processes avoided when 1 tonne of paper and board is recycled.

Table 5: Inventory for recycling 1 tonne of paper and board from C&I and C&D source

Item	Flow	Unit	Comment
Recycling process flows (Figure 2 — left hand side)			
Waste collection	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.
Transport to reprocessor	65	km	65km transport to reprocessor in Sydney metro area. Emissions from transport based on a trucking model developed from data provided by Apelbaum (2001)
Reprocessing paper and board into recycled paper	1	tonne	Energy requirement to reprocess one tonne of waste paper. Estimate from Grant and James (2005). Energy requirement to reprocess one tonne of waste paper. Estimate from Grant and James (2005): 0.311 GJ of electricity, 0.23 GJ of energy from coal, 0.685 GJ of energy from natural gas, 0.017 GJ of energy from fuel, 0.17 GJ of energy from steam (cogeneration), and 0.062 MJ of energy from woodwaste consumed for the reprocessing of 1 tonne of waste. Visy environment report 2003/2004 for water, electricity and energy data. Impact from the production of electricity high voltage in Australia based on ESAA, 2003 and other sources. This is the main inventory which is an integrated grid for QLD, NSW, ACT, SA and Victoria.
Avoided process flows (Figure 2 — 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 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 mixed paper	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 per cent Hyder (2006), 'Mid 2020' scenario.
Unbleached kraft pulp	750	kg	75 per cent fibre recovery in the pulping process (due partly to fibre losses as fibre length decreases) from the 1000 kg reaching paper recycling. 13.5 MJ of energy from woodwaste, plus the energy necessary to produce the pulp wood supply, consumed for the processing of 1 tonne of unbleached kraft pulp. Data from IVAM Environmental Research, University of Amsterdam

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 land filling of paper and board 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 waste paper	Grant and James (2005), Visy Industries	Australia	2003–2005	Average	Mixed data
Avoided unbleached kraft pulp	IVAM	Europe	2005	Unspecified	Unspecified
Avoided landfill impacts	Grant and James (2005)	Australia	1998–2004	Average	Mixed data

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Network diagrams — Kerbside collection

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

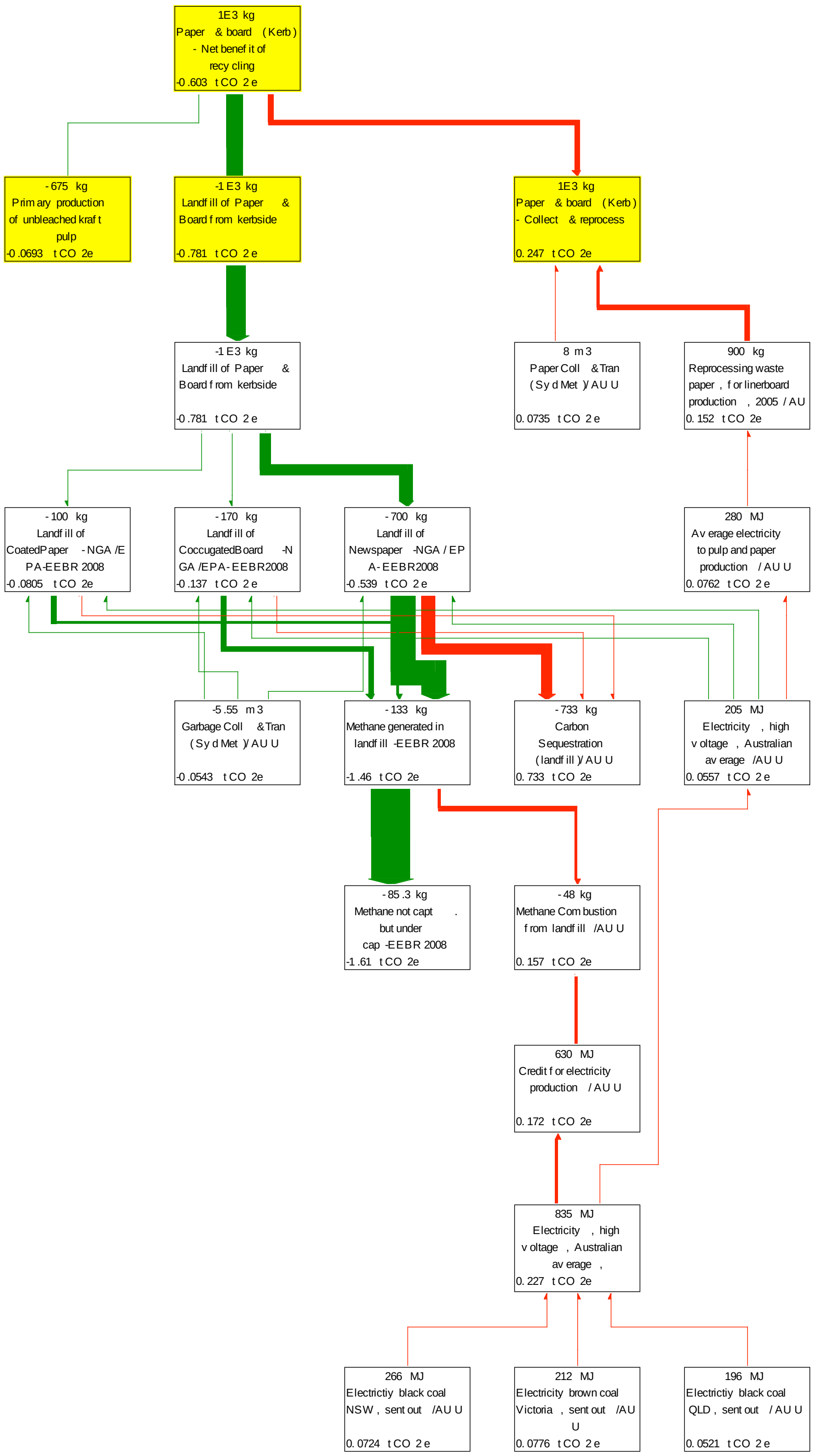


Figure 4: Recycling process network diagram — Cumulative energy demand indicator. Processes contributing less than 5 per cent to total are not shown. Major processes from results table above are shown shaded

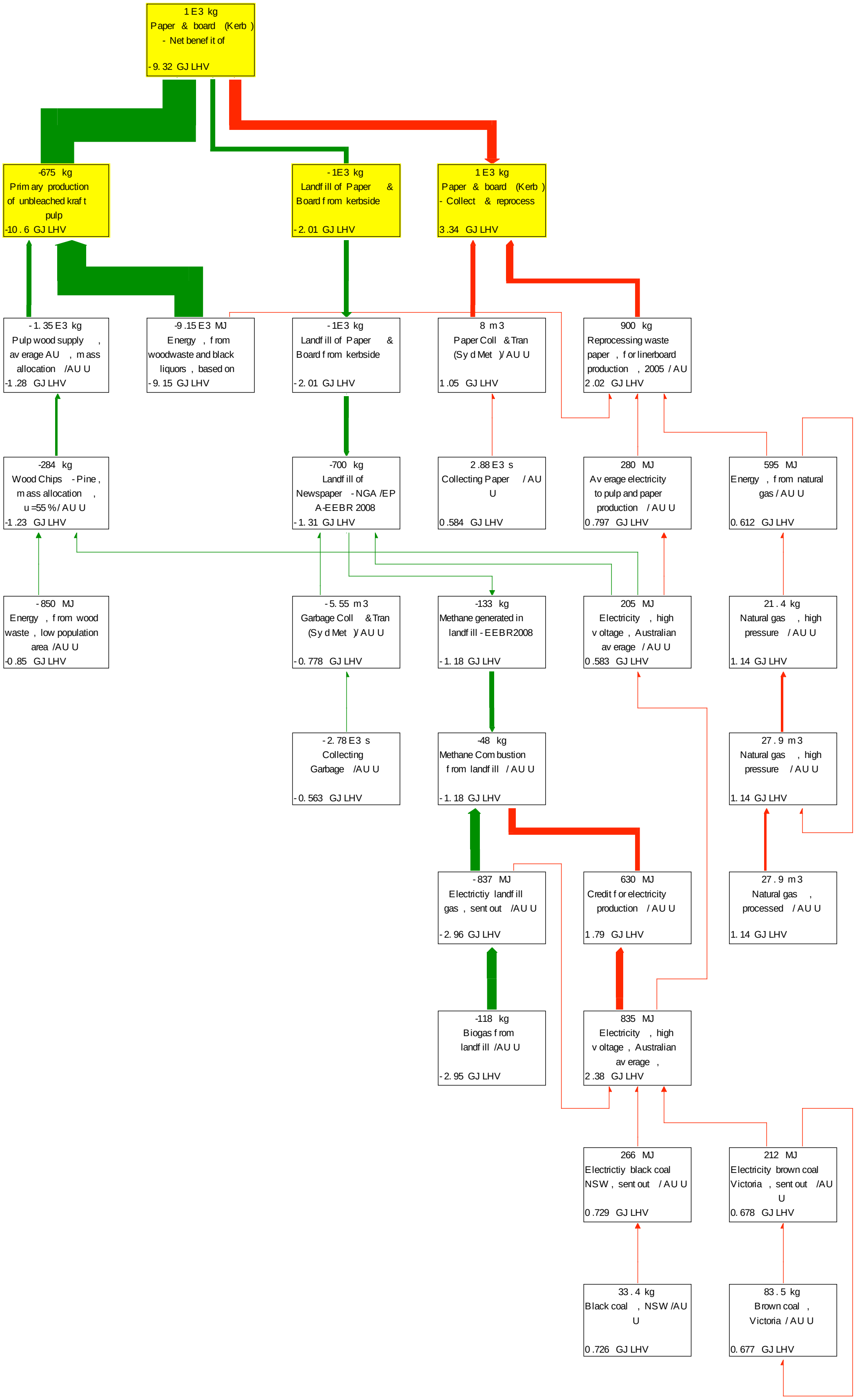


Figure 5: Recycling process network diagram — Water indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.

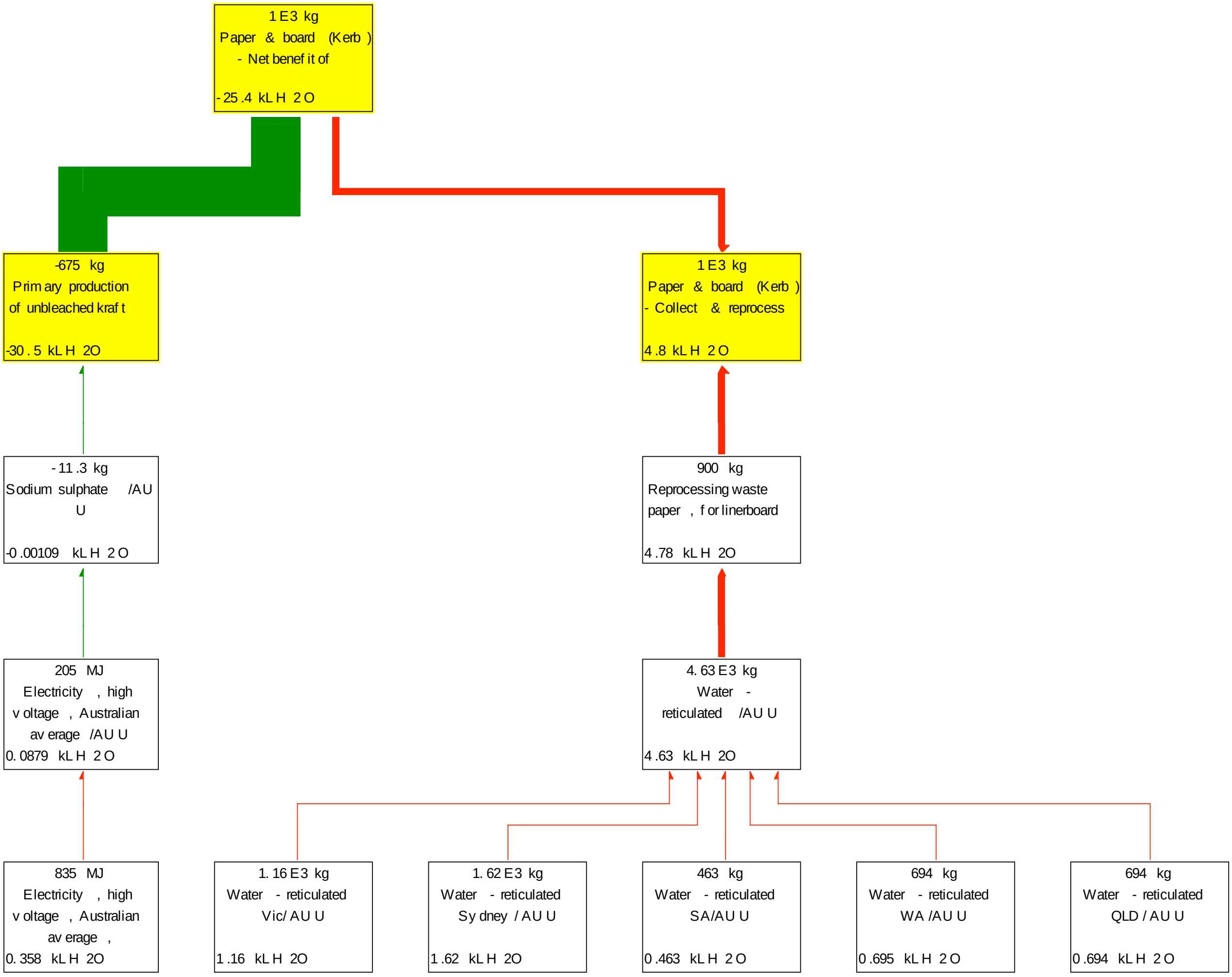
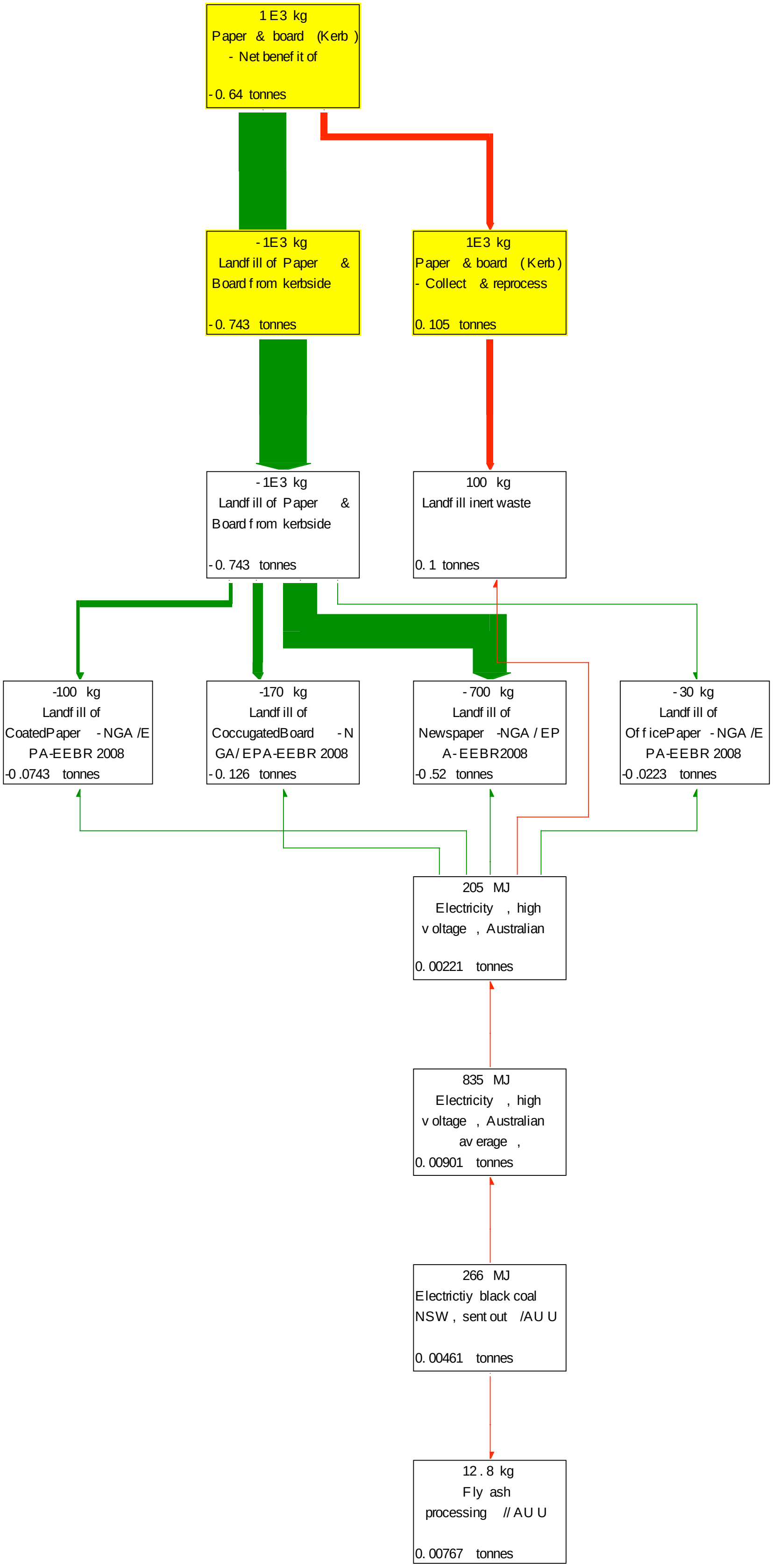


Figure 6: Recycling process network diagram — Solid waste indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.



Network diagrams — C&I and C&D collection

Figure 7: Recycling process network diagram — Green house gases indicator. Processes contributing less than 3 per cent to total are not shown. Major processes from results table above are shown shaded.

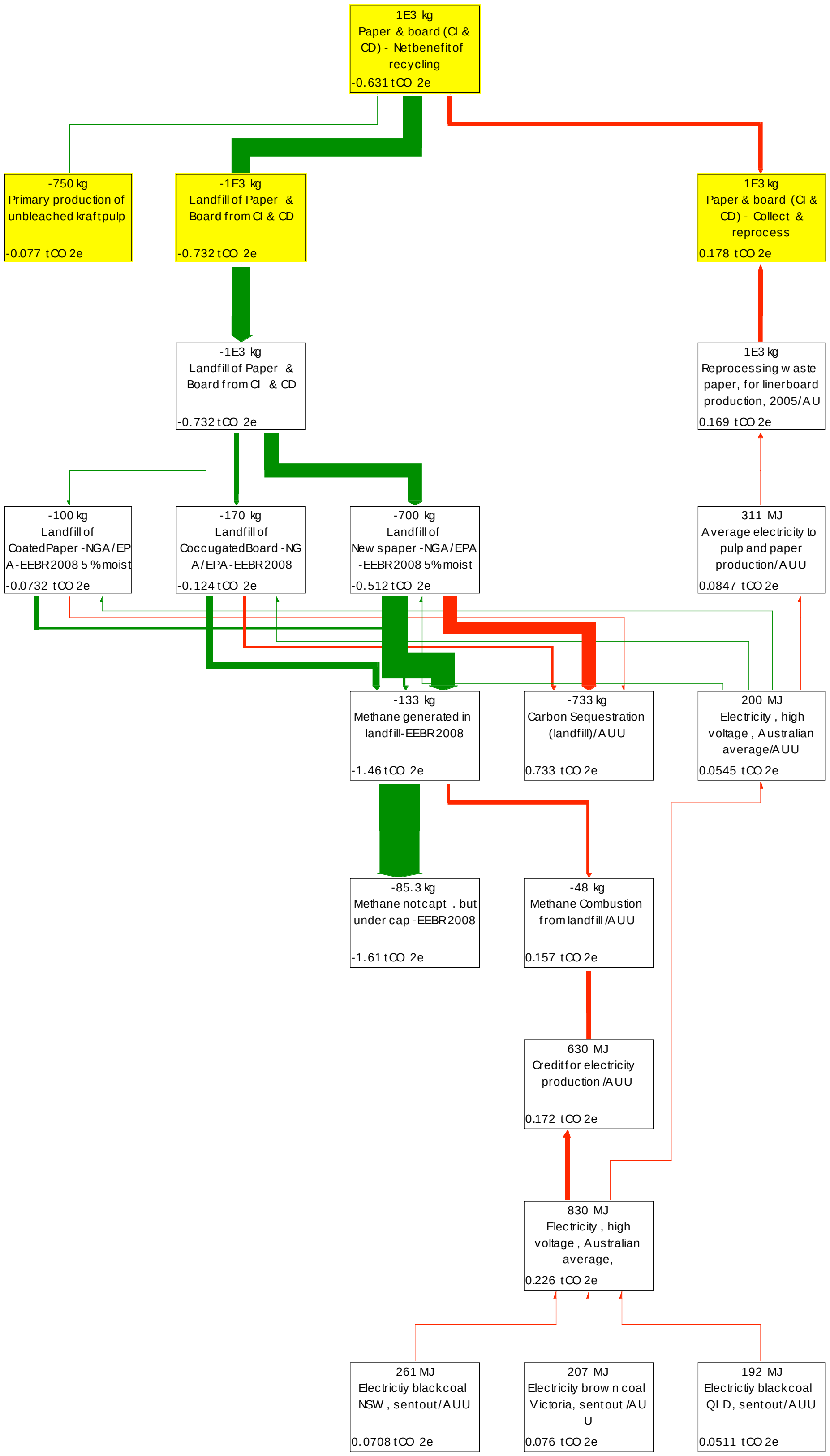


Figure 8: Recycling process network diagram — Cumulative energy demand indicator. Processes contributing less than 5 per cent to total are not shown. Major processes from results table above are shown shaded.

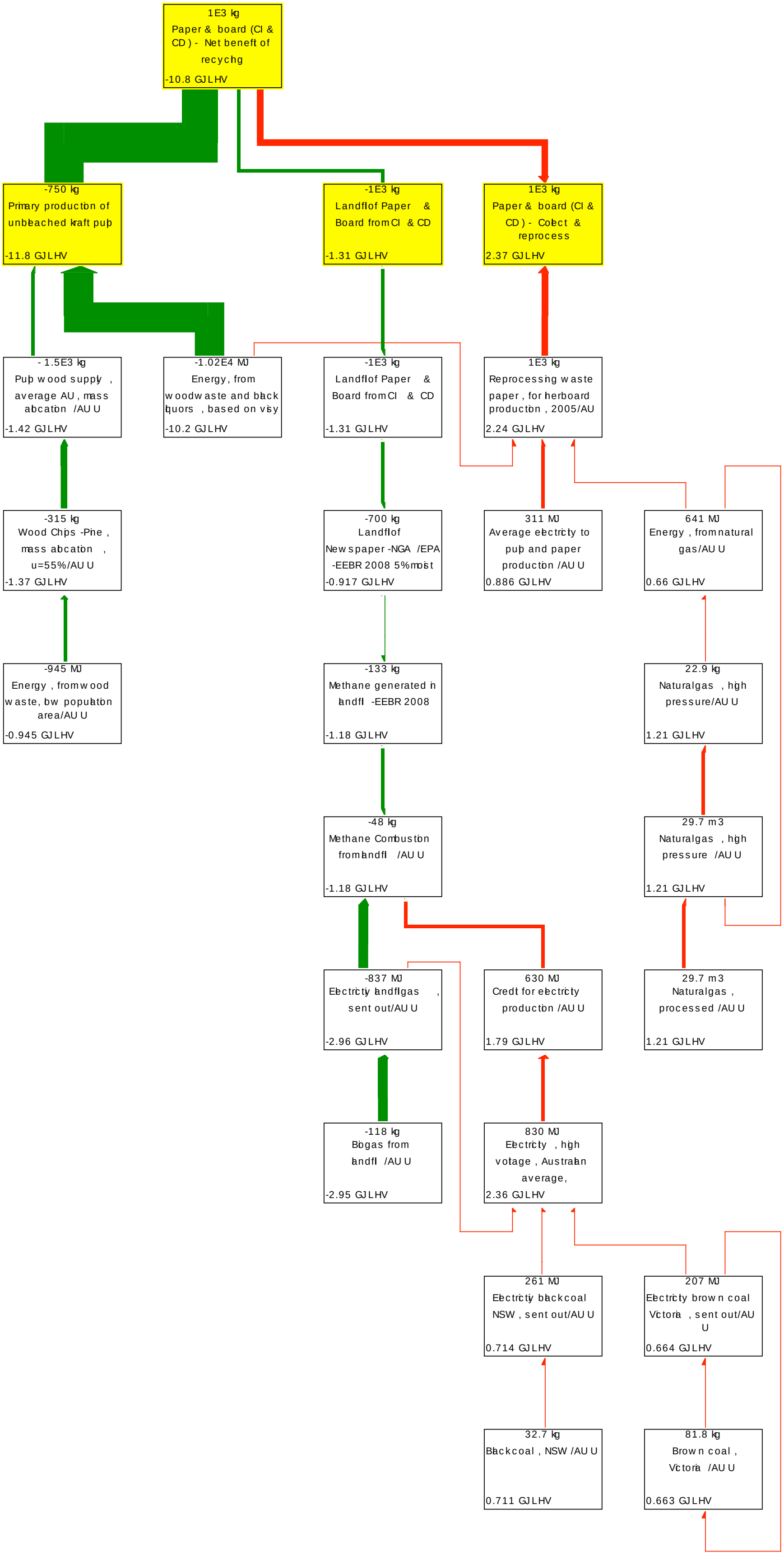


Figure 9: Recycling process network diagram — Water indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.

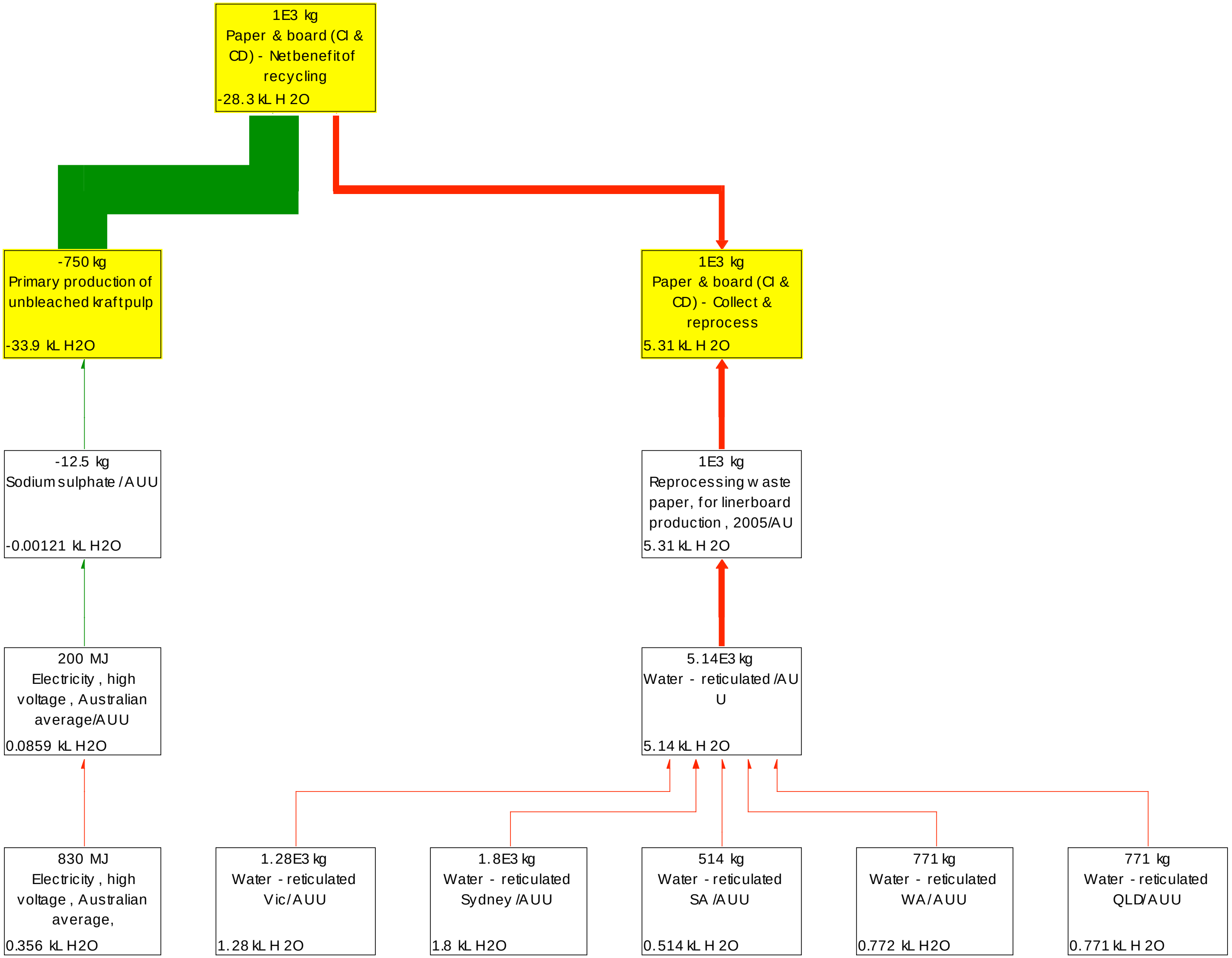
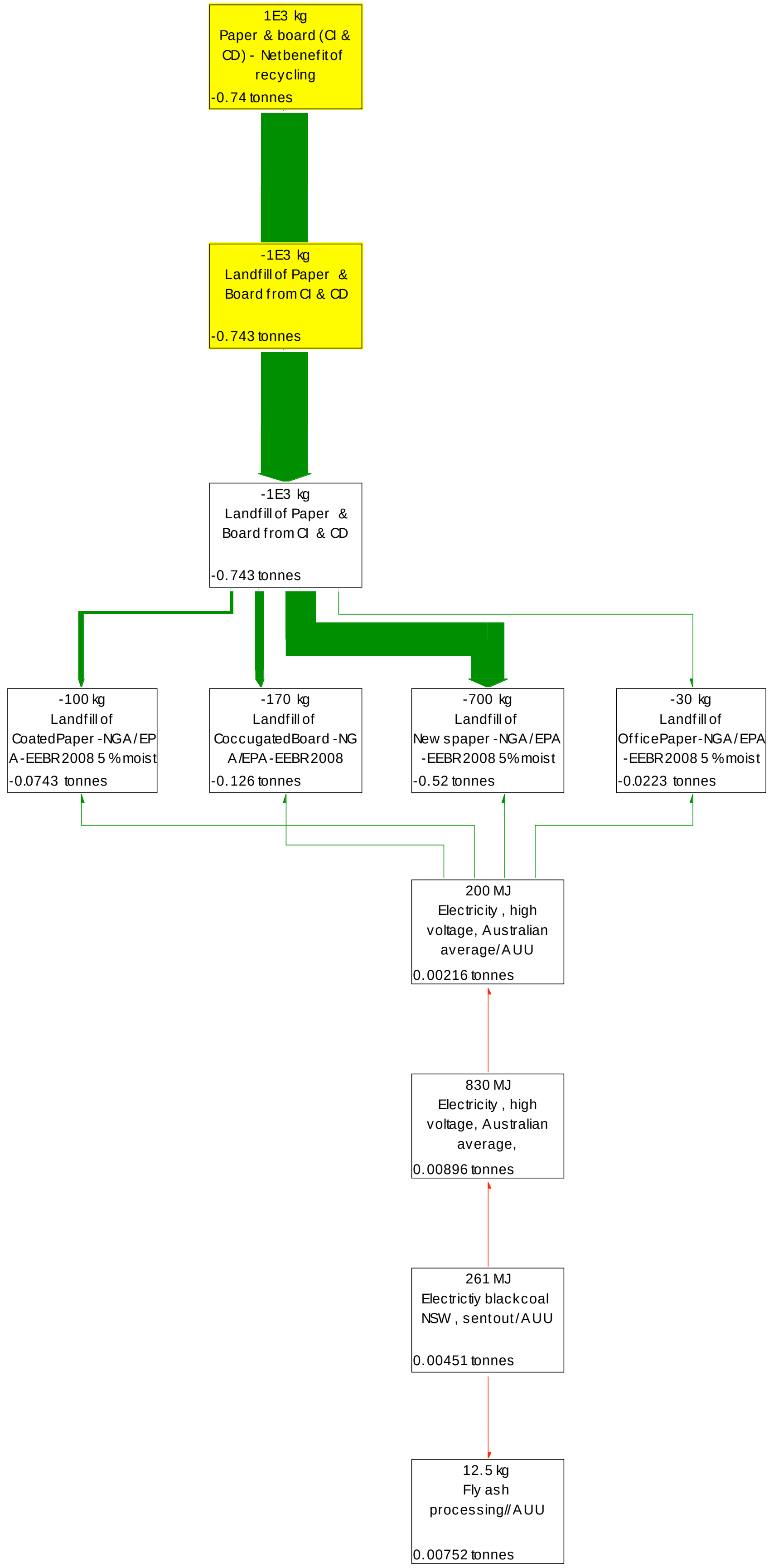


Figure 10: Recycling process network diagram — Solid waste indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.



Newsprint

Process description

Newspaper in NSW is assumed to be recovered from both the kerbside and C&I and C&D collection systems. The collected newspapers and magazines are mixed with water and agitated in a pulping vat to make slush. Small quantities of caustic soda, sodium silicate and hydrogen peroxide are added to help the repulping process. Screens remove impurities like stables and binding materials, and a deinking process is undertaken. The recycled pulp is then mixed with virgin pulp (radiate pine 60%, recycled pulp 30%, eucalypt pulp 10%). The process considered in this assessment is based on the Norske Skog plant in Albury. During reprocessing, part of the output is a pulp that is used in the Norske Skog's Boyer plant, displacing semi-bleached kraft pulp. The remaining pulp is reprocessed as newsprint and displaces production of newsprint from virgin fibre sources.

Two collection systems for waste newspapers considered in the model were:

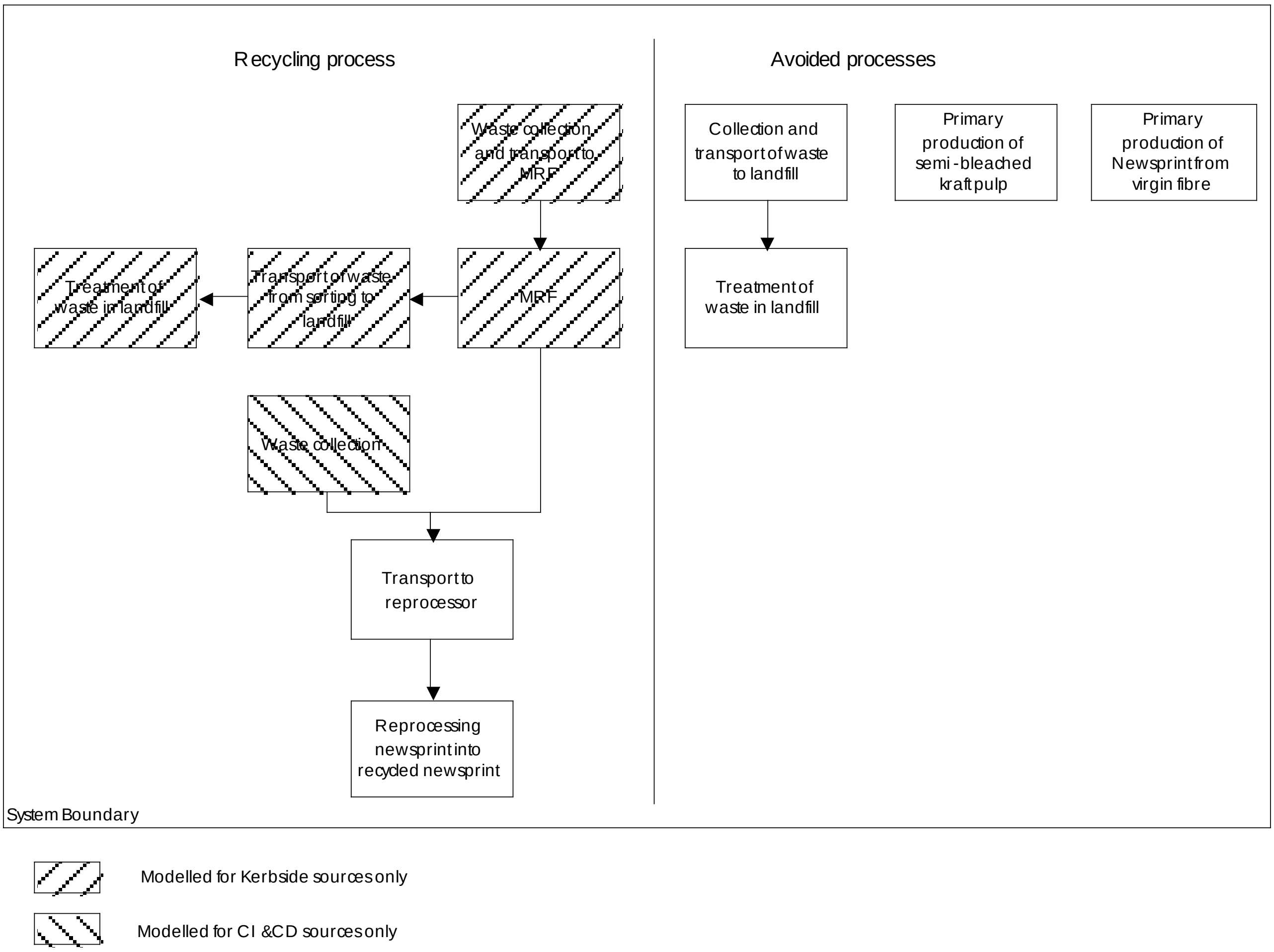
A) Kerbside collection — municipal collection from households, and processing through a Materials Recovery Facility

B) C&I, C&D collection — direct transfer of segregated waste from point of waste generation to a reprocessing facility

The unique nature of each collection system drives differences in the impacts associated with newspaper recycling. For this reason the newspaper recycling processes considered have been described separately in the following sections, according to the collection method used.

Figure 11 illustrates the processes considered in determining the overall impact of newsprint recycling from kerbside and C&I and C&D sources (shown to the left of the vertical line), and the processes considered in determining the overall impact of the avoided processes (shown to the right of the vertical line).

Figure 11: Processes considered in determining the net impacts of the recycling process from kerbside and C&I and C&D sources.



A) Kerbside collection system

Processes considered

The kerbside collection system involves collection of waste for recycling from the kerbside and transport to a Materials Recovery Facility (MRF), which sorts the commingled materials in the recycling stream. The model developed takes into account transportation impacts as well as sorting impacts incurred to bring the material from the kerbside to the material reprocessing facility. During sorting, waste material is generated and transported to landfill.

Once at the reprocessing facility, the model considers the impacts of material reprocessing required to convert the waste material into secondary products. Losses associated with this process are included in the analysis. The kerbside treatment system is illustrated in Figure 11 (processes unique to kerbside collection have been shaded accordingly).

In order to determine the benefit or impact of recycling a material, it is also necessary to consider the processes avoided when recycling is undertaken. Figure 11 also illustrates the processes that would be avoided if newsprint wastes are reprocessed (shown to the right of the vertical line). Three main processes are considered, the collection and disposal to landfill of newsprint wastes from the kerbside; the primary manufacture of semi-bleached kraft pulp from virgin resources for use in non-newsprint applications; and the production of newsprint from virgin fibre.

Results

Considering both the recycling process flows and the avoided process flows, described in Figure 11, 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 newsprint from kerbside sources (per tonne). Benefits are shown negative, impacts are shown positive.

Impact category	Unit	Recycling process impacts (Figure 53 - left side)	Avoided process impacts (Figure 53 - 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	1.30	-0.77	-1.52	-2.29	-0.99
Cumulative energy demand	GJ LHV	14.14	-1.87	-18.60	-20.47	-6.33
Water use	kL H_2O	12.33	0.26	-25.65	-25.39	-13.06
Solid w aste	tonnes	0.12	-0.74	-0.05	-0.79	-0.67

Network diagrams detailing key processes that influence the impact listed in Table 7 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 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 newsprint. The table also includes the products and processes avoided when 1 tonne of newsprint is recycled.

Table 8: Inventory for recycling 1 tonne of newsprint from a kerbside source

Item	Flow	Unit	Comment
Recycling process flows (Figure 11 — left hand side)			
Waste collection and transport to MRF	8	m^3	Density assumption from Warren (1997). Transport model for kerbside collection from Grant (2001b), see discussion below Emission of the truck from NGGIC (1997)
Sorting at Material Recovery Facility (MRF)	8	m^3	Density assumption from Warren (1997). Energy inputs from Nishtala (1997) and estimated from equipment specifications
Transport to reprocessor	400	km	Sorted material trucked to Norske Skog plant in Albury. Emissions from transport based on a trucking model from Apelbaum (2001)
Reprocessing newsprint into recycled newsprint,	0.9	tonne	Energy required to reprocess newsprint, data supplied by Norske Skog (2000) and Fletcher Challenge paper (PNEB 2000). Estimate from Grant and James (2005). 1.7 MWh of electricity and 4.14 GJ of natural gas consumed per tonne of waste reprocessed.
Transport of waste from sorting to landfill	20	km	Emissions from transport based on an articulated truck, 28 tonne load on 30 tonne truck. Trucking model developed from data provided by Apelbaum (2001).
Treatment of waste in landfill	100	kg	10 per cent of those wastes will be discarded during sorting. The 100 kg of waste discarded will be treated in landfill. Emission factors adapted from EcoInvent database to Australian conditions; energy and transport data changed to Australian data. 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.
Avoided process flows (Figure 11 — right hand side)			
Collection and transport of waste to landfill	8.0	m^3	Waste collection avoided by sending material to MRF 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.
Treatment of waste in landfill	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 Methane generated in landfill from NGGIC (2007). Capture of methane assumed to be 36 per cent Hyder (2006), 'Mid 2020' scenario.
Primary production of semi-bleached kraft pulp	0.125	tonne	The bleached sulphate pulp production involves the chemical processing of logged (pine) into pulp, using H2SO4, NaClO3, H2O2 as reactive bleaching agents. Data supplied by Norske Skog Mill (2000), energy referencing from Picken (1996). 20 kWh of electricity and 2.6 GJ of heat from fossil fuel consumed to process 1 tonne of semi-bleached kraft pulp.
Primary production of newsprint from virgin fibre	0.535	tonne	Full production of newsprint by virgin fibres, transport of logs removed. Electricity and energy data supplied by Fletcher Challenge paper (PNEB 2000) 1.75 MWh of electricity, 9.18 GJ of natural gas and 1.26 GJ of energy from wood waste consumed to process 1 tonne of newsprint from virgin fibre

Data Quality table and comment

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 newsprint, kerbside source

	Primary data source	Geography	Data Age	Technology	Representativeness
Recycling collection and transport	Apelbaum consulting group (2001)	Australia	2001	Average	Average from all suppliers
ONP reprocessing at Norske Skog	Norske Skog data provided by mill	Western Europe	1990 and 1994	Average technology	Mixed data
Avoided virgin newsprint production	Fletcher challenge data provided by mill	Western Europe	1990 and 1994	Average technology	Mixed data
Avoided virgin kraft pulp production	Norske Skog data provided by mill	Western Europe	1990 and 1994	Average technology	Mixed data
Avoided landfill impacts	Grant and James (2005)	Australia	1998–2004	Average	Mixed data

B) C&I and C&D collection system

Processes considered

In the case of the C&I and C&D collection system, it has been assumed that waste collected from such sources is sent directly to the reprocessing site without any further sorting processes 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 required to convert the waste material into recycled newsprint and semi-bleached kraft pulp. Losses associated with this process are included in the analysis. The model also illustrates the processes considered in determining the impact of the processes avoided when recycling newsprint from C&I and C&D sources. Three main processes are considered, the collection of newsprint wastes and landfill treatment, and the primary manufacture of semi-bleached kraft pulp and the production of newsprint from virgin resources. The system is also described in Figure 11 (processes unique to C&I, C&D collection are shaded accordingly).

Results

Considering both the recycling process flows and the avoided process flows, described in Figure 11, 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 newsprint from C&I and C&D sources (per tonne). Benefits are shown negative, impacts are shown positive.

Impact category	Unit	Recycling process impacts (Figure 53 - left side)	Avoided process impacts (Figure 53 - 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	1.21	-0.73	-1.52	-2.25	-1.04
Cumulative energy demand	GJ LHV	13.49	-1.31	-18.60	-19.91	-6.43
Water use	kL H_2O	13.43	0.27	-25.65	-25.39	-11.96
Solid w aste	tonnes	0.05	-0.74	-0.05	-0.79	-0.74

Network diagrams detailing key processes that influence the impact listed in Table 10 are shown in Figure 16 to Figure19. 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 newsprint. The table also includes the products and processes avoided when 1 tonne of newsprint is recycled.

Table 11: Inventory for recycling 1 tonne of newsprint from C&I and C&D source

Item	Flow	Unit	Comment
Recycling process flows (Figure 11 — left hand side)			
Waste collection	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.
Transport to reprocessor	400	km	Sorted material trucked to Norske Skog plant in Albury. Emissions from transport based on a trucking model from Apelbaum (2001)
Reprocessing newsprint into recycled newsprint	1	tonne	Energy required to reprocess newsprint, data supplied by Norske Skog (2000) and Fletcher Challenge paper (PNEB 2000). Estimate from Grant and James (2005). 1.7 MWh of electricity and 4.14 GJ of natural gas consumed per tonne of waste reprocessed.
Avoided process flows (Figure 11 — 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 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 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 Methane generated in landfill from NGGIC (2007). Capture of methane assumed to be 36 per cent Hyder (2006), 'Mid 2020' scenario.
Primary production of semi-bleached kraft pulp	0.125	tonne	The bleached sulphate pulp production involves the chemical processing of logged (pine) into pulp, using H2SO4, NaClO3, H2O2 as reactive bleaching agents. Data supplied by Norske Skog Mill (2000), energy referencing from Picken (1996). 20 kWh of electricity and 2.6 GJ of heat from fossil fuel consumed to process 1 tonne of semi-bleached kraft pulp.
Primary production of newsprint from virgin fibre	0.535	tonne	Full production of newsprint by virgin fibres, transport of logs removed. Electricity and energy data supplied by Fletcher Challenge paper (PNEB 2000) 1.75 MWh of electricity, 9.18 GJ of natural gas and 1.26 GJ of energy from wood waste consumed to process 1 tonne of newsprint from virgin fibre

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 newsprint 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
ONP reprocessing at Norske Skog	Norske Skog data provided by mill	Western Europe	1990–1994	Average technology	Mixed data
Avoided virgin newsprint production	Fletcher challenge data provided by mill	Western Europe	1990–1994	Average technology	Mixed data
Avoided virgin kraft pulp production	Norske Skog data provided by mill	Western Europe	1990–1994	Average technology	Mixed data
Avoided landfill impacts	Grant and James (2005)	Australia	1998–2004	Average	Mixed data

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Network diagrams — Kerbside collection

Figure 12: 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.

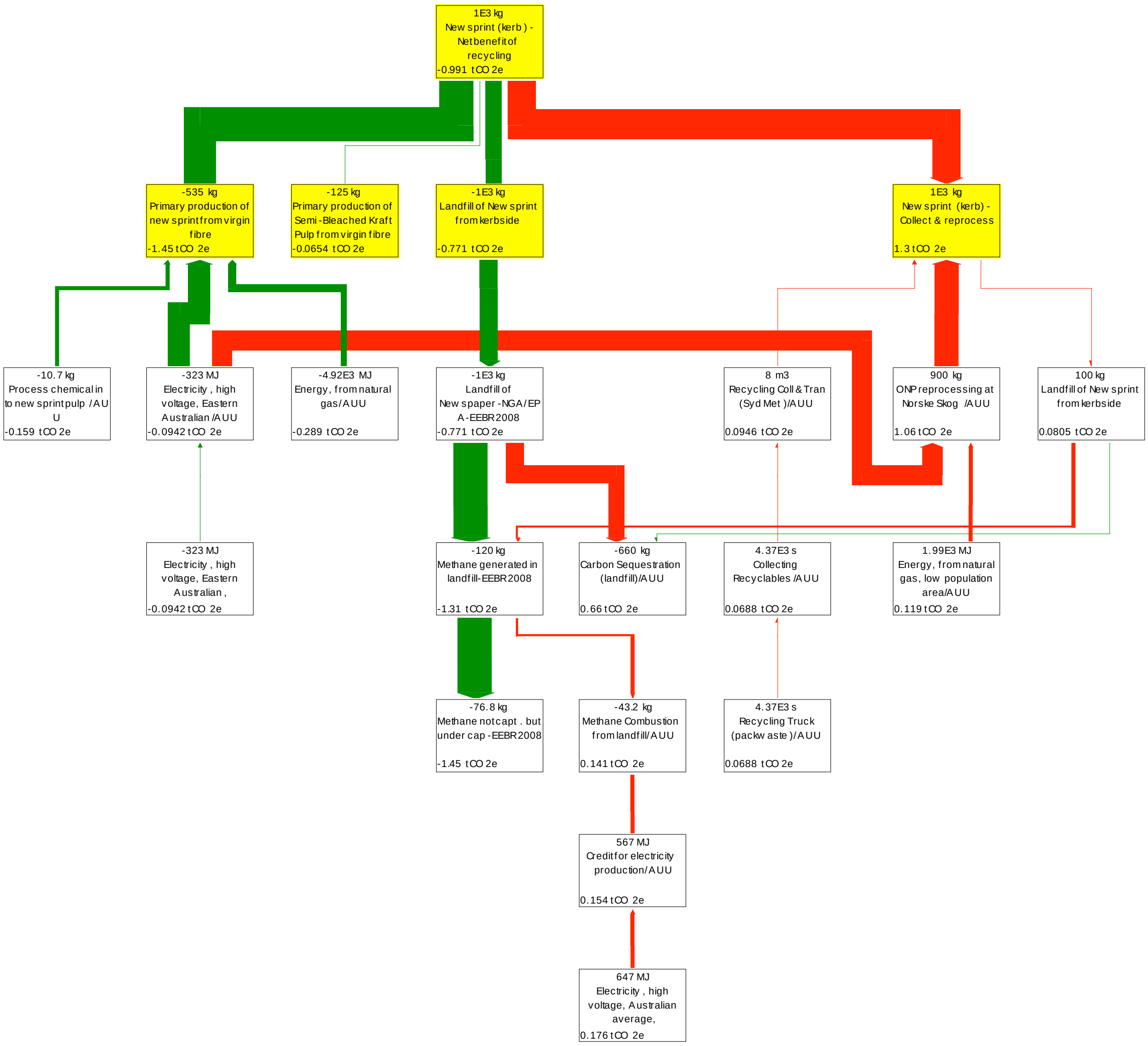


Figure 13: Recycling process network diagram — Cumulative energy demand indicator. Processes contributing less than 4 per cent to total are not shown. Major processes from results table above are shown shaded

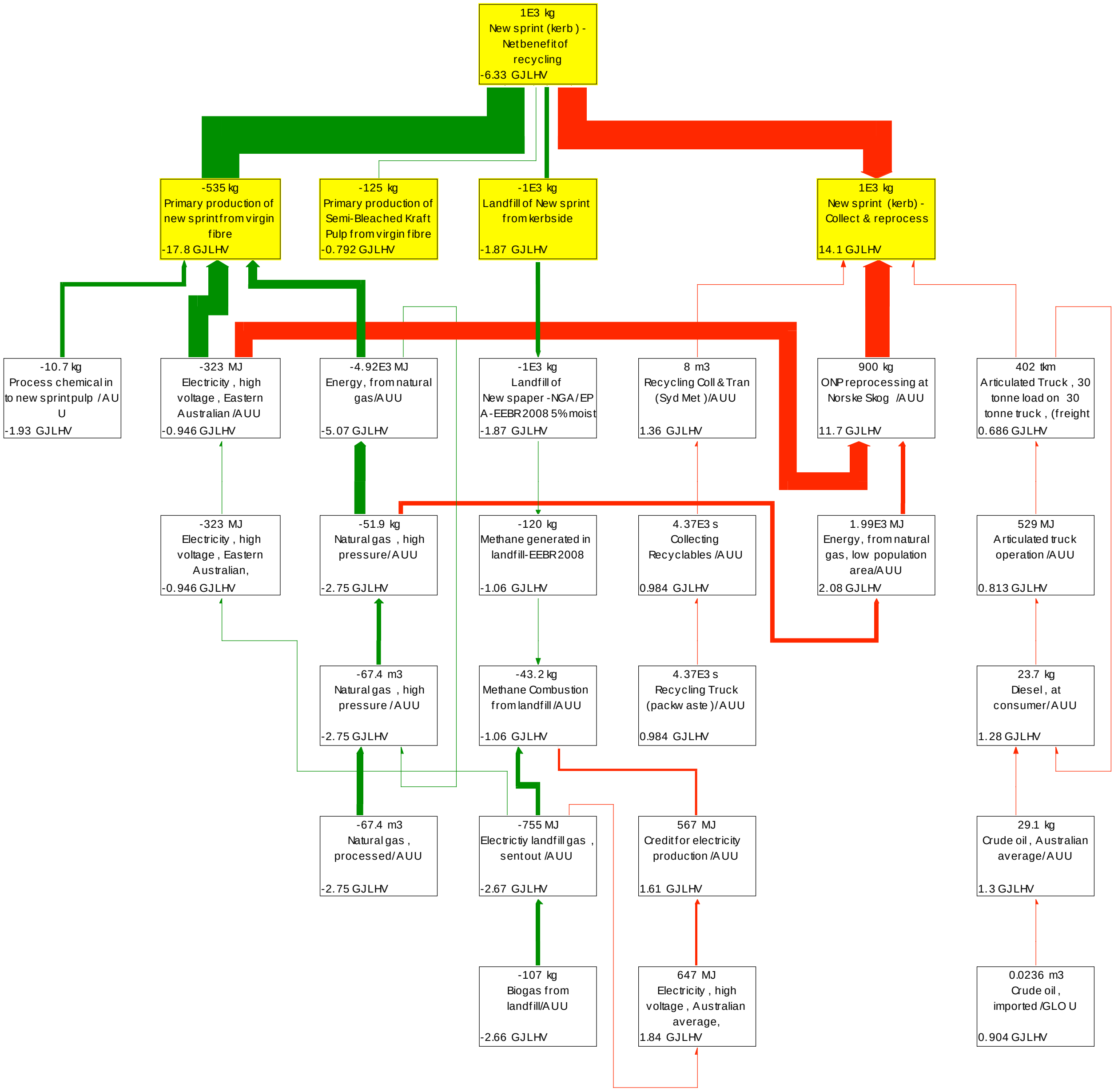


Figure 14: Recycling process network diagram — Water indicator. Processes contributing less than 2 per cent to total are not shown. Major processes from results table above are shown shaded.

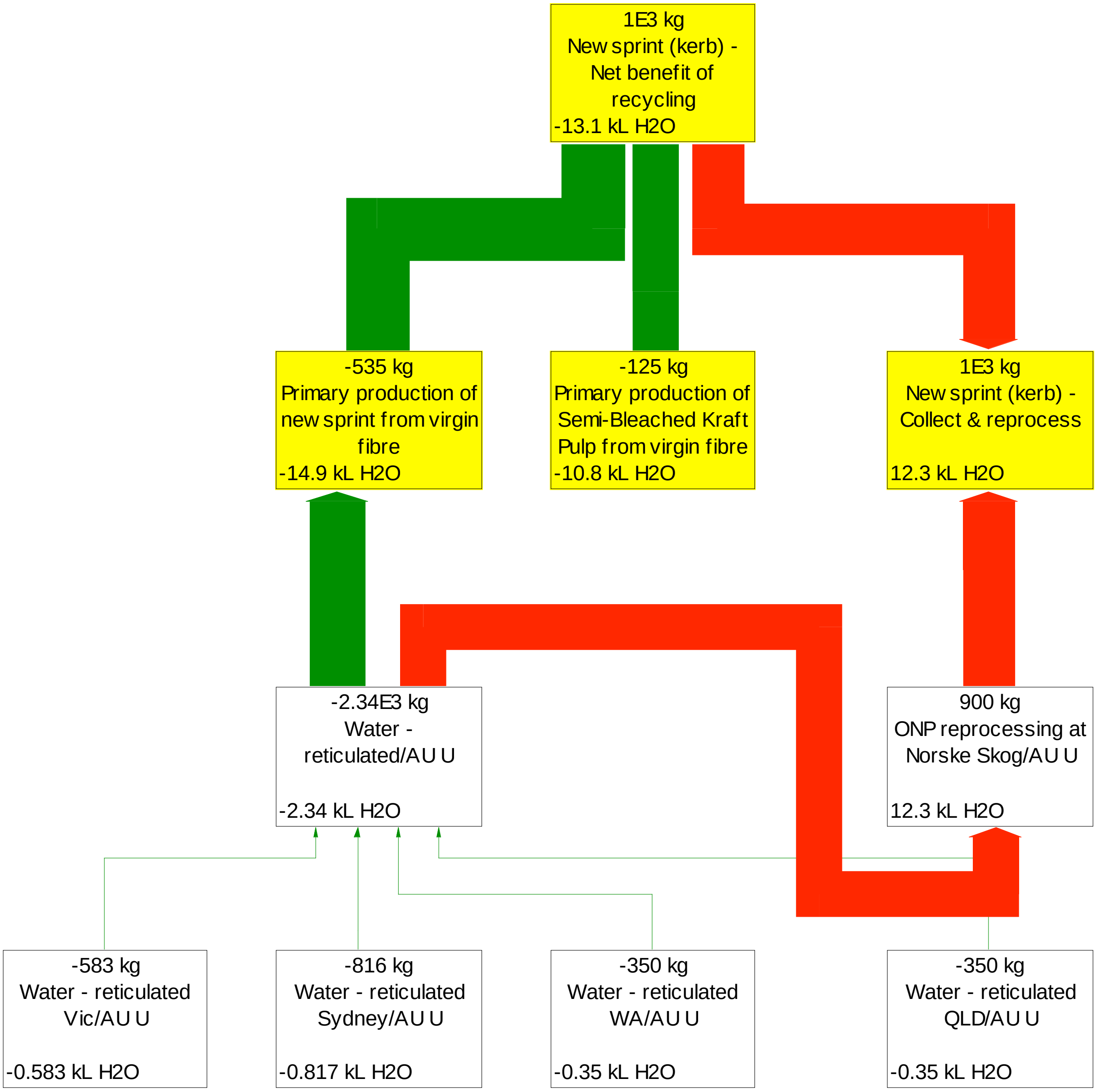
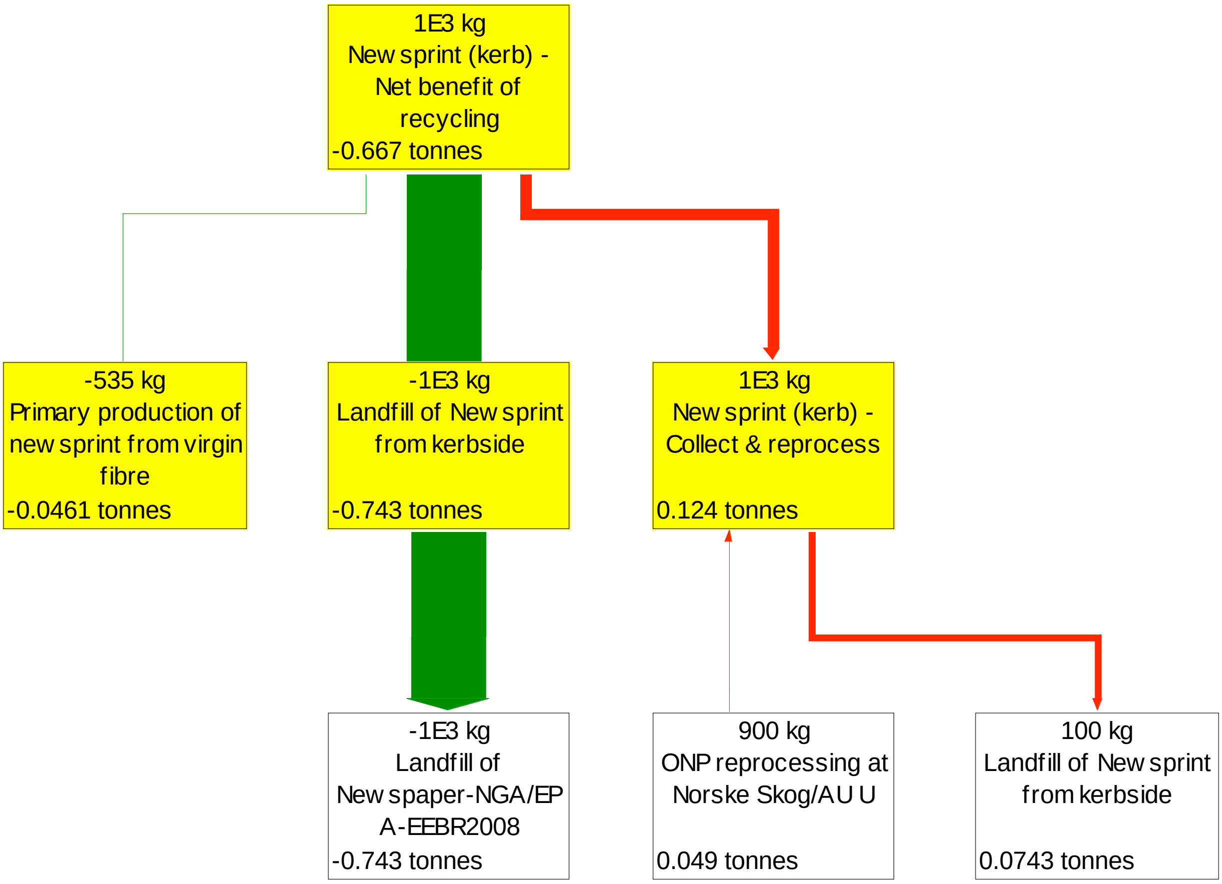


Figure 15: Recycling process network diagram — Solid waste indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.



Network diagrams — C&I and C&D collection

Figure 16: 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.

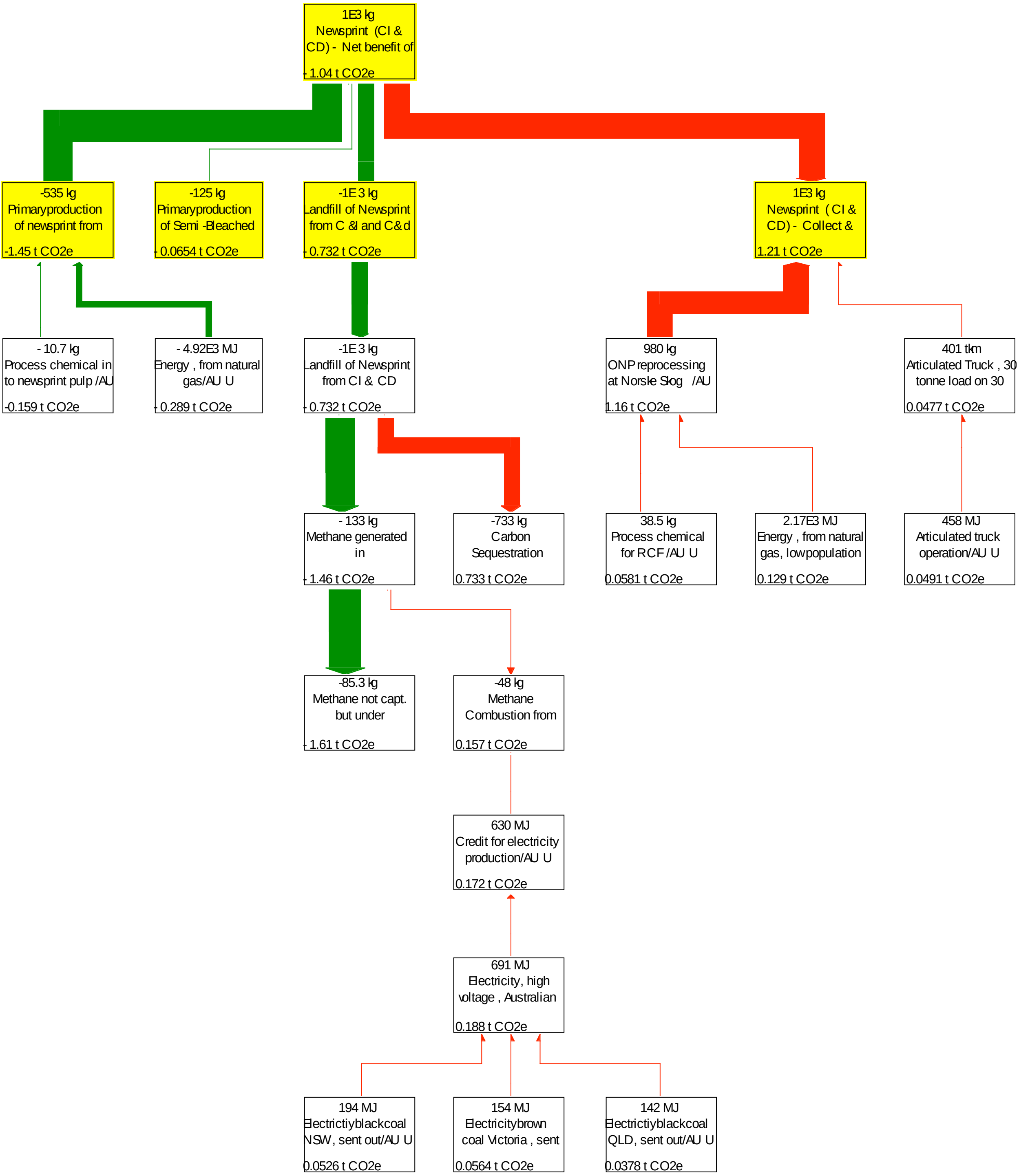


Figure 17: Recycling process network diagram – Cumulative energy demand indicator. Processes contributing less than 2 per cent to total are not shown. Major processes from results table above are shown shaded.

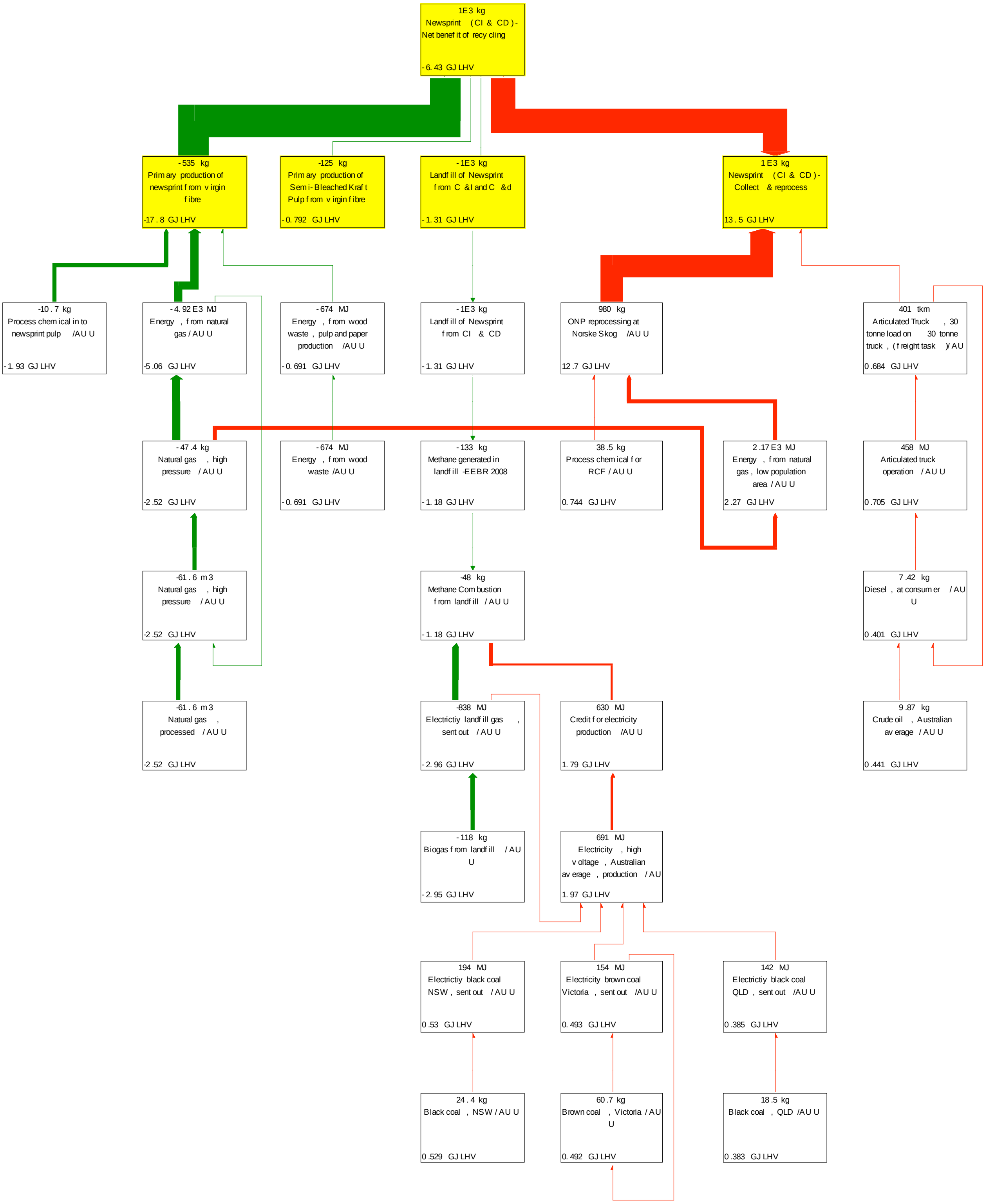


Figure 18: Recycling process network diagram — Water indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.

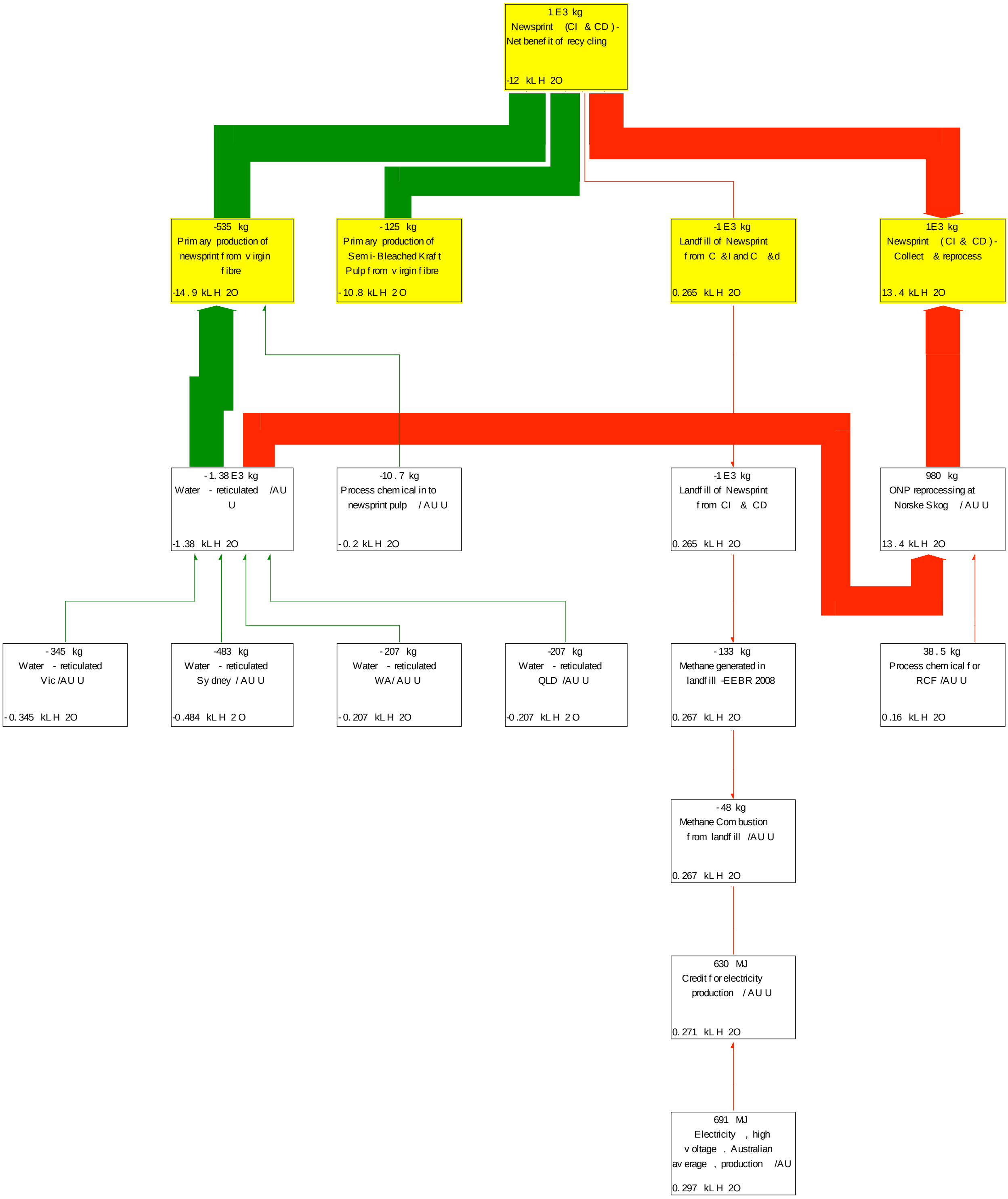
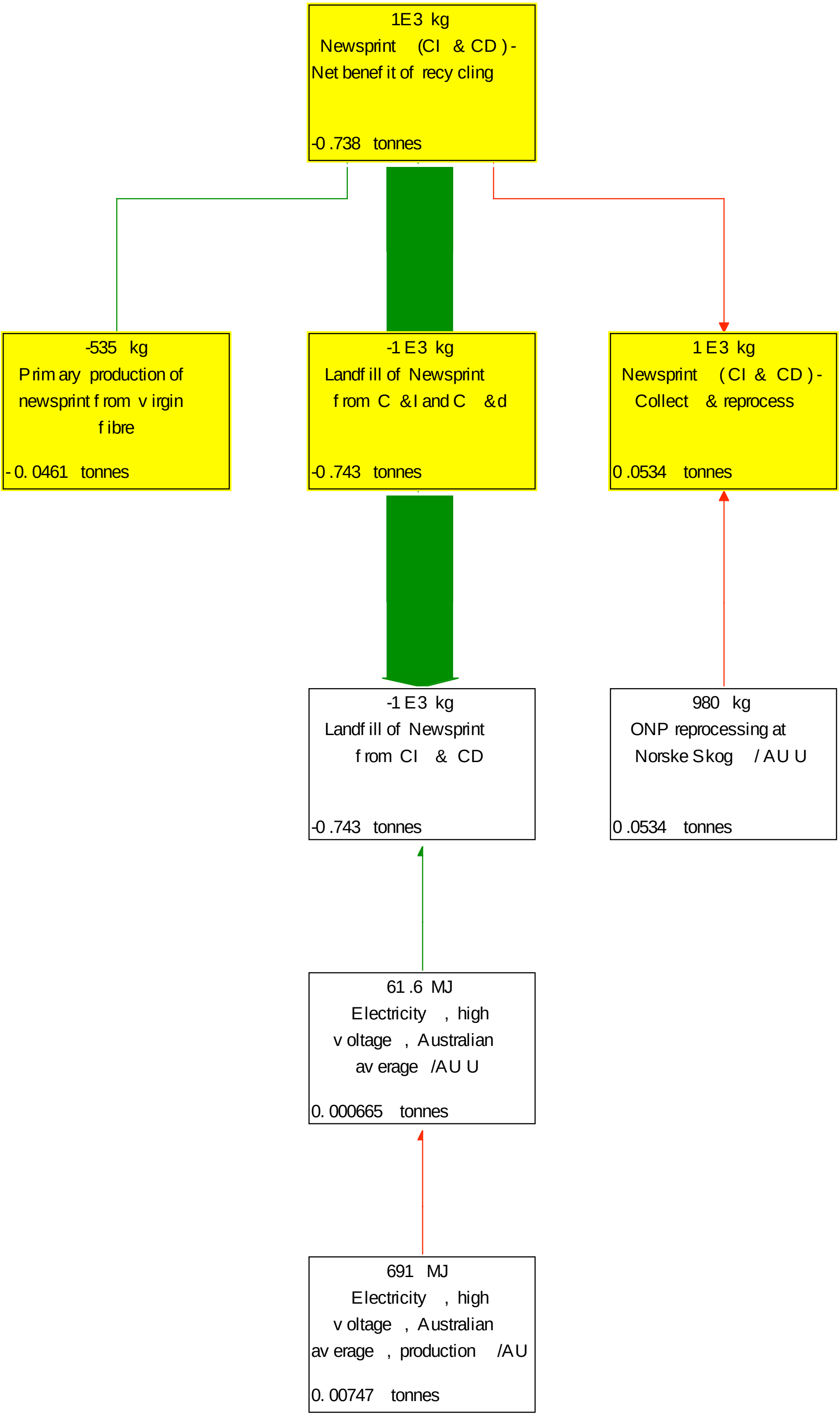


Figure 19: Recycling process network diagram – Solid waste indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.



Liquid paper board

Process description

Liquid paper board (LPB) is sourced from kerbside collection.

There are two types of liquid paper board containers:

A) Gable-top carton — which is used to package pasteurized/refrigerated products like milk and fruit juice. In this form LPB is typically made from a solid bleached sulphide (SBS) board sandwiched between polyethylene coating on both sides (assume: 12 per cent low density polyethylene (LDPE), 88 per cent SBS).

B) Aseptic carton — which is used to package shelf-stable products like long-life milk. In an aseptic application LPB is a more complex composite, being made up of a sandwich of polyethylene, aluminium and SBS board. A closure is also typically included, in this case polypropylene (PP) is assumed (assume 71 per cent SBS, 19 per cent LDPE, 5 per cent Aluminium, 5 per cent PP closure).

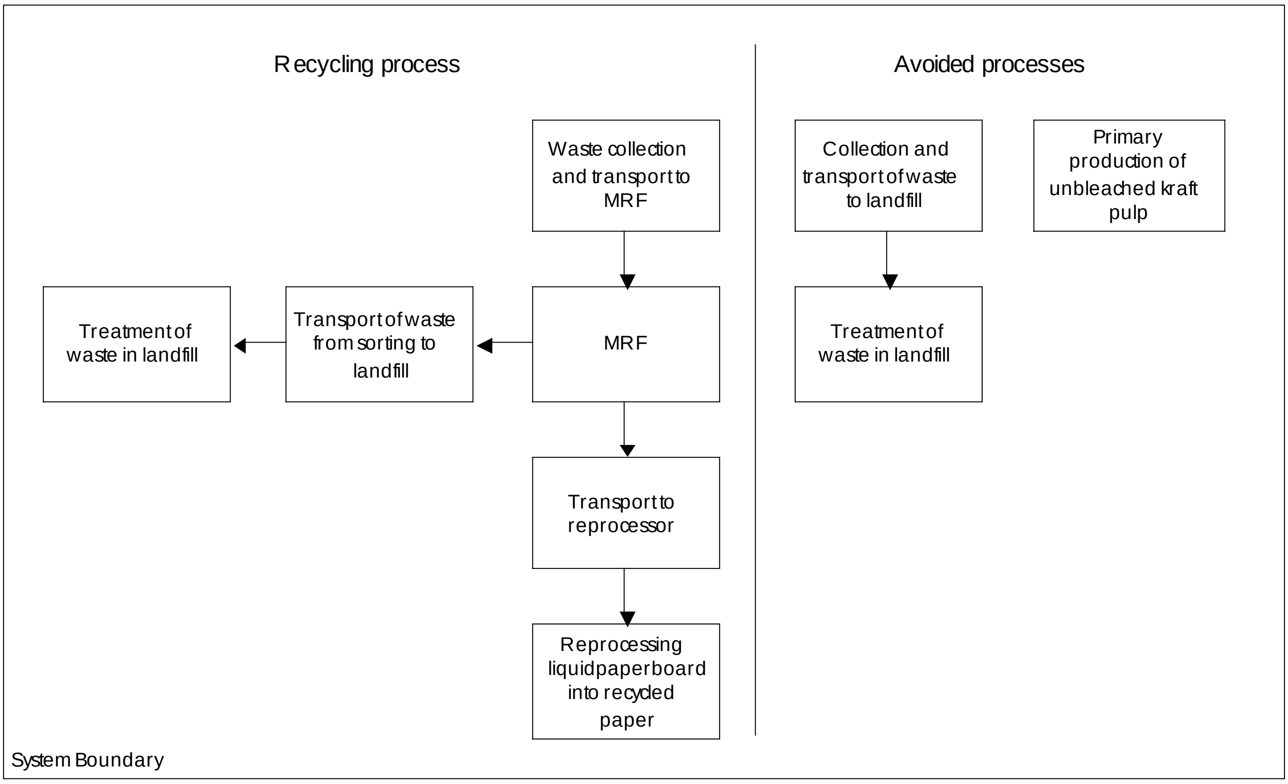
In this study, all recycling is assumed to be directed to Visy or Amcor reprocessing facilities assumed to be local to Sydney, where it is reprocessed into paper and board.

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

Kerbside collection — municipal collection from households, and processing through a Materials Recovery Facility. The model developed takes into account transportation impacts incurred to bring the material from kerbside sources to the MRF. Sorting impacts are also taken into account, as well as transport to reprocessing facility. Once at the reprocessing facility, the model considers the impacts of material reprocessing.

Figure 20 illustrates the processes considered in determining the overall impact of paper and board recycling from kerbside and C&I and C&D sources (shown to the left of the vertical line), and the processes considered in determining the overall impact of the avoided processes (shown to the right of the vertical line).

Figure 20: Processes considered in determining the net impacts of the recycling process from kerbside.



Collection system

The kerbside collection system involves collection of waste for recycling from the kerbside and transport to a Materials Recovery Facility (MRF), which sorts the commingled materials in the recycling stream. The model developed takes into account transportation impacts as well as sorting impacts incurred to bring the material from the kerbside to the material reprocessing facility. During sorting, waste material is generated and transported to landfill.

Once at the reprocessing facility, the model considers the impacts of material reprocessing required to convert the waste material into secondary products. Losses associated with this process are included in the analysis. The kerbside treatment system is illustrated in Figure 20.

In order to determine the benefit or impact of recycling a material, it is also necessary to consider the processes avoided when recycling is undertaken. Figure 20 also illustrates the processes that would be avoided if waste paper and board are reprocessed (shown to the right of the vertical line). Two main processes are considered, the collection and disposal to landfill of waste LPB from the kerbside, and the primary manufacture of unbleached kraft pulp from virgin sources.

Results

Considering both the recycling process flows and the avoided process flows, described in Figure 20, an inventory of environmental flows was developed. This inventory was then assessed using the Australian Impact Assessment Method, with results described in Table 13.

Table 13: Benefits and impacts of recycling and landfill of liquid paper board from a kerbside source (per tonne)

Impact category	Unit	Recycling process impacts (Figure 62 - left hand side)	Avoided process impacts (Figure 62 - 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	1.04	-0.71	-0.03	-0.74	0.30
Cumulative energy demand	GJ LHV	10.28	-2.08	-4.98	-7.07	3.22
Water use	kL H_2O	5.38	0.23	-14.27	-14.04	-8.66
Solid w aste	tonnes	0.46	-0.77	0.00	-0.77	-0.31

Network diagrams detailing key processes that influence the impact listed in Table 13 are shown in Figure 21 to Figure 24. For further information regarding interpretation of network diagrams, refer to Understanding Network Diagrams (Figure 1).

Key assumptions

Table 14 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 liquid paper board. The table also includes the products and processes avoided when 1 tonne of liquid paper board is recycled.

Table 14: Inventory for recycling 1 tonne of liquid paper board from a kerbside source

Item	Flow	Unit	Comment
Recycling process flows (Figure 20 — left hand side)			
Waste collection and transport to MRF	32	m^3	Transport model for kerbside collection based on Grant (2001b), refer discussion below Emission of the truck from Apelbaum (2001), NGGIC (1997) and other sources.
Sorting of LPB at Material Recovery Facility (MRF)	32	m^3	Energy inputs from Nishtala (1997) and estimated from equipment specifications 1/3 of material collected is sent through to landfill by MRF when they are not sorting for LPB.
Transport to reprocessor	65	km	Transportation to a local Visy or Amcor reprocessing facility. Emissions from transport based on a trucking model developed from data provided by Apelbaum (2001)
Reprocessing of LPB into recycled paper	667	kg	Assumes LPB reprocessing undertaken locally to Sydney into paper and board, Grant (2001a) Efficiency of fibre reclamation from fibre fraction of LPB is taken as 67%. Fibre content for LPB is taken as 70.8 per cent (taken from aseptic carton composition although some gable will also come through this stream). Energy requirement to reprocess waste paper. Estimate from Grant and James (2005) 500 kWh electricity and 1 GJ of natural gas consumed per tonne of waste treated (pulping and reprocessing). Visy environment report 2003/2004 for water, electricity and energy data. Impact from the production of electricity high voltage in Australia based on ESAA, 2003 and other sources. This is the main inventory which is an integrated grid for QLD, NSW, ACT, SA and Victoria.
Transport of waste from sorting to landfill	20	km	Emissions from transport based on an articulated truck, 28 tonne load on 30 tonne truck. Trucking model developed from data provided by Apelbaum (2001).
Treatment of waste in landfill	333	kg	1/3 of material collected is sent through to landfill by MRF when they are not sorting for LPB. 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 per cent Hyder (2006), 'Mid 2020' scenario.
Avoided processes (Figure 20 — right hand side)			
Collection and transport of waste to landfill	32	m^3	Waste collection avoided by sending material to MRF 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.
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 per cent Hyder (2006), 'Mid 2020' scenario.
Primary production of unbleached kraft pulp	316	kg	Data from IVAM Environmental Research, University of Amsterdam, adapted for Australian energy mix and fuels. Avoided product from Visy recycling. 667 kg of waste gets through MRF. Of this amount 29.2 per cent lost as polyethylene and aluminium fraction. Of the 472 kg of waste remaining it is assumed an efficiency of 67 per cent in pulp recovery.

Data quality table and comment

Table 15 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 15: Data quality for life cycle inventory data modelled for recycling and landfilling of liquid paper board, kerbside source

	Primary data source	Geography	Data Age	Technology	Representativeness
Recycling collection and transport	Apelbaum consulting group (2001)	Australia	2001	Average	Average from all suppliers
Reprocessing waste paper	Grant and James (2005), Visy Industries	Australia	2003–2005	Average	Mixed data
Avoided unbleached kraft pulp	IVAM	Europe	2005	Unspecified	Unspecified
Avoided landfill impacts	Grant and James (2005)	Australia	2000–2004	Average technology	Data from a specific process and company

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Network diagrams — Kerbside collection

Figure 21: Recycling process network diagram — Green house gases indicator. Processes contributing less than 3 per cent to total are not shown. Major processes from results table above are shown shaded.

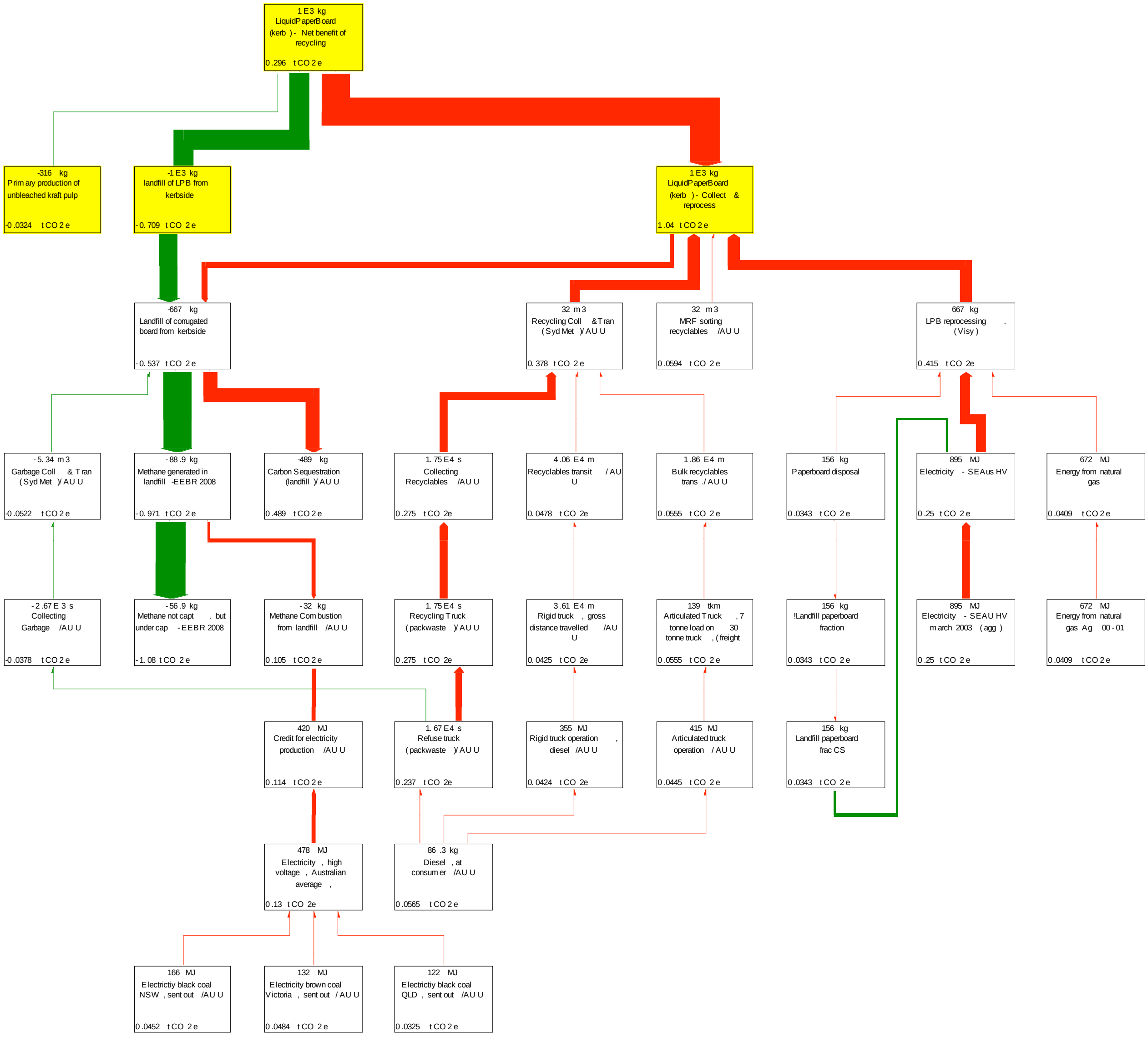


Figure 22: Recycling process network diagram — Cumulative energy demand indicator. Processes contributing less than 8 per cent to total are not shown. Major processes from results table above are shown shaded

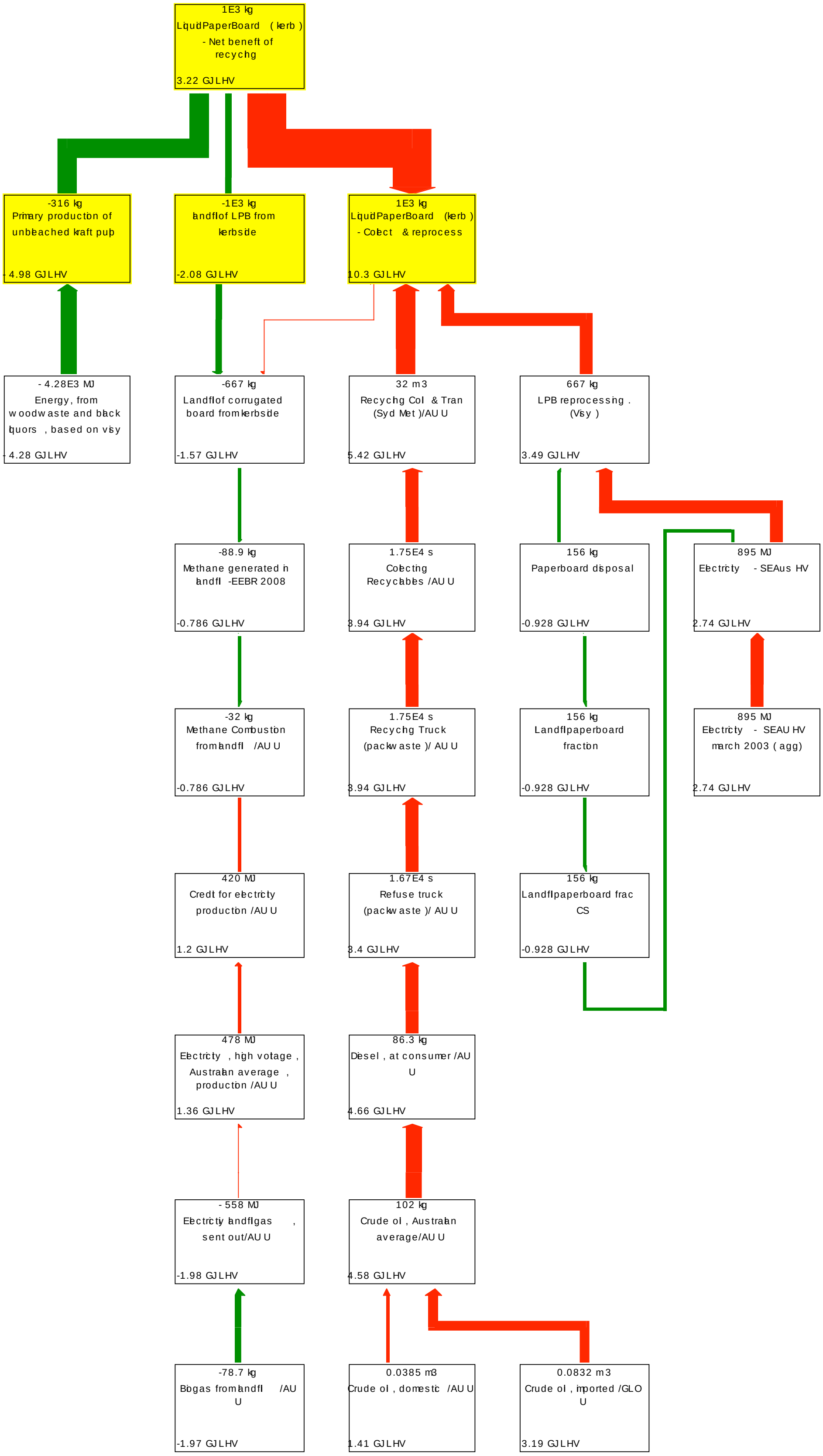


Figure 23: Recycling process network diagram — Water indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.

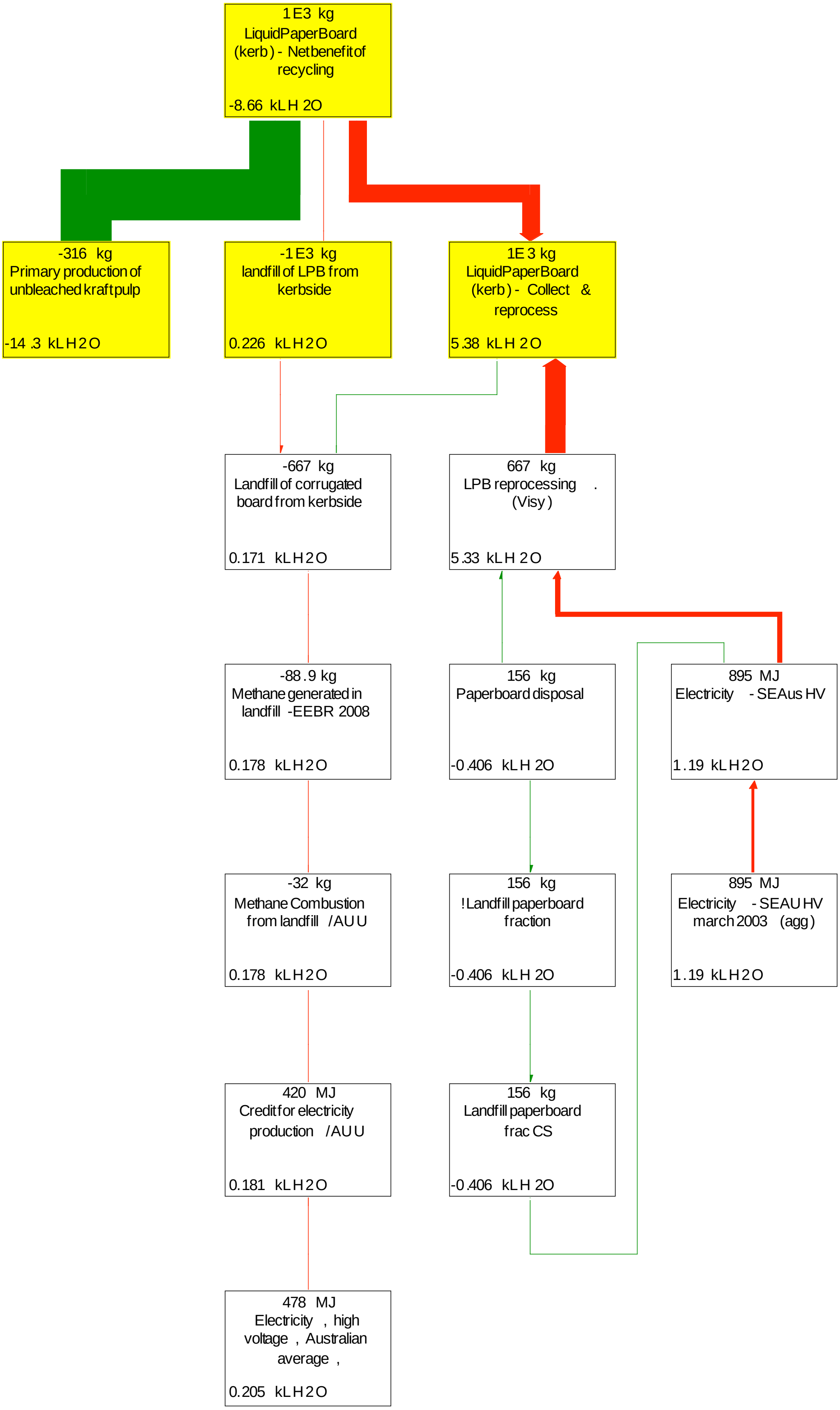
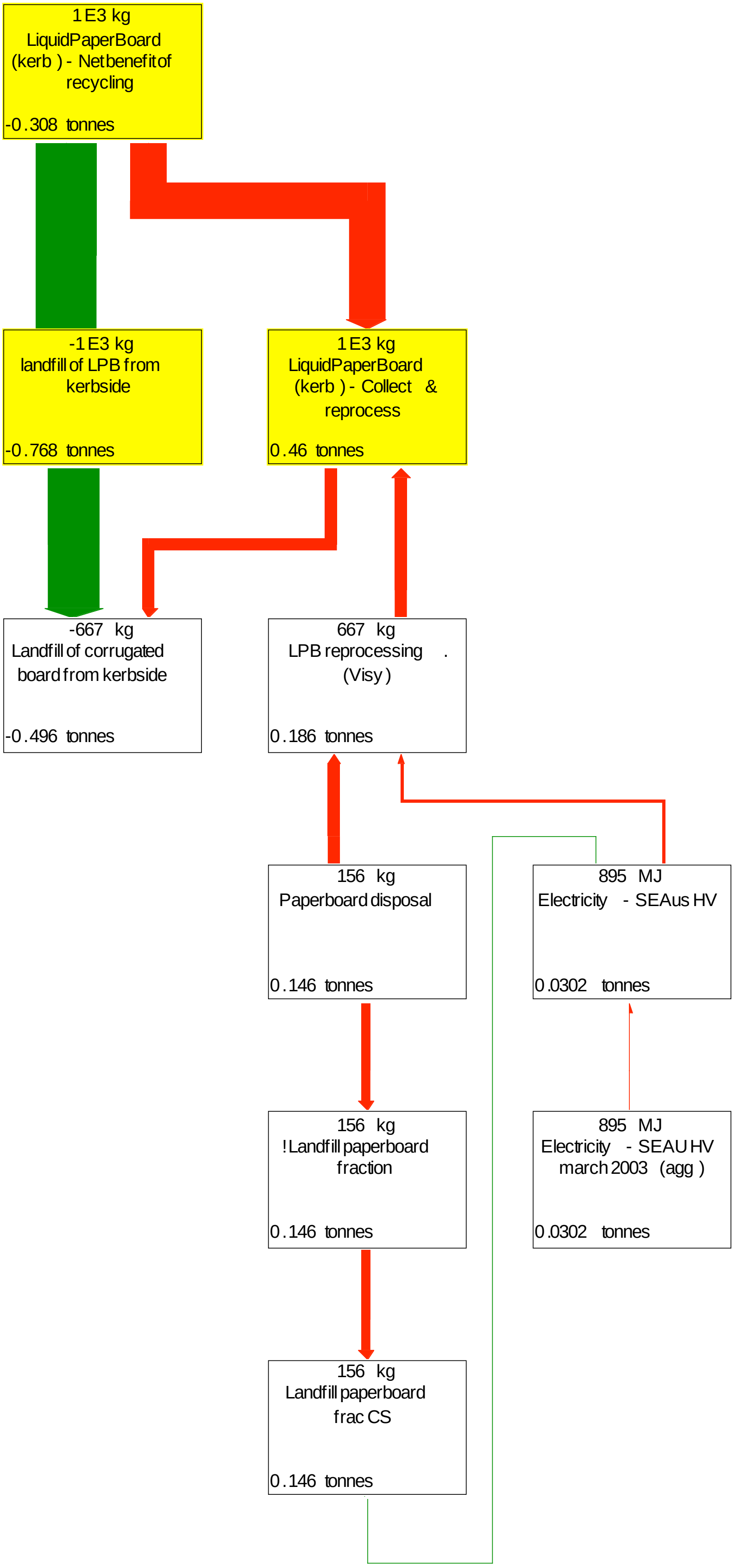


Figure 24: Recycling process network diagram — Solid waste indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.



Office paper

Process description

Office paper is generally recycled back into white office paper. The process involves sorting the paper into different grades. It is then mixed with water to form a pulp. The pulp is then screened, cleaned, de-inked and then mixed with sodium hypochlorite (bleach), and finally sent to the paper machine to be used to make different grades of paper ranging from envelopes to office paper. The avoided product from office paper production is assumed to be white office paper from virgin fibre.

Two collection systems for waste office paper were considered in the model:

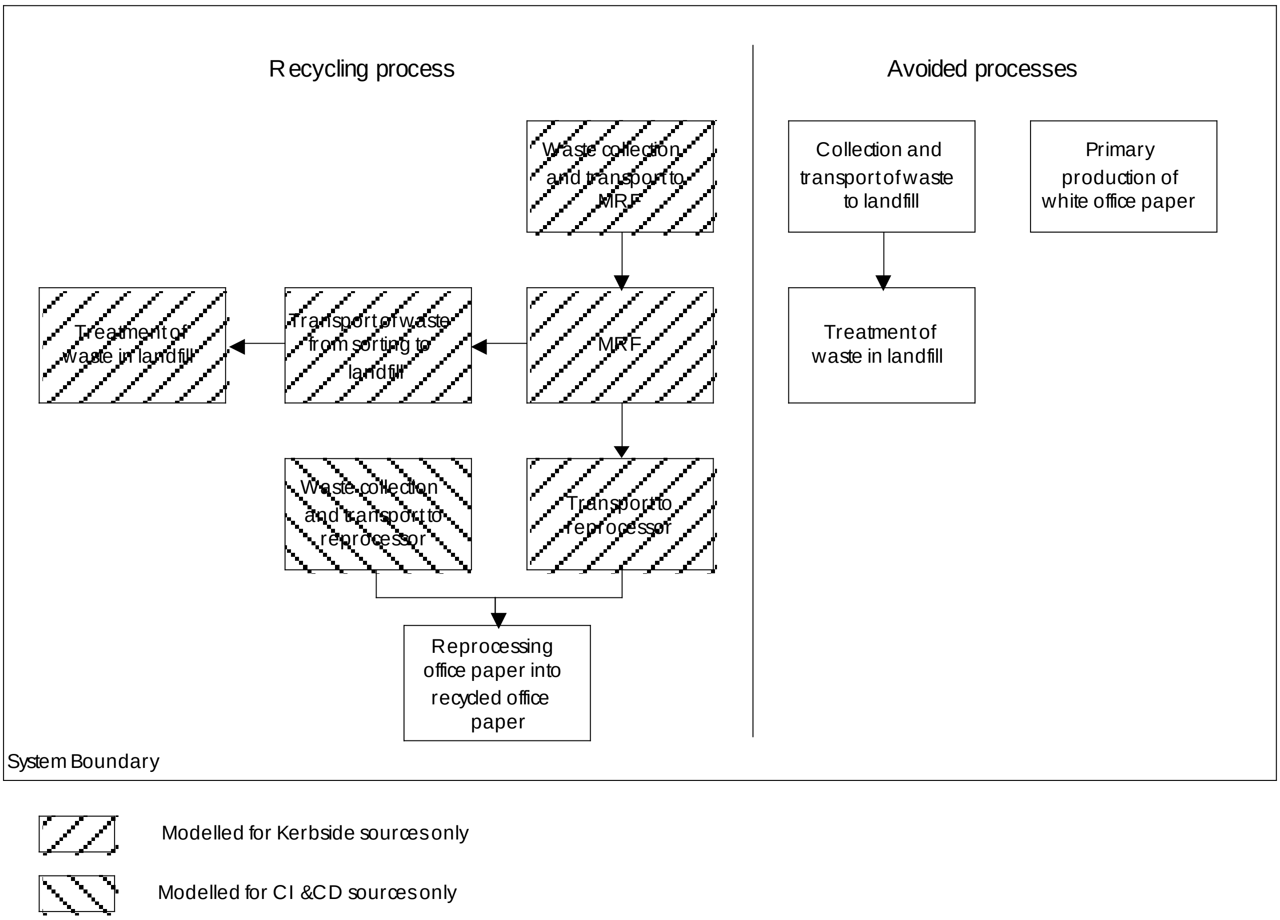
A) Kerbside collection — municipal collection of office paper in commingled from households, and processing through a Materials Recovery Facility

B) C&I, C&D collection — the segregated waste collected is sent directly to the reprocessing site without any sorting process, or associated losses.

The unique nature of each collection system drives differences in the impacts associated with office paper recycling. For this reason the recycling processes considered and impacts generated have been described separately in the following sections, according to the collection method used.

Figure 25 illustrates the processes considered in determining the overall impact of office paper recycling from kerbside and C&I and C&D sources (shown to the left of the vertical line), and the processes considered in determining the overall impact of the avoided processes (shown to the right of the vertical line).

Figure 25: Processes considered in determining the net impacts of the recycling process from kerbside and CI&CD sources.



A) Kerbside collection system

Processes considered

The kerbside collection system involves collection of waste for recycling from the kerbside and transport to a Materials Recovery Facility (MRF), which sorts the commingled materials in the recycling stream. The model developed takes into account transportation impacts as well as sorting impacts incurred to bring the material from the kerbside to the material reprocessing facility. During sorting, waste material is generated and transported to landfill.

Once at the reprocessing facility, the model considers the impacts of material reprocessing required to convert the waste material into secondary products. Losses associated with this process are included in the analysis. The kerbside treatment system is illustrated in Figure 25 (processes unique to kerbside collection have been shaded accordingly).

In order to determine the benefit or impact of recycling a material, it is also necessary to consider the processes avoided when recycling is undertaken. Figure 25 also illustrates the processes that would be avoided if office paper wastes are reprocessed (shown to the right of the vertical line). Two main processes are considered, the collection and disposal to landfill of office paper wastes from the kerbside, and the primary manufacture of white office paper from virgin resources.

Results

Considering both the recycling process flows and the avoided process flows, described in Figure 25, an inventory of environmental flows was developed. This inventory was then assessed using the Australian Impact Assessment Method, with results described in Table 16.

Table 16: Benefits and impacts of recycling of office paper from kerbside sources (per tonne). Benefits are shown negative, impacts are shown positive.

Impact category	Unit	Recycling process impacts (Figure 67 - left side)	Avoided process impacts (Figure 67 - 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	1.63	-0.78	-1.59	-2.37	-0.74
Cumulative energy demand	GJ LHV	19.17	-2.01	-21.29	-23.30	-4.12
Water use	kL H_2O	22.60	0.26	-25.76	-25.50	-2.91
Solid w aste	tonnes	0.09	-0.74	-0.28	-1.02	-0.93

Network diagrams detailing key processes that influence the impact listed in Figure 25 are shown in Figure 26 to Figure 29. For further information regarding interpretation of network diagrams, refer to Understanding Network Diagrams (Figure 1).

Key assumptions

Table 17 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 office paper. The table also includes the products and processes avoided when 1 tonne of office paper is recycled.

Table 17: Inventory for recycling 1 tonne of office paper from a kerbside source (1 tonne)

Item	Flow	Unit	Comment
Recycling process flows (Figure 25 — left hand side)			
Waste collection and transport to MRF	5.5	m^3	Transport model for kerbside collection based on Grant (2001), refer discussion below Emission of the truck from NGGIC (1997) Density of the material in cubic meter from Grant (2001)
Sorting of office paper at Material Recovery Facility (MRF)	5.5	m^3	10 per cent loss assumed at MRF Energy inputs from Nishtala (1997) and estimated from equipment specifications
Transport to reprocessor	65	km	65km transport to reprocessor in Sydney metro area. Fuel use data are from Apelbaum (1997). Greenhouse related emissions are based on fuel use with factors taken from NGGIC (1997). Non greenhouse emissions apart from lead are taken from Delft (1996).
Reprocessing office paper into recycled office paper	0.9	tonne	Based on linerboard but with hardwood kraft pulp input, de-inking included from EcoInvent data. Also referenced are Picken (1996) and FEFCO (1997) 1.152 GJ of electricity, 0.860 GJ of energy from coal, 4.392 GJ energy from natural gas, 0.025 GJ of energy from diesel, 1.245 MJ of energy from wood waste, plus the necessary energy input for the deinking process (0.748 MWh of electricity and 1.2 GJ of natural gas per tonne) are consumed for the reprocessing of 1 tonne of office paper.
Transport of waste from sorting to landfill	20	km	Emissions from transport based on an articulated truck, 28 tonne load on 30 tonne truck. Trucking model developed from data provided by Apelbaum (2001).
Treatment of waste in landfill	0.1	tonne	During the sorting process, 10 per cent of waste assumed to be discarded at MRF, and treated in landfill. This correspond to 100 kg.
Avoided process flows (Figure 25 — right hand side)			
Collection and transport of waste to landfill	5.5	m^3	Waste collection avoided by sending material to MRF 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.
Treatment of waste in landfill	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 AGO dissimilated in landfill factor for final inert waste and carbon sequestration.
Primary production of white office paper	0.85	tonne	Based on linerboard but with hardwood kraft pulp input Also referenced are Picken (1996) and FEFCO (1997) 1.15 GJ of electricity, 0.86 GJ of energy from coal, 4.4 GJ of energy from natural gas, 0.025 GJ of energy from diesel, and 1.25 MJ of energy from woodwaste are assumed to be consumed to process 1 tonne of white office paper from virgin sources.

Data Quality table and comment

Table 18 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 18: Data quality for life cycle inventory data modelled for recycling and landfilling of office paper, kerbside source

	Primary data source	Geography	Data Age	Technology	Representativeness
Recycling collection and transport	Apelbaum consulting group (1997)	Australia	2001	Average	Average from all suppliers
Transportation distances	Estimate	Sydney	2009	Average	Estimate based on simple radial transport model
Recycling paper to office paper with deinking	Ecoinvent data, Picken (1996), FEFCO (1997)	European data adapted to Australian conditions	1996–2004	Average	Mixed data
Avoided virgin material production	Unknown	Western Europe	1990–1994	Average	Mixed data
Avoided landfill impacts	Eco–invent, AGO and US EPA	European data adapted to Australian conditions, Australia and US	2001–2004	Unspecified	Unspecified

B) C&I and C&D collection system

Processes considered

In the case of the C&I and C&D collection system, it has been assumed that waste collected from such sources is directly sent 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 required to convert the waste material into recycled paper. Losses associated with this process are included in the analysis. The model also illustrates the processes considered in determining the impact of the processes avoided when recycling office paper from C&I and C&D sources. Three main processes are considered, the collection of office paper wastes and landfill treatment, and the primary manufacture of white office paper from virgin resources. The system is also described in Figure 25 (processes unique to C&I, C&D collection are shown shaded accordingly).

Results

Considering both the recycling process flows and the avoided process flows, described in Figure 25, an inventory of environmental flows was developed. This inventory was then assessed using the Australian Impact Assessment Method, with results described in Table 19.

Table 19: Benefits and impacts of recycling and landfill of office paper from C&I and C&D sources (per tonne). Benefits are shown negative, impacts are shown positive.

Impact category	Unit	Recycling process impacts (Figure 67 - left side)	Avoided process impacts (Figure 67 - 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	1.66	-0.73	-1.59	-2.32	-0.67
Cumulative energy demand	GJ LHV	19.97	-1.31	-21.29	-22.60	-2.63
Water use	kL H_2O	25.13	0.27	-25.76	-25.50	-0.37
Solid w aste	tonnes	0.05	-0.74	-0.28	-1.02	-0.96

Network diagrams detailing key processes that influence the impact listed in Table 19 are shown in Figure 30 to Figure 33. For further information regarding interpretation of network diagrams, refer to Understanding Network Diagrams (Figure 1).

Key assumptions

Table 20 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 office paper. The table also includes the products and processes avoided when 1 tonne of office paper is recycled.

Table 20: Inventory for recycling 1 tonne of office paper from C&I and C&D source

Item	Flow	Unit	Comment
Recycling process flows (Figure 25 — left hand side)			
Waste collection and transport to reprocessor	65	km	65km transport to reprocessor in Sydney metro area. 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 office paper into recycled office paper	1	tonne	Based on linerboard but with hardwood kraft pulp input, de-inking included from EcoInvent data. Also referenced are Picken (1996) and FEFCO (1997) 1.152 GJ of electricity, 0.860 GJ of energy from coal, 4.392 GJ energy from natural gas, 0.025 GJ of energy from diesel, 1.245 MJ of energy from wood waste, plus the necessary energy input for the deinking process (0.748 MWh of electricity and 1.2 GJ of natural gas per tonne) are consumed for the reprocessing of 1 tonne of office paper.
Avoided process flows (Figure 25 — 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 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 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 Methane generated in landfill from US EPA 2002 data AGO dissimilated in landfill factor for final inert waste and carbon sequestration
Primary production of white office paper	0.85	tonne	Based on linerboard but with hardwood kraft pulp input Also referenced are Picken (1996) and FEFCO (1997) 1.15 GJ of electricity, 0.86 GJ of energy from coal, 4.4 GJ of energy from natural gas, 0.025 GJ of energy from diesel, and 1.25 MJ of energy from woodwaste are assumed to be consumed to process 1 tonne of white office paper from virgin sources.

Data quality table and comment

Table 21 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 21: Data quality for life cycle inventory data modelled for recycling and land filling of office paper 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
Recycling paper to office paper with deinking	Ecoinvent data, Picken (1996), FEFCO (1997)	European data adapted to Australian conditions	1996–2004	Average	Mixed data
Avoided virgin material production	Unknown	Western Europe	1990–1994	Average	Mixed data
Avoided landfill impacts	Eco–invent, AGO and US EPA	European data adapted to Australian conditions, Australia and US	2001–2004	Unspecified	Unspecified

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Network diagrams — Kerbside collection

Figure 26: 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.

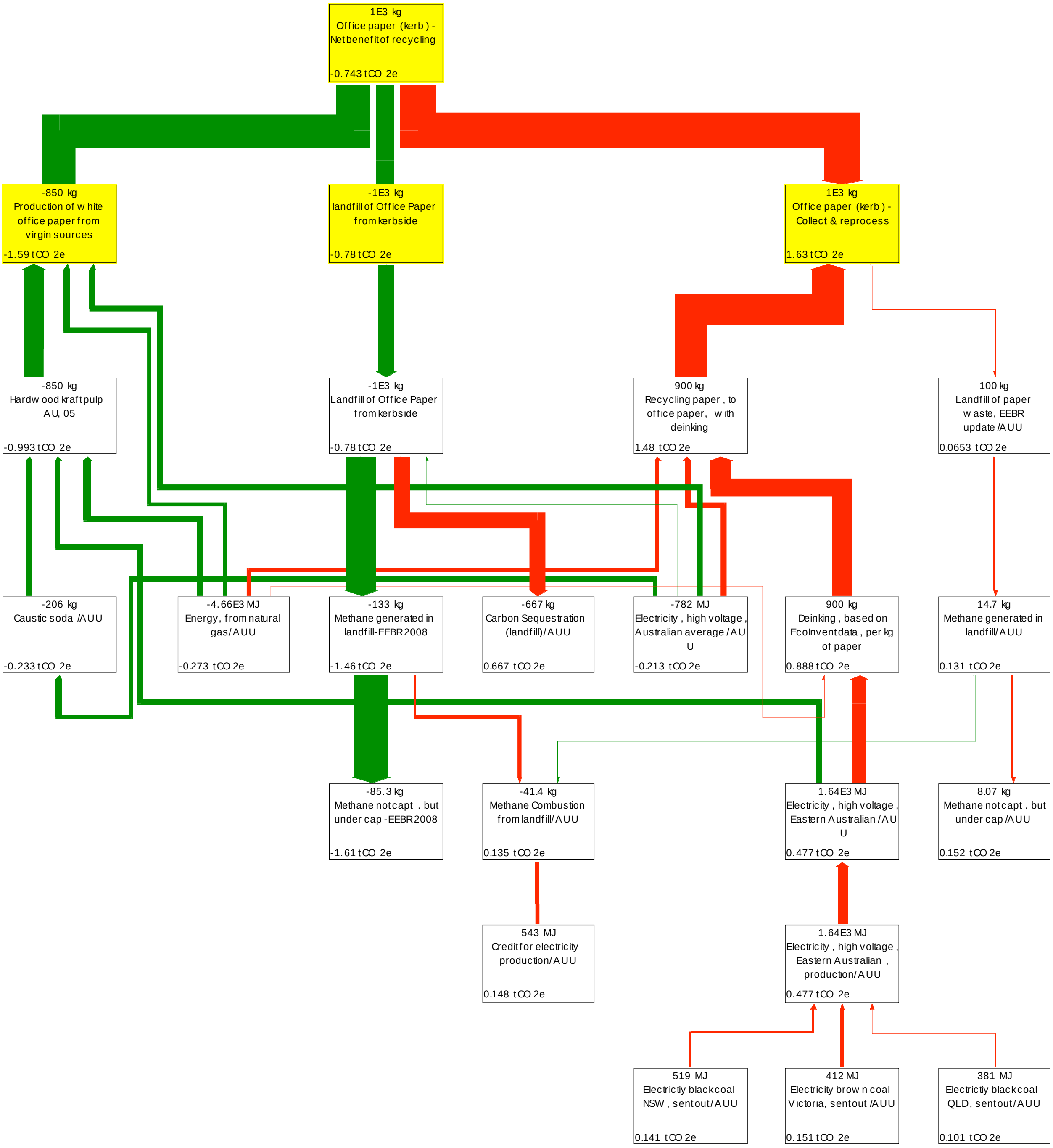


Figure 27: Recycling process network diagram — Cumulative energy demand indicator. Processes contributing less than 5 per cent to total are not shown. Major processes from results table above are shown shaded

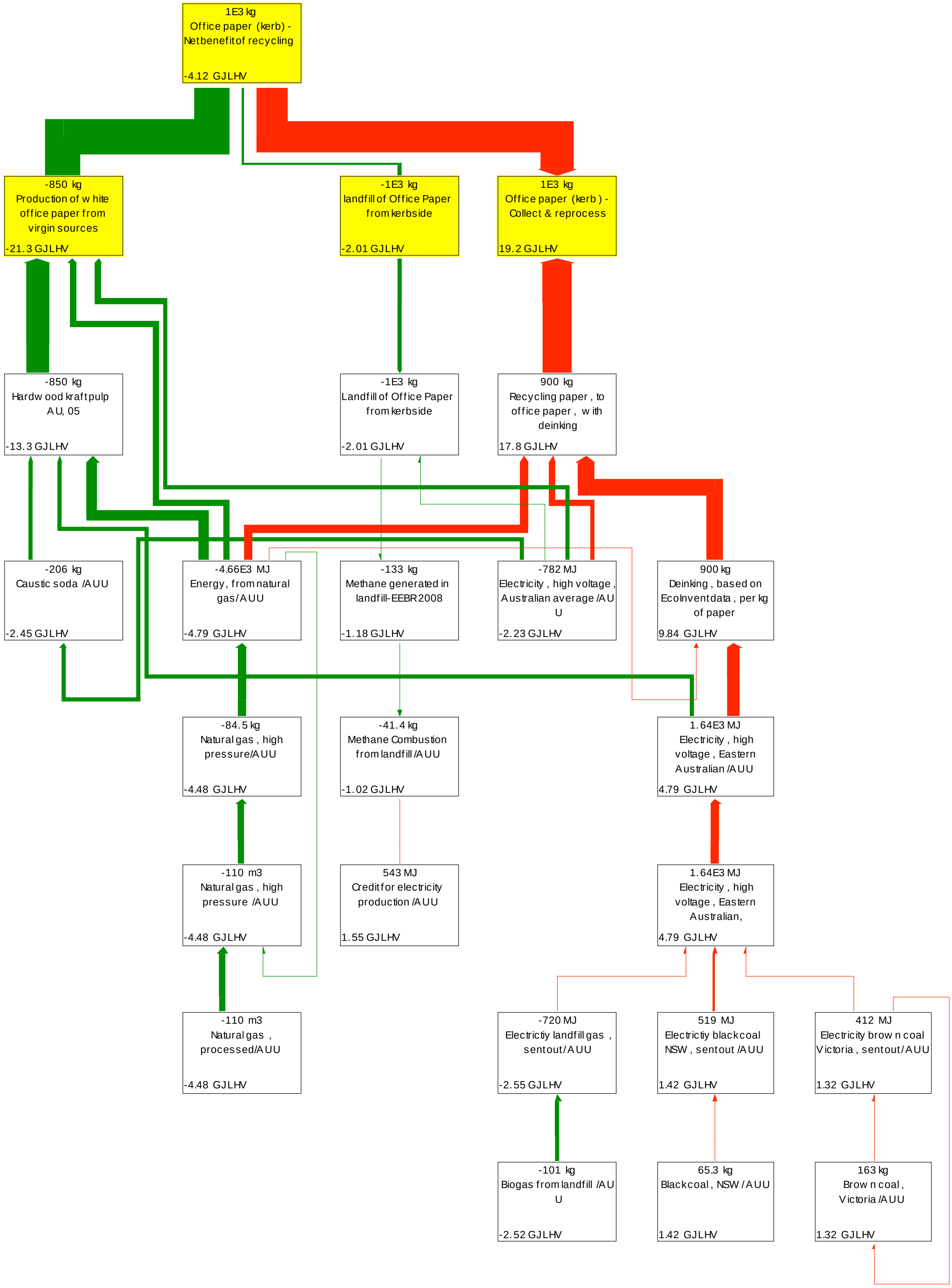


Figure 28: Recycling process network diagram — Water indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.

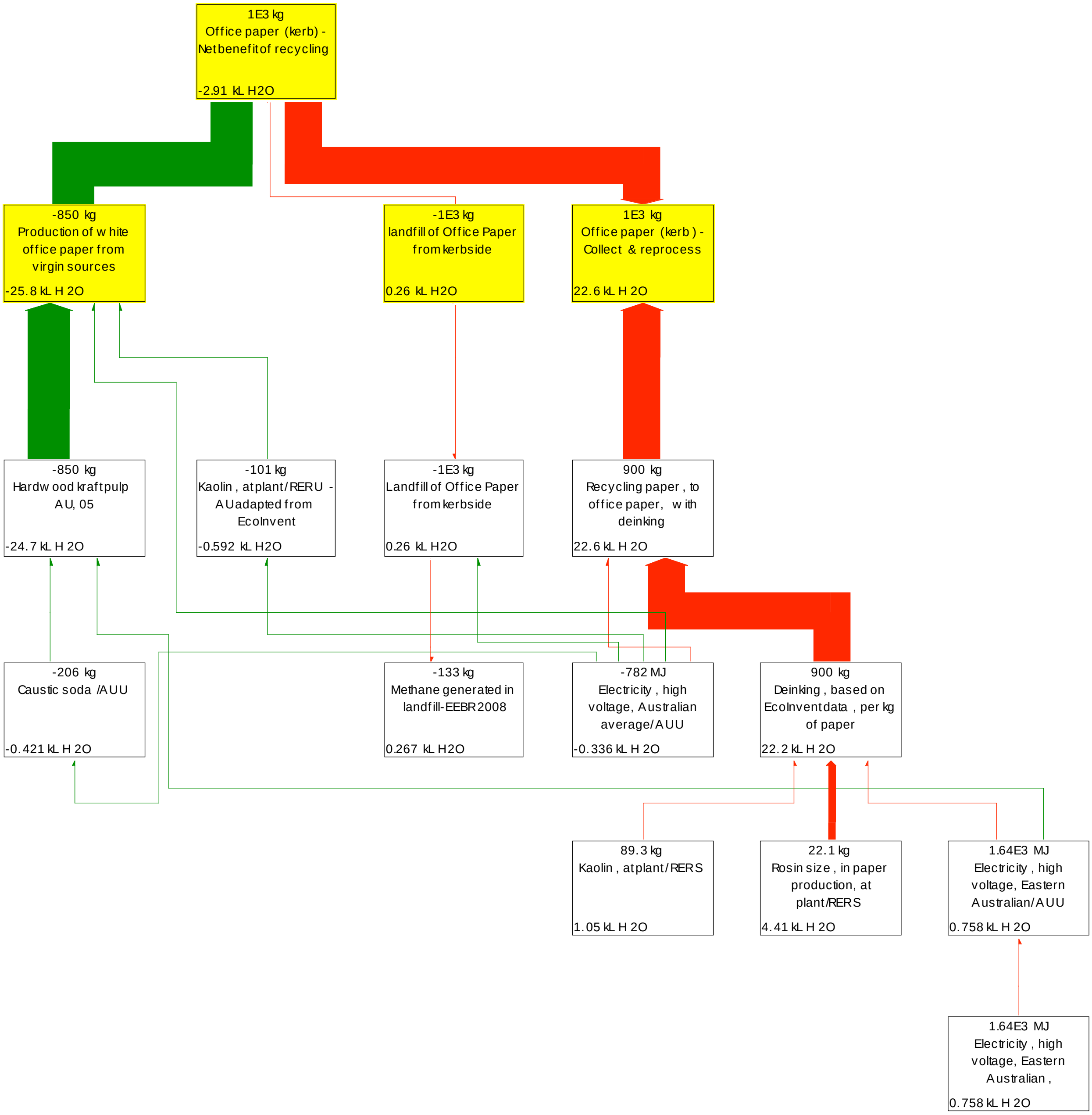
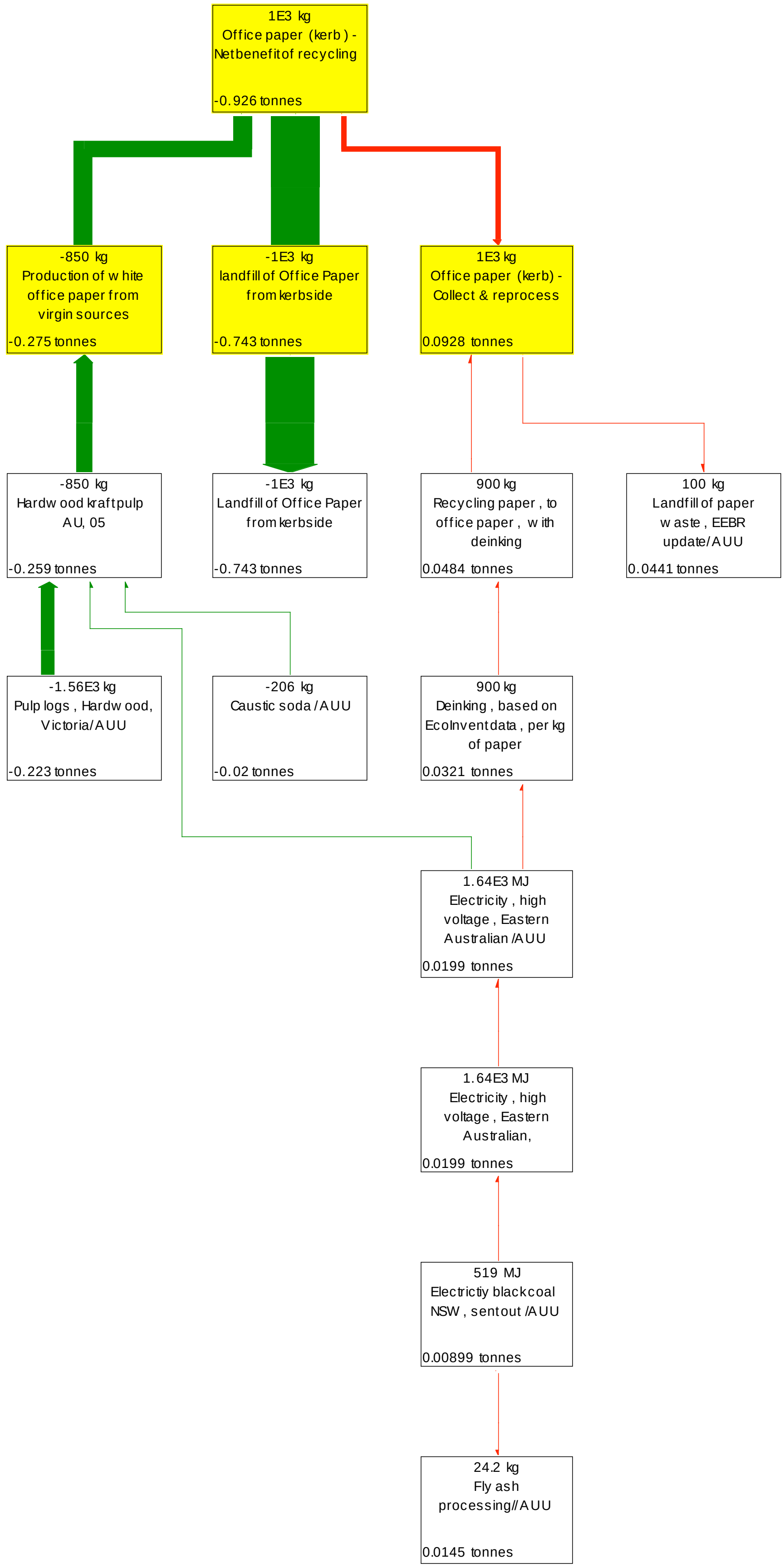


Figure 29: Recycling process network diagram — Solid waste indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.



Network diagrams — C&I and C&D collection

Figure 30: 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.

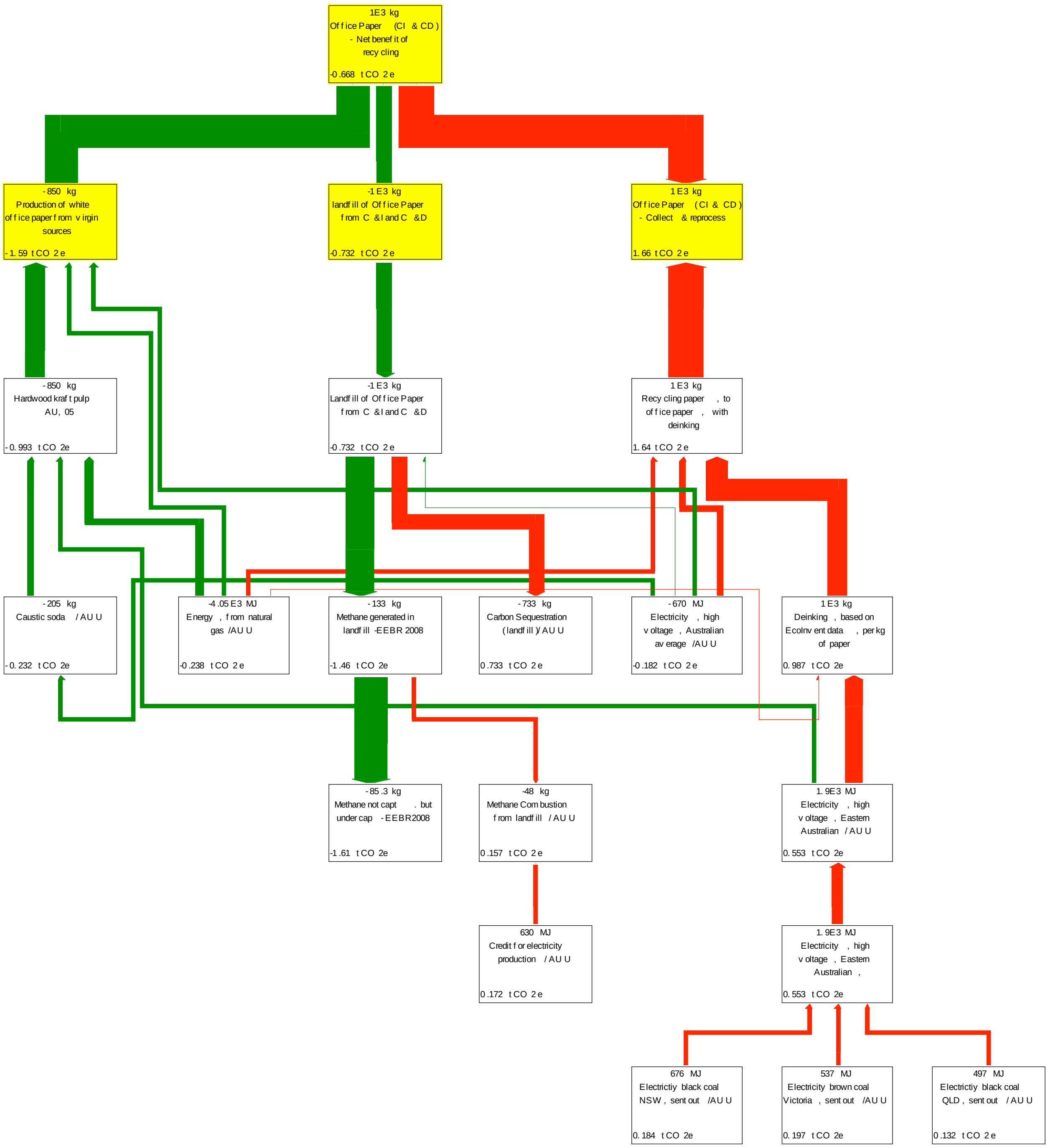


Figure 31: Recycling process network diagram — Cumulative energy demand indicator. Processes contributing less than 6 per cent to total are not shown. Major processes from results table above are shown shaded.

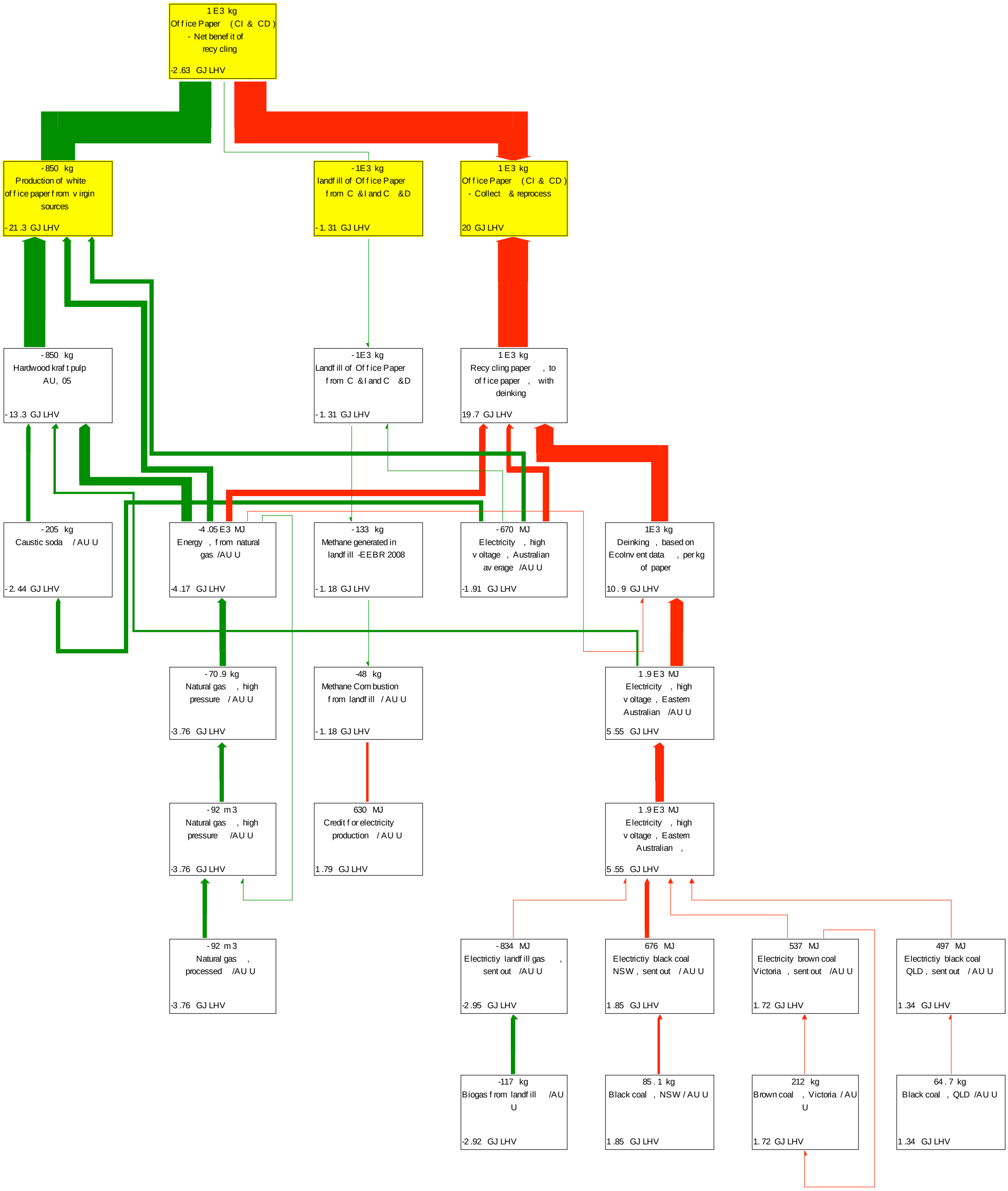


Figure 32: Recycling process network diagram — Water indicator. Processes contributing less than 1 per cent to total are not shown. Major processes from results table above are shown shaded.

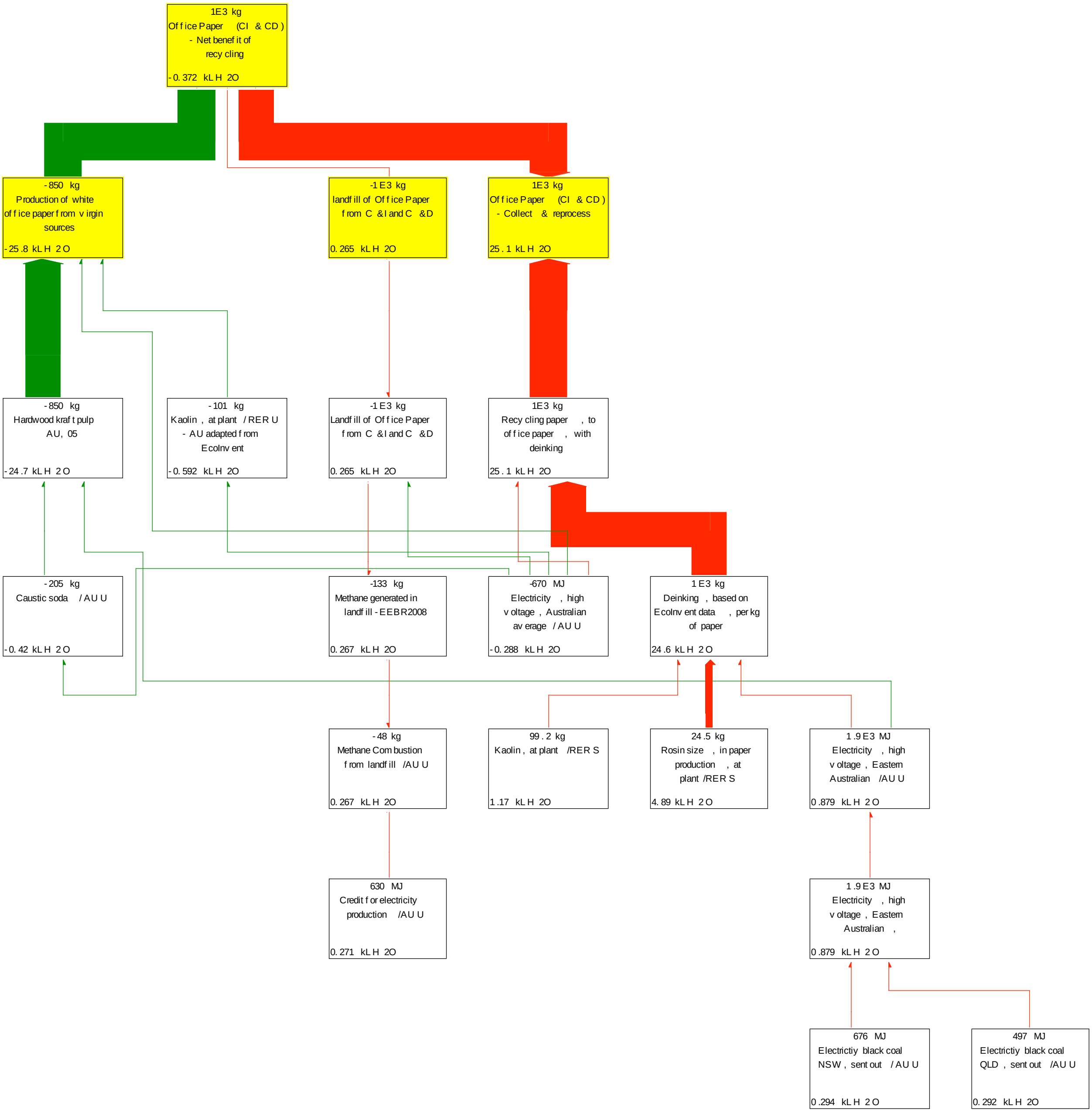


Figure 33: Recycling process network diagram — Solid waste indicator. Processes contributing less than 2 per cent to total are not shown. Major processes from results table above are shown shaded.