E.ON Climate & Renewables UK Developments Limited

Portbury Dock Renewable Energy Plant

Carbon Dioxide Emissions Study

August 2009

This report takes into account the particular instructions and requirements of our client.
It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party

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Executive Summary

Introduction

This carbon footprinting study has been undertaken by Ove Arup and Partners Ltd (Arup) to assess the carbon dioxide (CO_2) emissions arising from the likely supply chain providing biomass fuel to the proposed Portbury Dock Renewable Energy Plant sited at Bristol Dock. The study has been commissioned by E.ON Climate and Renewables (E.ON). E.ON is proposing to develop a 150MW[1] Renewable Energy Plant within the Royal Portbury Dock estate. E.ON Climate and Renewables is E.ON's dedicated renewable energy business; responsible for managing E.ON's renewable energy portfolio.

The Development

The proposed Portbury Dock Renewable Energy Plant ('Renewable Energy Plant') will burn woodchip derived from both waste wood and mostly the by-products of forestry operations ('forestry products' and virgin wood). It is proposed to use a fuel mix of approximately 30% waste wood and 70% forestry products. The waste wood will be sourced from within the UK and will be transported to the site by road or potentially rail. The forestry products are likely to be sourced from overseas. This portion of the fuel will be delivered to the site by ship. Waste products (ash and metals) will be recycled where possible and remaining waste streams will be landfilled.

Biomass fuels are generally classed as *carbon neutral* because the CO_2 released by the burning of the fuel is equal to the CO_2 absorbed previously by the growing trees supplying the biomass. However, other energy inputs required over the life cycle of the fuel such as processing, transport and disposal all have CO_2 emissions and as a result, affect this carbon neutrality. In addition, biomass must be sourced from long-established, sustainable managed forests to ensure this carbon neutrality.

Goals of the Study

The goals of the study are as follows:

Base Case:

Develop an understanding of the CO_2 emissions arising from the likely supply chain providing biomass fuel to the proposed Renewable Energy Plant development relative to the CO_2 emissions arising from the provision of the same electricity supply via the UK National Grid.

Scenario 1:

Quantify the CO_2 emission reduction (benefits) of utilising waste heat arising from the Renewable Energy Plant in local industrial and residential applications.

Scenarios Considered – Scope, Methodology and Key Data

Base Case

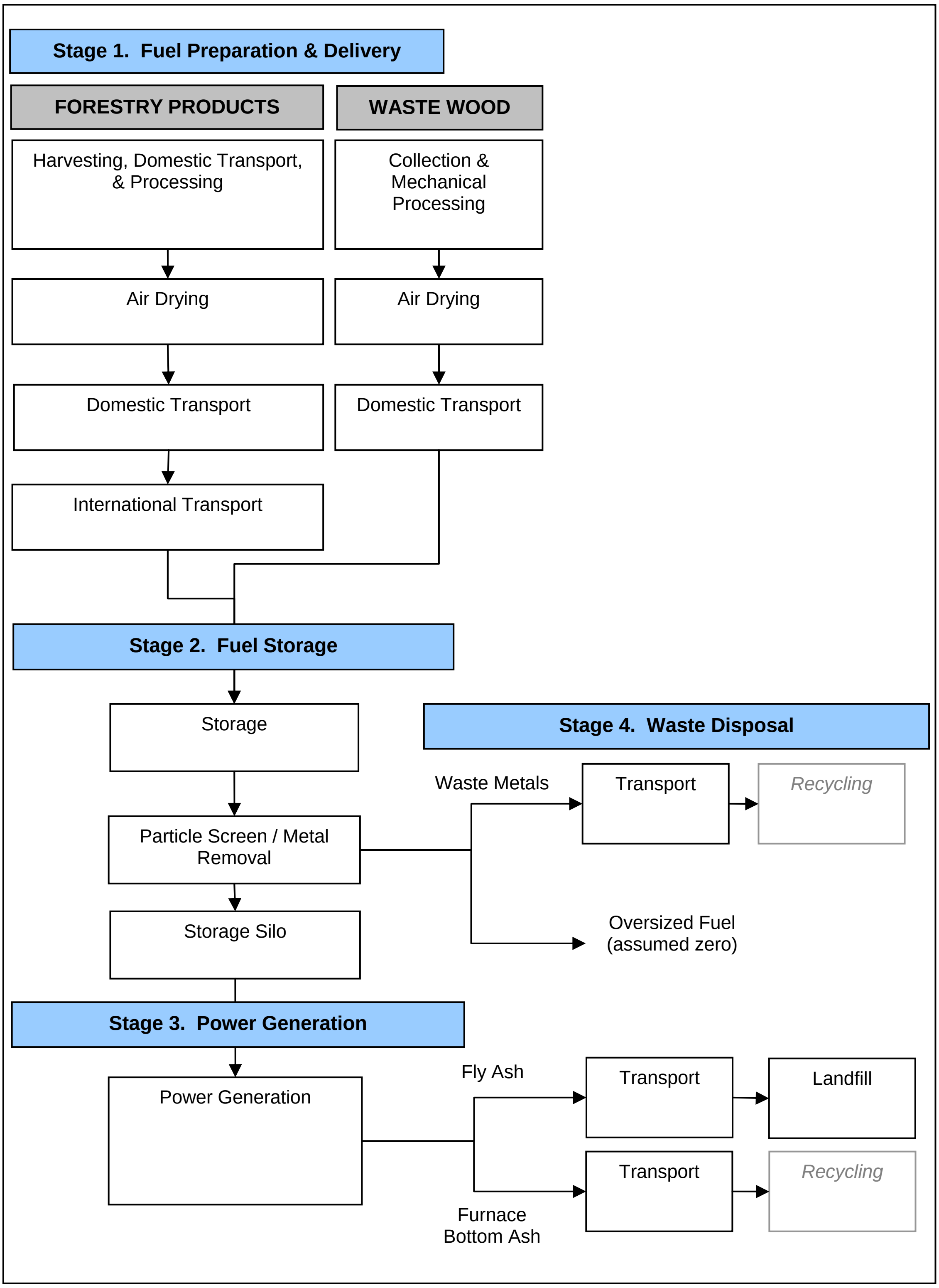
The base case considers the proposed Renewable Energy Plant operating at a generation capacity of 150MWe[2]. The Renewable Energy Plant is to be supplied with a mix of 70% forestry products sourced from overseas forestry activities and 30% waste wood sourced from the South West region. The study has considered the CO_2 emissions associated with the following aspects of the plant operation:

[1] The anticipated generating capacity for the Renewable Energy Plant is 150MW. A margin of plus or minus 10% has been applied to this figure for modelling purposes. . As a result, this carbon footprinting study considers the maximum generating capacity of 165MW (i.e. 150MW plus 10%) as the basis for all calculations and comparisons to reflect a 'worst case' scenario for CO_2 emissions arising from the operation of the biomass renewable energy plant.

[2] Megawatts of Electricity (MWe)

- Growth, harvesting, and transport of forestry products from overseas[3] to the UK;
- Processing and transport of waste wood (from within a 50 mile radius of the site); and
- Transport and disposal of waste streams to recycling facilities and landfill as appropriate (within a 50 mile radius of the site).

This is presented in the following flowchart.



3 The Study has considered locations in both North America and South America as potential sources.

The CO_2 emissions arising from the biomass base case are compared to CO_2 emissions arising as a result of supply of electricity on the UK National Grid. A range of emissions factors have been used to undertake this comparison. The two of most relevance to the study are shown below.

Key Emissions Factors

Name	Emission Factor (kg CO_2 / kWh)	Source	Basis
Long term marginal factor	0.4300	Defra	• UK emissions only – Excludes emissions associated with fuel supply chain. • Reflects avoiding the need to source the equivalent power from a combined cycle gas turbine (CCGT) power station. • Excludes distribution losses - Represents emissions per kWh at the point of electricity generation (i.e. Power station).
UK Grid mix	0.5423	Based on GaBi 4 [4]	• Life cycle emissions, including pre-combustion – Include emissions associated with fuel supply chain. • Adapted for the study to exclude distribution losses of 8.24% - Represents emissions per kWh at the point of electricity generation (i.e. Power station).

[4] GaBi 4 is the proprietary life cycle assessment (LCA) software tool of PE International GmBH.

The key data used within the study is presented in the following table.

Key Data

Category	Base Case Values	Source
Net Electrical Output (Actual)	150 MW 1,182,600 MWh/year	E.ON
Net Electrical Output (Modelled)	165MW 1,300,860 MWh/year	E.ON
Fuel Quantity into boiler	1,200,000 Tonnes / year	E.ON
Fuel Mix	70% Virgin wood	E.ON
	30% Waste wood	E.ON
Plant downtime	10% Annually	Assumed
Heat demand	0 MWh/year	Assumed
UK Fuel Delivery – truck load	20 Tonnes	E.ON
Waste generation – bottom ash	21,600 Tonnes / year	EON
Waste generation – fly ash	86,400 Tonnes / year	E.ON
Waste generation – waste metals	702 Tonnes / year	Calculated
UK Waste Disposal – truck load	27 Tonnes	Assumed
Metal content – forestry products	0%	E.ON
Metal content – waste wood	0.2%	Calculated

Scenario 1

This scenario considers the CO_2 benefits associated with the utilisation of heat which is assumed to be waste in the base case. E.ON has advised that there are potential opportunities for the heat to be utilised in the following applications:

- Option A: 6 MW of heat demand by a local industrial operation (52,560 MWh/year);
- Option B: 25.7 MW of heat demand by an urban extension for 6 months of the year (112,566 MWh/ year).

The study assumes that there are no additional CO_2 emissions associated with the supply of the heat from the Renewable Energy Plant to meet the demand.

Key Assumptions

The following key assumptions have held an overarching role in the development of this study:

- The calorific value and moisture content of all wood fuels is constant. This assumption has been suggested by E.ON. It is likely that the carbon footprint results would be influenced by changes in both of these values in either fuel type.
- This study has not considered the implications of potential land use changes to support forestry operations.[5]
- This study assumes that imported wood will be sourced from forestry that is sustainably managed.
- Within the study, in many cases it has been assumed that waste wood will be sourced within a 50 mile radius of the Renewable Energy Plant. This assumption has been suggested by E.ON. Transport related emissions make up a significant proportion of the overall carbon footprint. As a result, the detailed assumptions made in relation to wood transport (including transport distance and load utilisation) will have a significant impact on the overall carbon footprint.

[5] Within the PAS 2050 carbon footprinting guidance, CO_2 emissions associated with direct land use change should be included where this change occurs after 1st January 1990. This CO_2 'cost' recognises the requirement to avoid destruction of natural habitat.

Results

Base Case

The following table shows a breakdown of the CO_2 emissions associated with each of the process stages within the fuel supply chain and waste disposal processes.

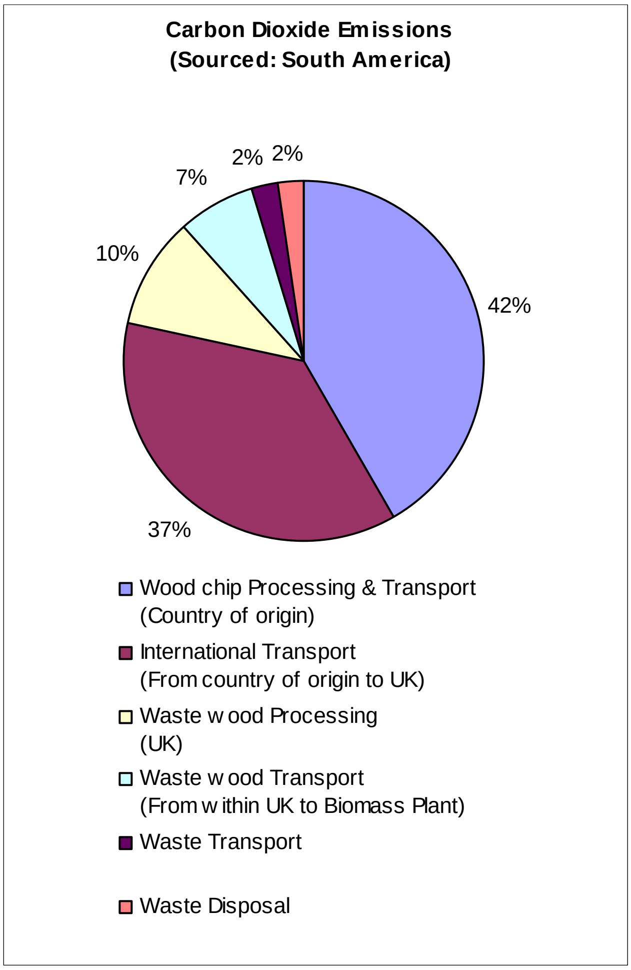
Overall Emissions by Activity

Process Stage		**South American Biomass[1]**		**North American Biomass[2]**	
		tCO_2/ year	**$kgCO_2$/ t fuel**	**tCO_2/ year**	**$kgCO_2$/ t fuel**
Forestry Products	**Processing** (Country of origin)	2,791	3.3	2,791	3.3
	Transport (Country of origin)	17,353	20.7	15,866	18.9
	International transport (Country of origin to UK)	17,674	21.0	9,038	10.8
Waste wood	**Processing** (UK)	4,818	13.4	4,818	13.4
	Transport (Within UK to Biomass Plant)	3392	9.4	3392	9.4
Waste Management	**Transport**	1176	1.0	1176	1.0
	Disposal	1,037	0.9	1,037	0.9
TOTAL		**48,240**	**69.6**	**38,116**	**57.6**
	($kgCO_2$/kWh)	**0.037**		**0.029**	

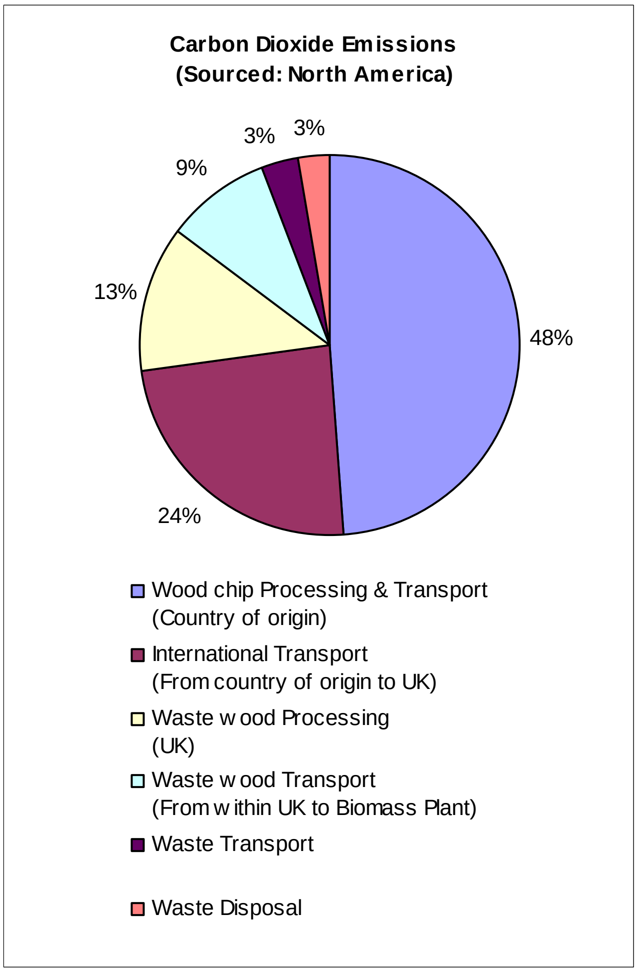
1: 70% woodchip from South America, 30% UK sourced waste wood

2: 70% woodchip from North America, 30% UK sourced waste wood

The following figure displays the emissions arising by supply chain activity and highlights areas of the supply chain where the emissions vary between the two sourcing options; primarily within the area of international shipping.



Carbon Dioxide Emissions by Activity South American biomass source.



Carbon Dioxide Emissions by Activity North American biomass source.

Comparison with UK Grid Mix

The study has considered the comparison of the life cycle emissions arising from the likely supply chain providing biomass fuel to the proposed biomass Renewable Energy Plant against the emissions arising from the generation of electricity from the UK National Grid.

The following table and figure display the overall emissions arising from the biomass Renewable Energy Plant and the carbon intensity (tonnes CO_2/MWh) of the Renewable Energy Plant relative to key measures of the UK National Grid[6].

Overall Emissions in comparison with UK National Grid – Base Case

<table>
<tr><th colspan="2" rowspan="3">Carbon Dioxide Emissions</th><th colspan="2" rowspan="2">Biomass</th><th colspan="2">UK National Grid</th></tr>
<tr><th>Defra</th><th>GaBi</th></tr>
<tr><th>South American biomass[1]</th><th>North American biomass[2]</th><th>Long Term Marginal Factor</th><th>Current UK Grid mix</th></tr>
<tr><td rowspan="4">CO_2 Emissions per year

Emissions at point of production (excluding distribution losses)</td><td>tonnes CO_2/year</td><td>48,240</td><td>38,116</td><td>508,518</td><td>641,371</td></tr>
<tr><td>tonnes CO_2/MWh</td><td>0.037</td><td>0.029</td><td>0.430</td><td>0.542</td></tr>
<tr><td>Savings over calculated UK grid mix (GaBi)</td><td>593,131 (92%)</td><td>603,255 (93%)</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>Savings over Defra long term marginal factor</td><td>460,278 (91%)</td><td>470,402 (93%)</td></tr>
</table>

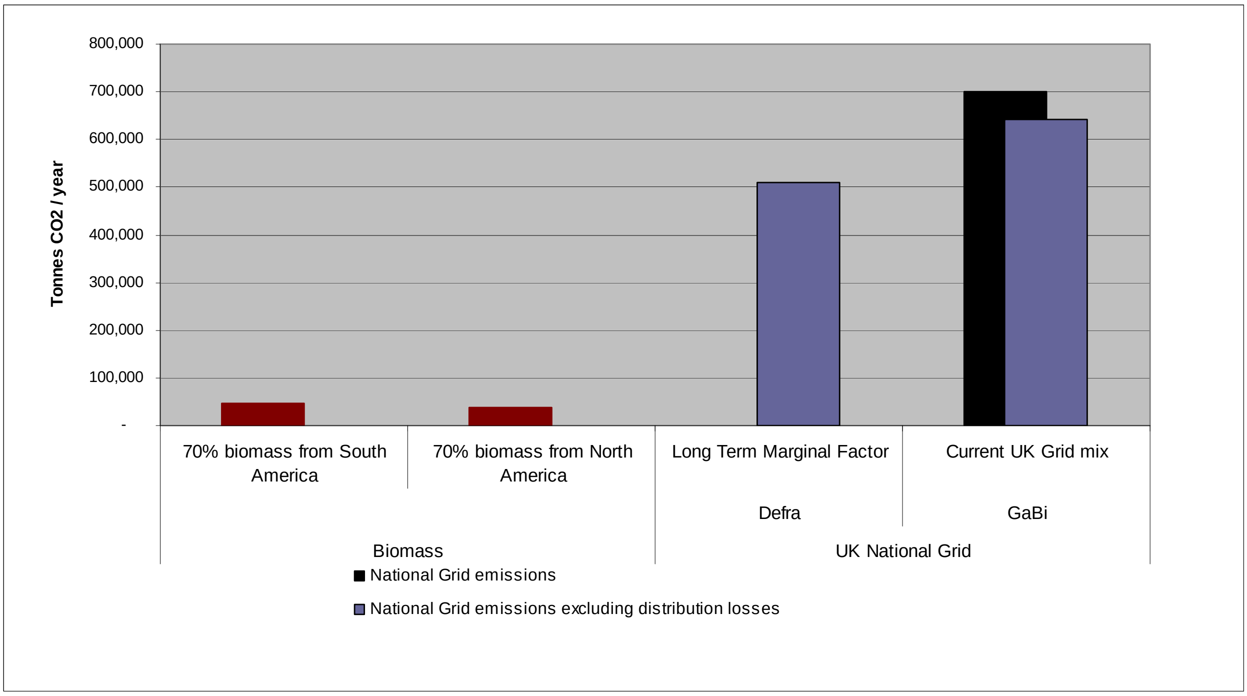
1: 70% woodchip from South America, 30% UK sourced waste wood

2: 70% woodchip from North America, 30% UK sourced waste wood

The base case and the GaBi figures reflect emissions arising from the whole life cycle, including the fuel supply chain. The Renewable Energy Plant represents savings of approximately 600,000 tonnes of carbon dioxide (CO_2) per year for biomass sourced from either North America or South America, provided the biomass is sourced from sustainably managed forestry operations. The Defra Long Term Marginal figure considers emissions arising from activities in the UK and excludes emissions associated with fuel supply chain. The Renewable Energy Plant represents savings of over 450,000 tonnes per year for biomass sourced from sustainably managed forests in either North America or South America.

[6] Comparable emissions arising from the National Grid are calculated assuming a 150MWe electrical output.

The figure below shows the results with and without the adjustment for distribution losses. The biomass base case compares favourably when compared to the selected measures of the National Grid mix.



Overall Emissions in comparison with UK National Grid – Base Case

Scenario 1: Utilisation of Waste Heat

E.ON has identified potential opportunities to utilise waste heat from the Renewable Energy Plant for industrial and residential applications; avoiding the need to use natural gas to supply the same heat demand. If the 6MW industrial heat demand was met by the waste heat, it would result in a CO_2 emissions saving of 11,224 tonnes CO_2 per year. If the residential heat demand (25.7MW for six months of the year) was met by the waste heat, it would avoid 24,039 tonnes CO_2 per year.

Conclusions

Base Case

The proposed Portbury Dock Renewable Energy Plant compares favourably from a CO_2 emission perspective when compared with emissions arising from the same generation capacity of the National Grid. The emissions arising from the fuel supply chain for the Renewable Energy Plant have been assessed relative to a range of grid emissions factors. Of most relevance are the Defra long term marginal factor and the GaBi emissions factor for the UK national grid (adjusted to remove distribution losses associated with transmission of electricity to consumers). The Renewable Energy Plant presents savings of 450,000 tonnes CO_2 per year and around 600,000 tonnes CO_2 per year when compared with these two figures respectively. It is important to note that woodchip should be sourced from long-established forestry operations to realise these calculated carbon savings.

The scenario where the forestry products fuel stream is sourced from North America results in over 20% less CO_2 emissions than when forestry products are sourced from South America. The variance arises primarily from the relative differences in transport distance both by road within the different countries and then by ship to the UK.

A significant portion (greater than 60%) of both carbon footprints arises from transport emissions and the results are strongly influenced by the assumptions made in relation to transport in both the UK and overseas. As a result, there will be particular sensitivity in the results in relation to:

- Approach to transport management in the UK and overseas;
- Transport distances;
- Lorry utilisation rates; and
- Shipping distances.

E.ON should investigate opportunities to maximise the proportion of locally sourced biomass fuels where possible and minimise fuel transport distances.

Scenario 1: Use of waste heat

The use of waste heat for the specified industrial and residential applications has been modelled. Using waste heat in these scenarios results in CO_2 savings of over 11,000 tonnes CO_2 per year and 24,000 tonnes CO_2 per year respectively.

1 Introduction

1.1 Background to the Study

This carbon footprinting study has been undertaken by Ove Arup and Partners Ltd (Arup) to assess the carbon dioxide (CO_2) emissions arising from the proposed Portbury Dock Renewable Energy Plant ('Renewable Energy Plant'). The study has been commissioned by E.ON Climate and Renewables (E.ON) in response to queries raised by consultees during the Scoping stage consultations undertaken as part of the Environmental Impact Assessment process for the scheme.

The study considers the CO_2 emissions arising from the biomass fuel supply chain of the Renewable Energy Plant including fuel transport and waste disposal and compares these to emissions associated with the UK National Grid. The study also considers a scenario for the utilisation of waste heat.

1.2 Portbury Dock Renewable Energy Plant

E.ON is proposing to develop a 150 MW[7] Renewable Energy Plant within the Royal Portbury Dock estate. The Royal Portbury Dock is located within the Port of Bristol which is owned and managed by The Bristol Port Company. The proposed site is within an area of reclaimed land recovered from the River Severn during the mid 1990s. The site is currently being used as an imported car store.

The proposed Renewable Energy Plant will burn wood derived from both waste wood and mostly the by-products of forestry operations ('forestry products'). It is proposed that the proposed plant will be fuelled by a mix of approximately 30% waste wood and 70% forestry products. The waste wood will be sourced from within the UK and will be transported to the site by road freight. The forestry products will be sourced from overseas and will be delivered to the site by ship.

Biomass fuels are generally classed as *carbon neutral* because the CO_2 released by the burning of the fuel is equal to the CO_2 absorbed previously by the growing trees supplying the biomass. However, other energy inputs required over the life cycle of the fuel such as processing, transport and disposal all generate CO_2 emissions and as a result, affect this carbon neutrality. In addition, biomass must be sourced from long-established, sustainable managed forests to ensure this carbon neutrality.

1.3 E.ON[8]

E.ON is the world's largest investor-owned energy service provider, supplying over 30 million customers. E.ON UK plc was formed following E.ON's purchase of Powergen UK plc in 2002. E.ON has significant operations in power generation and natural gas production, energy trading and wholesale, transport and distribution, and end customer supply. At the end of 2007, E.ON's installed generating capacity was:

- 36% coal;
- 29% natural gas and oil;
- 21% nuclear; and
- 14% renewables.

As a group, E.ON plans to invest 60 billion Euros between 2007 and 2010 and aims to reduce its specific CO_2 emissions by at least 50% by 2030 (compared to 1990 levels).

[7] The anticipated generating capacity for the Renewable Energy Plant is 150MW. A margin of plus or minus 10% has been applied to this figure for modelling purposes. As a result, this carbon footprinting study considers the maximum generating capacity of 165MW (i.e. 150MW plus 10%) as the basis for all calculations and comparisons to reflect a 'worst case' scenario for CO_2 emissions arising from the biomass renewable energy plant.

[8] Source: Portbury Dock Renewable Energy Plant, Environmental Scoping Report, August 2008

1.3.1 E.ON Climate and Renewables

E.ON Climate and Renewables (EC&R) is E.ON's dedicated renewables business, responsible for managing E.ON's renewable energy portfolio. E.ON aims to generate 18% of energy from renewable sources by 2015. By 2030, 50% of its energy mix should be generated using carbon free renewable and nuclear energy sources. The other 50% should come exclusively from low-emission generation.

EC&R is planning to develop 2.3GW of renewable projects in the UK by building new onshore and offshore wind farms, biomass-fired renewable energy plants and tidal and wave power schemes.

Within the biomass area, the group has delivered one of the UK's largest dedicated biomass fired renewable energy plants, Steven's Croft, in Scotland with outline approval granted for a second site, Blackburn Meadows in Sheffield. The proposed Portbury Dock Renewable Energy Plant will be E.ON's third biomass Renewable Energy Plant in the UK.

1.4 Definition of Carbon Dioxide in this Report

Reference to "carbon dioxide" in this report means CO_2 emitted as a result of the combustion of fossil fuels – *fossil fuel derived CO_2.* This represents atmospheric CO_2 that had been absorbed by growing plant life over long time periods (millennia). Release of this CO_2 therefore represents a net addition to current atmospheric CO_2 levels

Carbon dioxide from combustion of biomass is excluded in this report. Combustion of biomass emits CO_2, but the CO_2 had previously been absorbed from the atmosphere by the growing trees from which the biomass is derived, over short timescales (years). Therefore, emission of this *biomass derived CO_2* returns CO_2 back to the atmosphere from which it had recently been removed, meaning there is no net addition to atmospheric levels of CO_2. This statement is true, provided:

- The source of biomass is from sustainable forestry practices, i.e. there is no net depletion of forest in order to supply biomass for combustion.
- Old growth forest, such as tropical rainforest, and ancient woodland is not cleared to make way for commercial forestry operations even if these operations are managed sustainably. To this end, and in accordance with PAS 2050[9], no account needs to be taken of CO_2 emissions as a result of land use change provided no such land use change has occurred since 1st January 1990.

Emissions of biomass derived CO_2 are excluded from this report on the basis that E.ON will source forestry products from sustainable sources where there has been no land use change since 1st January 1990.

1.5 Scope of the Report

This report sets out the methodology used to calculate CO_2 emissions, based on guidance in PAS 2050 and the ISO 14040[10] standards. The report is set out as follows:

Section 2: Goals of the study.

Section 3: Scope and Methodology, including definition of modelled scenarios, boundaries, key data and assumptions.

Section 4: Results of CO_2 assessment.

Section 5: Conclusions and recommendations

[9] BSi, Carbon Trust, Defra; PAS 2050: Specification for the assessment of the life cycle greenhouse gas emissions of goods and services; 2008

[10] ISO 14040; Environmental management – Life cycle assessment – Principles and framework; 2006 and ISO 14044; Environmental management – Life cycle assessment – Requirements and guidelines; 2006.

2 Goals of the Study

The goals of this study are as follows:

1. Develop an understanding of the CO_2 emissions arising from the proposed Renewable Energy Plant development relative to the CO_2 emissions arising from the provision of the same electricity supply via the UK National Grid.
    - Quantify the CO_2 emissions associated with supply of biomass (70% forestry products, 30% waste wood) to fuel a 150MW energy plant at the Royal Portbury Dock. Aspects of the life cycle considered included:
        - Forestry Products – Supply, chipping and transport of wood chips in North or South America, shipping to Bristol, mechanical handling at Portbury Dock, transport of waste materials to landfill/recycling, and landfill process emissions.
        - Waste Wood – Chipping of wood, transport of woodchip, mechanical handling at Portbury Dock, transport of waste materials to landfill/recycling, and landfill process emissions.
    - Compare to the emissions arising from the UK National Grid.
2. Quantify the CO_2 emission reduction (benefits) of utilising waste heat arising from the Renewable Energy Plant in named local industrial and residential applications.

2.1 Carbon Footprinting

Carbon footprinting (or "greenhouse gas assessment") is a systems analysis and accounting tool for quantifying emissions of CO_2 (and potentially other greenhouse gases). It is a systematic approach, where the system of interest comprises the operations that collectively produce a product or deliver a service. The system being assessed is linked to other industrial systems supplying and transporting inputs and carrying away and disposing of outputs, for which the CO_2 emissions associated with these activities are also taken into account. This assessment considers CO_2 emissions only.

Carbon footprinting offers a clear and comprehensive picture of the CO_2 emissions arising from use of fossil fuels and other materials and provides a holistic and objective basis for comparisons.

Results of a carbon footprint do not consider other environmental impacts, such as air acidification, waste generation and non-renewable resource depletion, as well as wider sustainability criteria, such as local job creation. They are used to help identify opportunities for improvement and to indicate less carbon intensive options. Results may also contribute to the design process by facilitating understanding of significant processes contributing to climate change in the supply chain and targeting effort towards these for carbon reductions.

PAS 2050, launched in the UK in October 2008, provides guidance on carbon footprinting. It is based on the ISO 14040 life cycle assessment (LCA) standards, which form part of the ISO 14000 environmental management standards.

3 Scope and Methodology

This section sets out the approach to the study, including the boundaries of the study and the rules by which it has been carried out.

3.1 Scope

This study compares the CO_2 emissions arising as a result of likely fuel supply chain for providing biomass fuel for a 150MW biomass Renewable Energy Plant located at the Royal Portbury Dock, Bristol. This is compared to emissions arising from the equivalent electricity generation via the UK National Grid.

Carbon dioxide emissions are expressed in tonnes as a result of annual electricity supply to the National Grid of approximately 1,300 GWh. The boundaries of the study and processes included therein are outlined below and summarised in Figures 3.1 to 3.4.

3.1.1 Base Case - Biomass

The proposed Renewable Energy Plant is to be supplied with a mix of 70% wood cuttings and trimmings sourced from overseas forestry activities and 30% waste wood sourced from the local Bristol area.

The study has considered the CO_2 emissions associated with the following aspects of the fuel lifecycle:

Forestry Products:

- Growing, harvesting and transport of softwood in either South America or North America;
- Processing of the wood in a mill in the local country to produce wood chips (as a co-product of round wood production);
- Transport of wood chips from the mill to a local port (overseas); and
- Shipping of wood chips from the local port to the Royal Portbury Dock.

Waste Wood:

- Chipping of waste wood in the UK using a mobile electric chipper; and
- Transport of wood chips to the Royal Portbury Dock by truck.

Disposal of Waste Streams

- Transport by truck and disposal of waste streams to local landfill disposal sites (waste fly ash); and
- Transport by truck of furnace bottom ash and waste metals to local recycling facility.

3.1.2 Base Case – National Grid Electricity

The CO_2 emissions arising from the biomass base case are compared to CO_2 emissions arising as a result of supply of electricity on the UK National Grid.

Where appropriate we have adapted these emissions factors to remove distribution losses since electricity generated by the proposed Renewable Energy Plant is based on production rather than consumption, and therefore does not include distribution losses.

A range of emissions factors have been used to undertake this comparison, which are shown in Table 3.1.

Table 3.1. UK National Grid Emissions Factors

Name	Emission Factor (kg CO_2 / kWh)	Source	Basis
Grid rolling average	0.537	Defra	• UK emissions only – Excludes emissions associated within the fuel supply chain. • Includes distribution losses – Represents emissions per kW at the point of electricity consumption (i.e. end user).
	0.493	Defra *(adapted for study)*	• UK emissions only. • Excludes distribution losses – Represents emissions per kW at the point of electricity production (i.e. Power station).
Long term marginal factor	0.430	Defra	• UK emissions only – Excludes emissions associated with fuel supply chain. • Reflects avoiding the need to source the equivalent power from a combined cycle gas turbine (CCGT) power station. • Excludes distribution losses - Represents emissions per kW at the point of electricity generation (i.e. Power station).
UK Grid mix	0.570	EcoInvent	• Life cycle emissions, including pre-combustion – Includes emissions associated with fuel supply chain. • Includes distribution losses - Represents emissions per kW at the point of electricity consumption (i.e. end user).
	0.523		• Life cycle emissions. • Excludes distribution losses - Represents emissions per kW at the point of electricity production (i.e. Power station).
UK Grid mix	0.591	Based on GaBi 4	• Life cycle emissions, including pre-combustion – Includes emissions associated with fuel supply chain. • Includes distribution losses - Represents emissions per kW at the point of electricity consumption (i.e. end user).
	0.542		• Life cycle emissions. • Adapted to exclude distribution losses of 8.24% - Represents emissions per kW at the point of electricity generation (i.e. Power station).
Long term marginal factor - GaBi	0.532	Based on GaBi 4	• Life cycle emissions, including pre-combustion – Includes emissions associated with fuel supply chain. • Reflects avoiding the need to source the equivalent power from UK gas fired power stations.
	0.489		• Life cycle emissions. • Adapted for the study to exclude distribution losses of 8.24% - Represents emissions per kWh at the point of electricity generation (i.e. Power station).

Emissions associated with the fuel supply chain include:

Forestry Products

- Forestry Operations - Emissions include growing, cultivation, sawing, lifting, transport and chipping of wood. The study considers emissions associated with the generation of waste by-products (i.e. an appropriate portion of the overall emissions arising as a result of the forestry operations).
- Domestic transport – Transport (via truck) from location of forestry operations to port.
- International Transport – Transport (via Ship) from international port to UK port.

Waste Wood

- Emissions associated with the chipping of waste wood in the UK.
- Domestic transport – Transport (via truck) from location of waste wood to power station.

The boundary and processes included in the Base Case are illustrated in Figure 3.1.

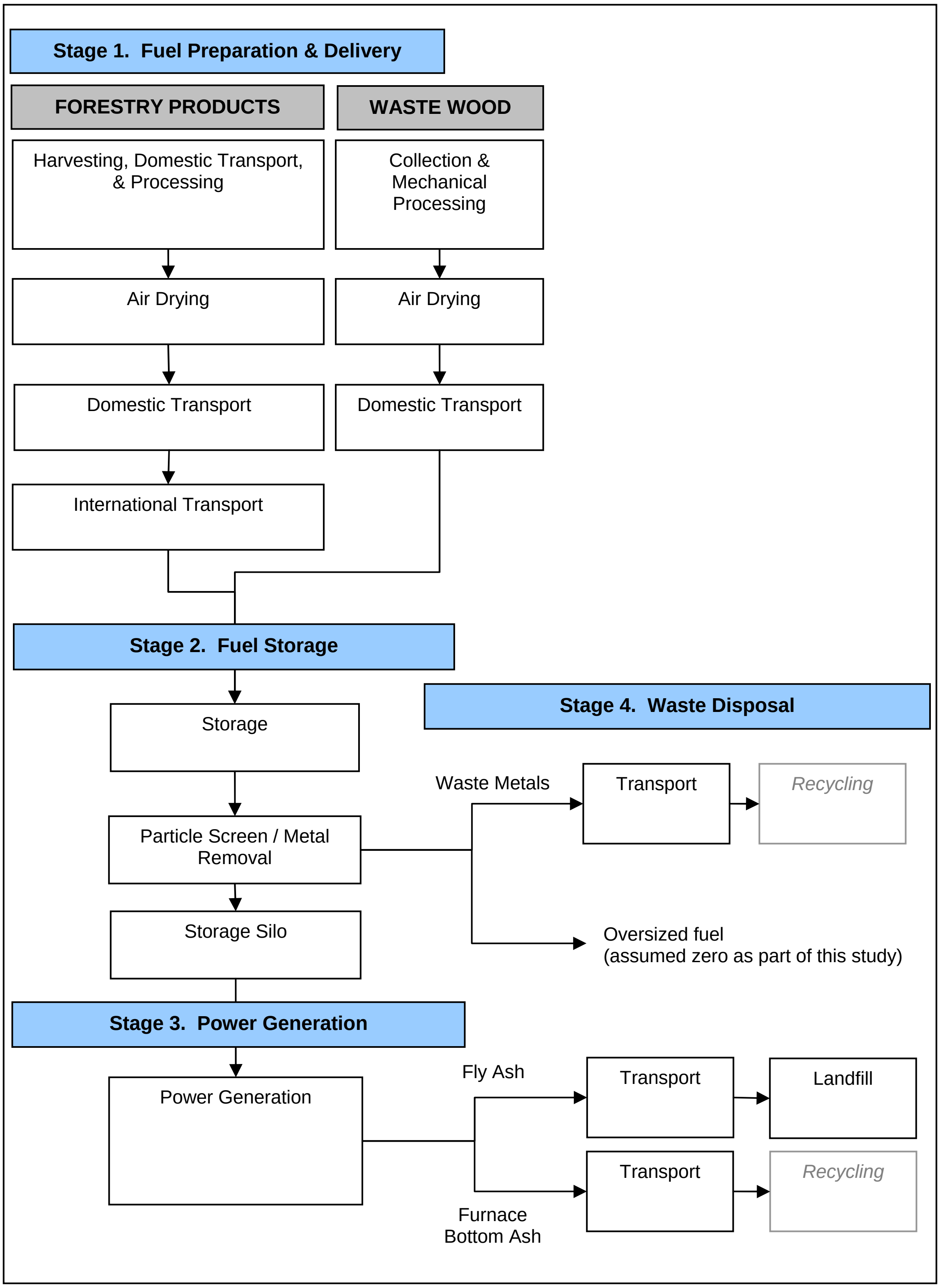


Figure 3.1 System Boundary – Base Case

3.1.3 Scenario 1: Base Case plus use of waste heat

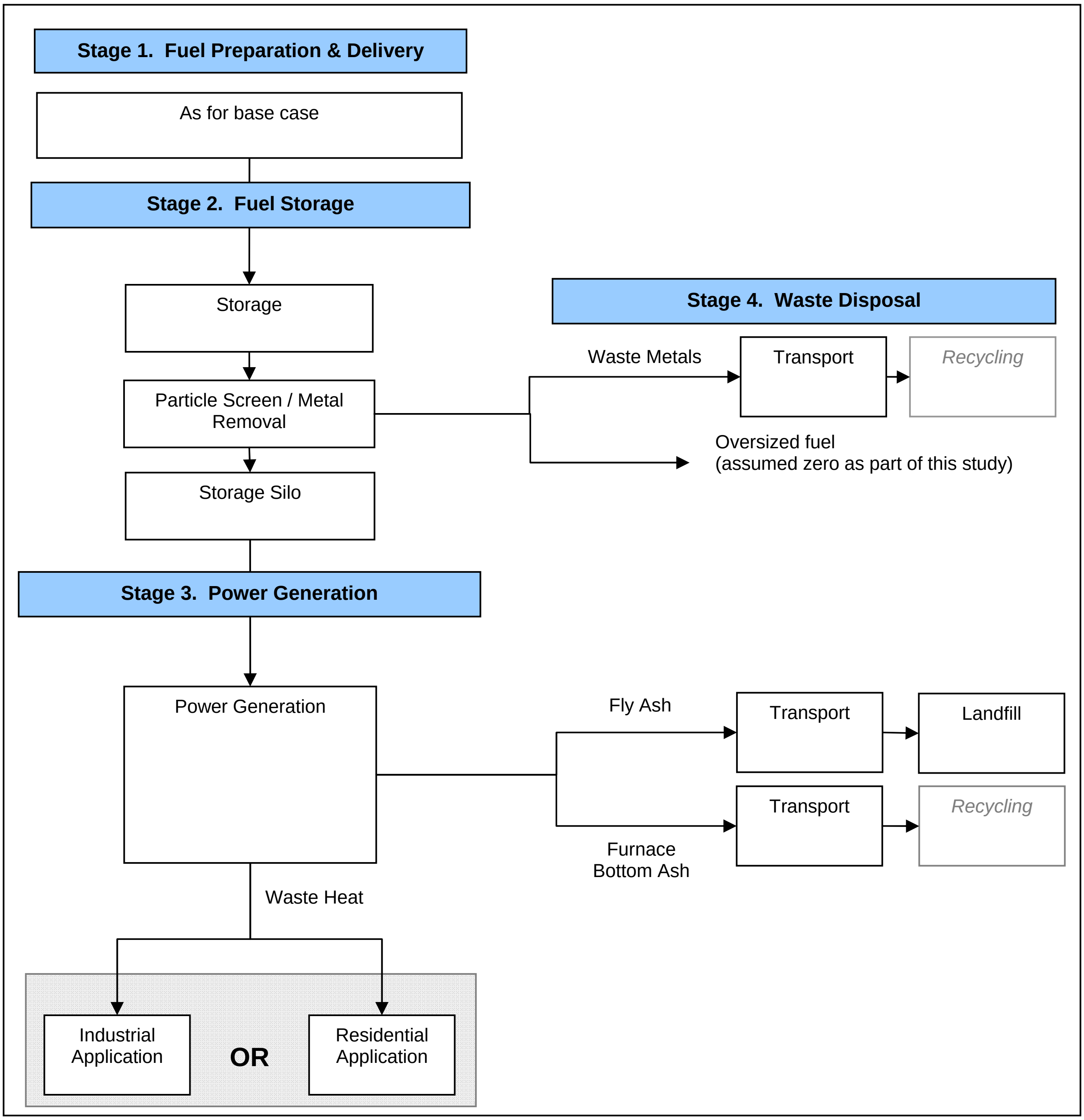
E.ON would like to understand the CO_2 emissions benefits of supplying heat as well as electricity from the operation of the proposed Renewable Energy Plant. E.ON has specified that some of the heat may be used in an industrial or residential application. This scenario still considers the operation of a 150MW plant supplied with a mix of 70% forestry products and 30% waste wood as per the base case.

Heat, which is assumed to be waste in the base case, is used in the following applications:

- Option A: 6 MW of heat demand by a local industrial operation;
- Option B: 25.7 MW of heat demand by an urban extension for 6 months of the year.

This study does not consider the potential additional CO_2 emissions associated with the supply of heat to meet this demand from the proposed Renewable Energy Plant. However, in the comparative options that consider the supply of equivalent electricity from the UK National Grid, we assume that the heat demands in Options A and B are met by combustion of natural gas. This system is represented in Figure 3.2.

Figure 3.2 System Boundary – Scenario



3.2 Data Categories

Primary data has been provided by E.ON as set out in Section 3.3. Key assumptions have also been used, which are provided in Section 3.3. Further supporting assumptions are listed in Appendix A.

In order to calculate the associated CO_2 emissions, Arup has used secondary supporting data derived from databases such as EcoInvent, GaBi 4 and the European Reference Life Cycle Database (ELCD). These provide CO_2 emission factors per unit of output, e.g. per tonne-km of truck and ship transport.

Data used in carbon footprints are based on measured, calculated or estimated figures.

Appendix B provides a data quality matrix which has been used as the basis for a data quality assessment which is provided in Appendix C.

The quality of data used in this study has been assessed as being of High/Medium quality, on the basis of the following criteria, as defined in the ISO 14040 standards:

- Accuracy / precision;
- Representativeness;
- Consistency; and
- Reproducibility.

We therefore conclude that the data used is appropriate for the project.

Data categories used in this study include:

- Energy inputs, e.g. coal, natural gas and nuclear contributing to National Grid electricity.
- Raw material inputs, e.g. wood.
- Emissions to air (CO_2 emissions only).

In undertaking this study Arup has relied on data provided by E.ON. Arup has not verified the data as part of this study.

3.3 Key Data and Assumptions

Key data used in this analysis for the base case and alternative scenarios are summarised below.

Table 3.1 Key Data

Category	Units	Source	Base Case Values	Scenario 1 Values	
				Option A – heat to residential development	Option B – heat to industrial complex
Net Electrical Output (Actual)	MW	E.ON	150		
	MWh/year	Calculated	1,182,600		
Net Electrical Output (Modelled)	MW	E.ON	165	165	165
	MWh/year	Calculated	1,300,860	1,300,860	1,300,860
Fuel Quantity into boiler	Tonnes / year	E.ON	1,200,000	1,200,000	1,200,000
Fuel Mix	Virgin wood	E.ON	70%	70%	70%
	Waste wood	E.ON	30%	30%	30%
Plant downtime	Annually	Assumed	10%	10%	10%
Heat demand	MWh/year	Calculated	0	112,566	52,560
Fuel Transport – truck load	Tonnes	E.ON	20	20	20
Waste generation – bottom ash	Tonnes / year	EON	21,600	21,600	21,600
Waste generation – fly ash	Tonnes / year	E.ON	86,400	86,400	86,400
Waste generation – waste metals	Tonnes / year	Calculated	702	702	702
Waste Transport – truck load	Tonnes	Assumed	27	27	27
Metal content – forestry products	%	E.ON	0%	0%	0%
Metal content – waste wood	%	Calculated	0.2%	0.2%	0.2%

A summary of the main assumptions are provided below. Full assumptions are provided in Appendix A.

Key Assumptions

Overarching Assumptions

The following key assumptions have held an overarching role in the development of this study:

- The anticipated generating capacity for the Renewable Energy Plant is 150MW. A margin of plus or minus 10% has been applied to this figure for modelling purposes. As a result, this carbon footprinting study considers the maximum generating capacity of 165MW (i.e. 150MW plus 10%) as the basis for all calculations and comparisons to reflect a 'worst case' scenario for CO_2 emissions arising from the biomass renewable energy plant. The comparable grid emissions have been calculated based on a 150MW output to ensure the emissions reductions achieved by the biomass renewable energy plants are not overstated.
- The calorific value and moisture content of all wood fuels is constant. This assumption has been suggested by E.ON. It is likely that the carbon footprint results would be influenced by changes in both of these values in either fuel type.
- This study has not considered the implications of potential land use changes to support forestry operations.[11]
- This study assumes that imported wood chip will be sourced from forestry that is sustainably managed.
- Within the study, in many cases it has been assumed that waste wood will be sourced within a 50 mile radius of the Renewable Energy Plant. This assumption has been suggested by E.ON. Transport related emissions make up a significant proportion of the overall carbon footprint. As a result, the detailed assumptions made in relation to wood chip fuel transport (including transport distance and load utilisation) will have a significant impact on the overall carbon footprint.

Transport

- All forestry products fuel is sourced from either North America or South America from sustainable sources. There has been no land use change associated with the provision of this fuel source.
- All waste wood fuel is sourced from within a 50 mile radius of Portbury Dock and is transported to the site by road. (E.ON)
- All UK road based fuel transport is by a lorry delivering 20 tonnes per load. (E.ON)
- All waste fly ash is sent to landfill within a 50 mile radius of the Royal Portbury Dock. (E.ON)
- Waste metals and furnace bottom ash are recycled within a 50 mile radius of the Royal Portbury Dock. The CO_2 emissions of recycling are not taken into account. (E.ON)
- All UK road based waste transport is by a lorry delivering 27 tonnes per load.

[11] Within the PAS 2050 carbon footprinting guidance, CO_2 emissions associated with direct land use change should be included where this change occurs after 1st January 1990. This CO_2 'cost' recognises the requirement to avoid destruction of natural habitat.

Process

- No oversized particles within the forestry products or waste wood fuel streams. (E.ON)
- No differences in calorific value and moisture content of forestry products and waste wood. (E.ON)
- No auxiliary boiler emissions included. (E.ON)
- No losses of wood chip in transport and storage.
- CO_2 emissions from capital equipment on site are excluded from the study.

Waste Streams

- Generation of waste ash (furnace bottom and fly ash) is assumed to be at a rate of 9% of the fuel supply (108,000 tonnes/year base case). Of this 9%, 30% (21,600 tonnes/year base case) is furnace bottom ash and 70% (86,400 tonnes/year base case) is fly ash. Furnace bottom ash will be recycled and fly ash will be landfilled. (E.ON)
- Generation of waste metals is assumed to be at a rate of 0.2% of waste wood (702 tonnes/year base case) This figure is calculated based on an estimation that one truck of metal is removed every two weeks (assuming 27 tonne payload).
- Oversized fuel has not been considered within the waste calculations as there is currently no working assumption for the potential quantity generated.

3.4 Scenario 1: Base Case with Heat Use

The following assumptions apply to Scenario 1:

- CO_2 emissions from infrastructure and pumping requirements to transport heat to user are excluded from the study.
- Where natural gas is supplying heat (instead of the waste heat from the biomass renewable energy plant) calculations are based on the UK natural gas mix.
- The combustion of natural gas is based on lower heat value.

4 Results of the Carbon Dioxide Assessment

The following section presents the findings of the carbon footprinting study.

4.1 Base Case

Absolute Emissions

The base case considered the CO_2 emissions arising from the generation of electricity from a 150MWe Renewable Energy Plant based in the Royal Portbury Dock estate using 70% forestry products (overseas source) and 30% waste wood (UK source). This power generation process gives rise to CO_2 emissions through the processing and transport of the wood fuel (both forestry product and waste wood) and the disposal of waste by-products (ash and waste metals).

Table 4.1 shows a breakdown of the CO_2 emissions associated with each of the process stages within the fuel supply chain and waste disposal processes. These results are represented graphically in Figures 4.1 and 4.2 below.

Table 4.1 Carbon Dioxide Emissions by Activity (tonnes CO_2/year)

Process Stage		**South American Biomass[1]**		**North American Biomass[2]**	
		tCO_2/ year	**$kgCO_2$/ t fuel**	**tCO_2/ year**	**$kgCO_2$/ t fuel**
Forestry Products	**Processing** (Country of origin)	2,791	3.3	2,791	3.3
	Transport (Country of origin)	17,353	20.7	15,866	18.9
	International transport (Country of origin to UK)	17,674	21.0	9,038	10.8
Waste wood	**Processing** (UK)	4,818	13.4	4,818	13.4
	Transport (Within UK to Biomass Plant)	3,392	9.4	3,392	9.4
Waste Management	**Transport**	1176	1.0	1176	1.0
	Disposal	1037	0.9	1037	0.9
TOTAL		**48,240**	**69.6**	**38,116**	**57.6**
	($kgCO_2$/kWh)	**0.037**		**0.029**	

1: 70% woodchip from South America, 30% UK sourced waste wood

2: 70% woodchip from North America, 30% UK sourced waste wood

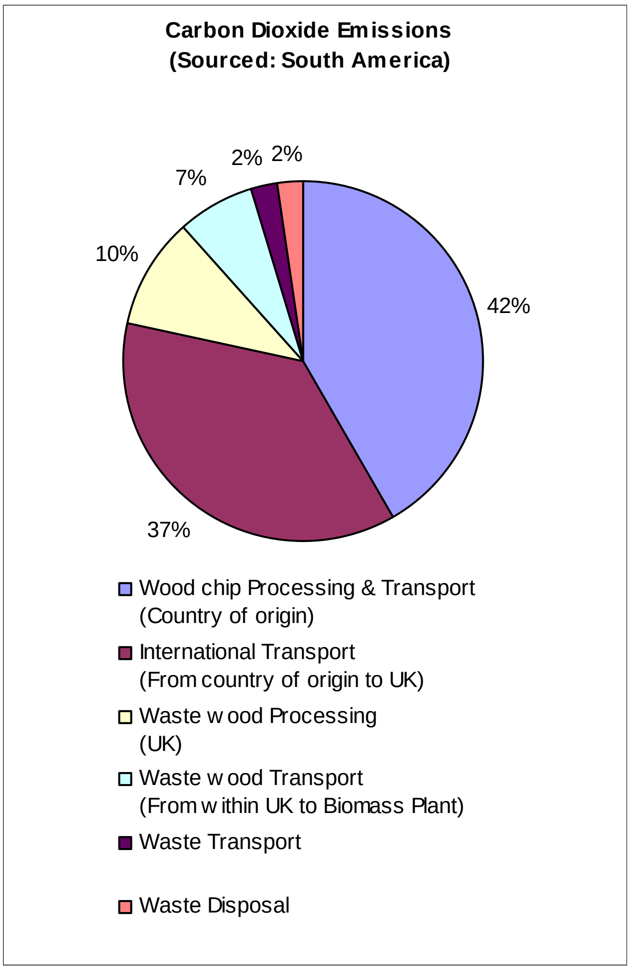


Figure 4.1 Carbon Dioxide Emissions by Activity South American biomass source.

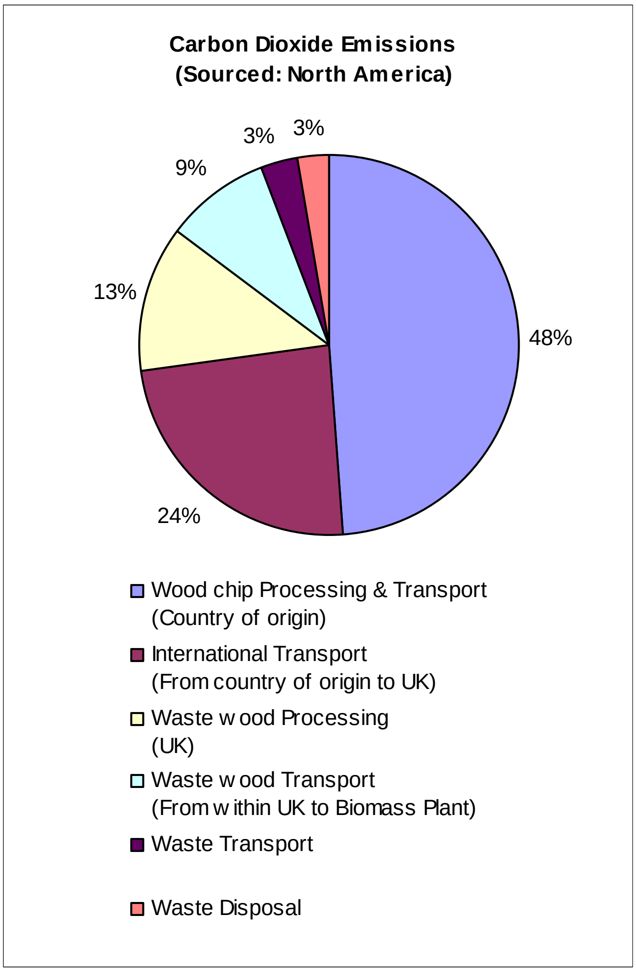


Figure 4.2 Carbon Dioxide Emissions by Activity North American biomass source.

The results demonstrate that the most CO_2 intensive processes within the elements of the life cycle we have assessed accompanies the transport of wood fuel; both overseas and in the UK.

The two sourcing options have considered the use of wood fuel from example locations in either North or South America. Within these options, the most significant source of emissions is the local processing and transport of wood cuttings and trimmings. This figure accounts for 42% (South America) and 48% (North America) of the overall life cycle emissions. This is followed by the international transport of the wood fuel from its source country to Portbury Dock which accounts for 37% (South America) and 24% (North America) of overall emissions.

The combined total fuel transport related emissions are summarised below.

Extract from Table 4.1		**South American Biomass**	**North American Biomass**
		tCO_2/ year (% of total emissions)	**tCO_2/ year (% of total emissions)**
Forestry Products	**Transport** (Country of origin)	17,353 (36%)	15,866 (42%)
	International transport (Country of origin to UK)	17,674 (37%)	9,038 (24%)
Waste wood	**Transport** (UK to Biomass Plant)	3,392 (7%)	3,392 (9%)
Total	**Fuel Transport Emissions**	38,419 (80%)	28,296 (74%)

Clearly, with over 70% of the overall emissions arising from transport of fuel in both options, the carbon footprint of the proposed Portbury Dock Renewable Energy Plant is heavily dependent on the management of the transport process. Issues that may affect the CO_2 emissions arising from this include:

- Local transport distance – Distance from source of fuel to processing sites and distance from forestry operations to local port facilities. In practice, this may represent significant distances and require long road haulage journeys.
- Local transport method – The vehicle type and haulage characteristics (e.g. % load capacity).
- Shipping distances – Distance from overseas port to the Royal Portbury Dock estate and the nature of vessel used.

Waste wood processing in the UK is also a carbon intensive process within the lifecycle (13.4kgCO_2/t fuel). However, due to the smaller fuel volumes of waste wood it represents a smaller portion of the overall carbon footprint.

Figure 4.3 displays the areas of the supply chain where the emissions vary between the two sourcing options; primarily within the area of international shipping.

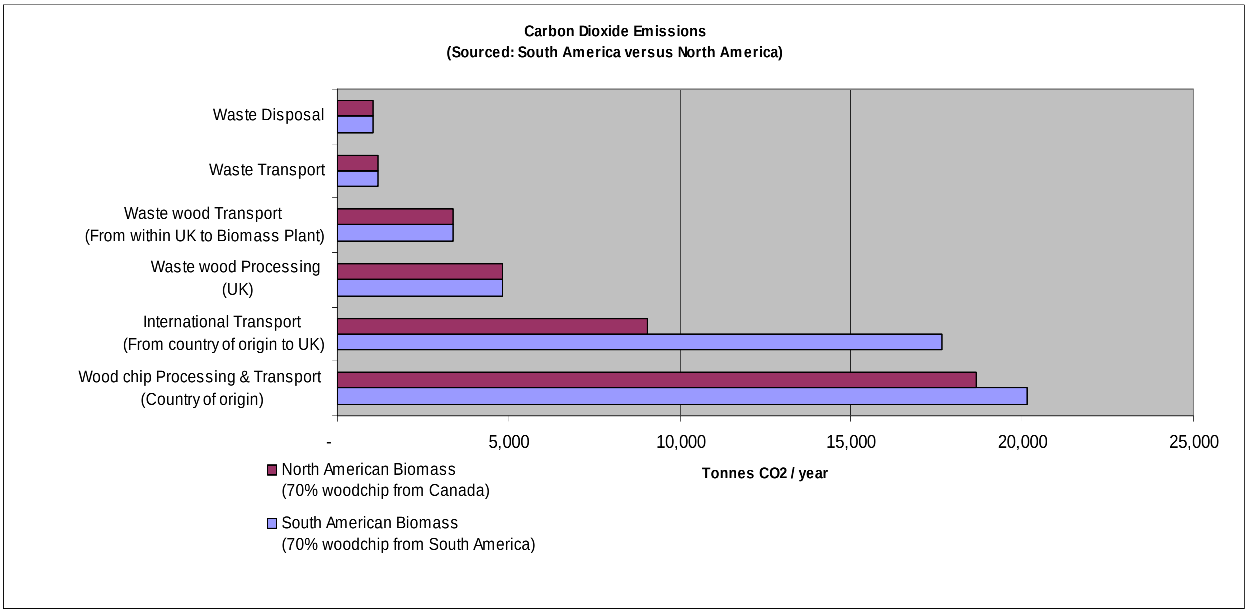


Figure 4.3. Overall Carbon Dioxide Emissions by Activity

Comparison with UK Grid Mix

The study has considered the comparison of the life cycle emissions arising from the proposed biomass Renewable Energy Plant against the emissions arising from the generation of electricity from the UK national grid.

Table 4.2 displays the overall emissions arising from the proposed biomass Renewable Energy Plant and the relative carbon intensity (tonnes CO_2/ MWh) of the plant operation relative to a range of measures of the UK National Grid. This is also displayed graphically in Figure 4.4.

Table 4.2. Overall Emissions in comparison with UK National Grid – Base Case

Carbon Dioxide Emissions		**Biomass**		**UK National Grid**				
				Defra		**Ecoinvent**	**GaBi**	
		South American biomass[1]	*North American biomass[2]*	*Grid Rolling Average*	*Long Term Marginal Factor*	*UK Grid Mix*	*Current UK Grid mix*	*Grid Mix (long term marginal)*
Emissions at point of consumption (including distribution losses)	tonnes CO_2/year	-	-	635,080	-	673,514	698,917	629,143
	tonnes CO_2/MWh	-	-	0.537	-	0.570	0.591	0.532
Emissions at point of production (excluding distribution losses)	tonnes CO/year	48,240	38,116	583,022	508,518	618,017	641,371	577,830
	tonnes CO_2/MWh	0.037	0.029	0.493	0.430	0.523	0.542	0.489

1 - 70% forestry products from South America, 30% UK sourced waste wood

2 - 70% forestry products from North America, 30% UK sourced waste wood

GaBi and EcoInvent emissions factors include distribution losses since they represent emissions as a result of point of consumption rather than point of production of electricity. Arup has calculated the GaBi emissions factors without distribution losses as the data are disaggregated such that they represent emissions at the point of production. These are reflected in blue in the above table. We have also applied the distribution loss figure in GaBi (approximately 8%) and adjusted other emissions factors from Defra and EcoInvent downwards (except the Defra long term marginal factor which is already based on electricity produced rather than consumed). These adjusted figures are provided in red in the above table.

Table 4.2 displays the calculated CO_2 emissions compared to a range of emissions factors. It is considered most appropriate to directly compare the emissions from the base case with those arising from the Defra Long Term Marginal factor and the GaBi current UK grid mix as summarised below.

Extract from Table 4.2	**Base Case**		**UK National Grid**	
	South American biomass[1]	*North American biomass*[2]	*Defra long term marginal factor*	*GaBi Grid Mix*
Tonnes CO2/year *(Emissions at point of production, excluding distribution losses)*	48,240	38,116	508,518	641,371
Saving over calculated UK grid mix (GaBi)	593,131 (92%)	603,255 (93%)		
Savings over defra long term marginal factor	460,278 (91%)	470,402 (93%)		

1 - 70% forestry products from South America, 30% UK sourced waste wood

2 - 70% forestry products from North America, 30% UK sourced waste wood

The base case and the GaBi figures reflect emissions arising from the whole life cycle, including the fuel supply chain. The proposed Renewable Energy Plant represents savings of around 600,000 tonnes per year for biomass sourced from either North America or South America.

The Defra Long Term Marginal figure considers emissions arising from activities in the UK and excludes emissions associated with fuel supply chain. The proposed Renewable Energy Plant represents savings of over 450,000 tonnes per year for biomass sourced from either North America or South America.

Figure 4.4 below shows the results with and without the adjustment for distribution losses.

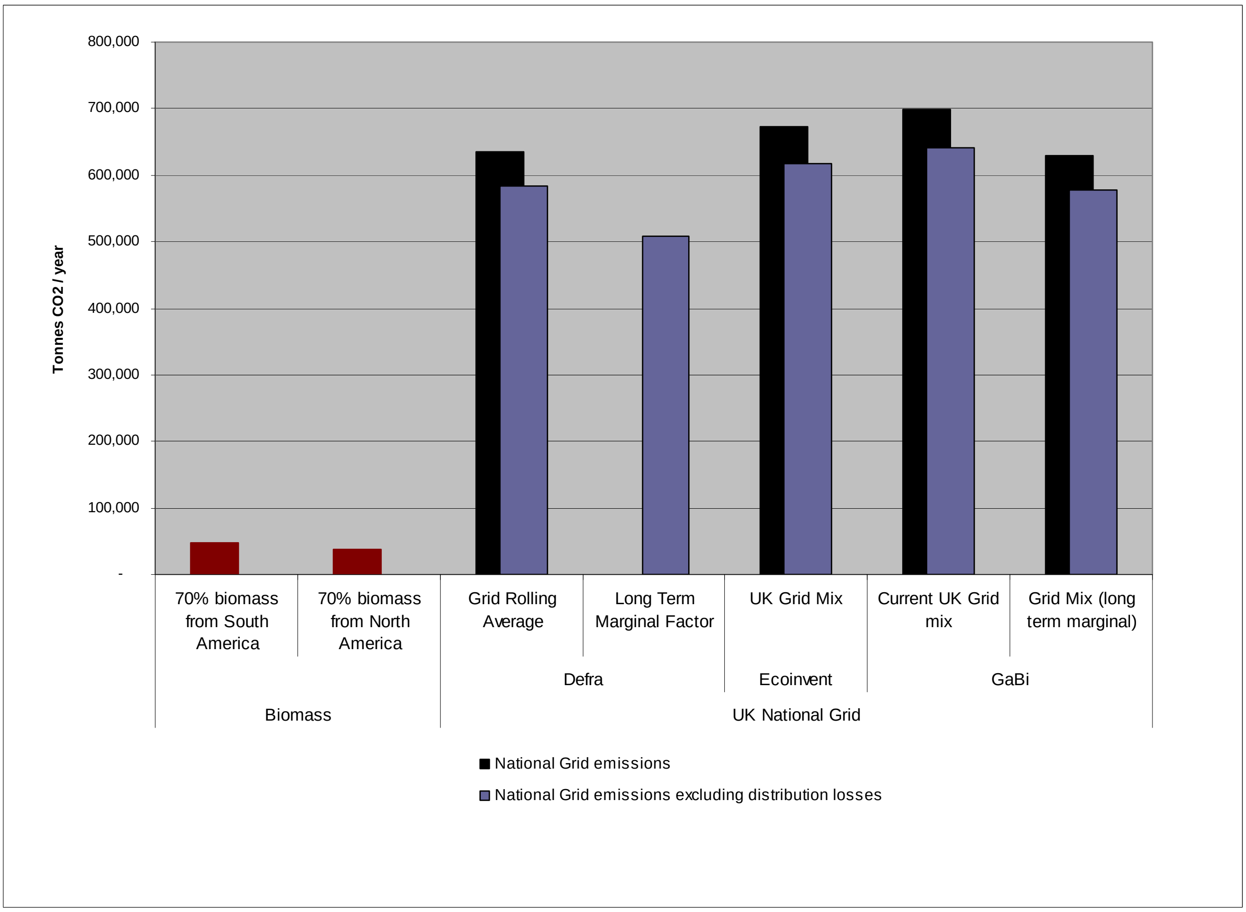


Figure 4.4. Overall Emissions in comparison with UK National Grid – Base Case

The biomass base case compares favourably when compared to all measures of the National Grid mix.

The Defra long term marginal factor and GaBi Grid Mix factor are the most appropriate comparators for this study. The Defra long term marginal factor represents emissions from a combined cycle gas turbine (CCGT) which would potentially need to be constructed to meet demand otherwise being met by the proposed Renewable Energy Plant. However, the Defra figure does not include pre-combustion emissions associated with extraction and transport of natural gas outside the UK and is therefore not equivalent to the boundaries of this study. We have therefore used the GaBi Grid Mix figure as a basis for taking into account combustion related emissions from power stations supplying the UK National Grid, and the pre-combustion emissions that are required to get fuels to these power stations.

4.2 Scenario 1: Base Case with Heat Use

The operation of the proposed biomass Renewable Energy Plant will result in the generation of waste heat. This study has considered the CO_2 emissions benefits associated with the utilisation of that waste heat in two discrete applications as specified by E.ON.

Table 4.3. Overall Emissions in comparison with national grid – Scenario 1 (Waste Heat)

Scenario	Biomass		UK National Grid				
			Defra		EcoInvent	GaBi	
	South America[1]	*North America*[2]	*Grid Rolling Average*	*Long Term Marginal Factor*	*UK Grid Mix*	*Current UK Grid mix*	*Grid Mix (long term marginal)*
Base Case *(tonnes CO_2 / yr)* *(Extract from Table 4.2)*	48,240	38,116	583,022	508,518	618,017	641,371	577,830
Industrial Heat Use *(tonnes CO_2 / yr)*	-	-	11,224	11,224	11,224	11,224	11,224
Residential Heat Use *(tonnes CO_2 / yr)*	-	-	24,039	24,039	24,039	24,039	24,039

1 - 70% woodchip from South America, 30% UK sourced waste wood

2 - 70% woodchip from North America, 30% UK sourced waste wood

E.ON has identified the potential opportunity to use 6MW of heat with an industrial application within the Royal Portbury Dock estate. If the 6MW demand was met by the waste heat, it would avoid the use of natural gas to provide the same heat. This would result in a CO_2 emissions saving of 11,224 tonnes per year. The overall impact of these avoided emissions on the performance of the base case is displayed in Figure 4.5.

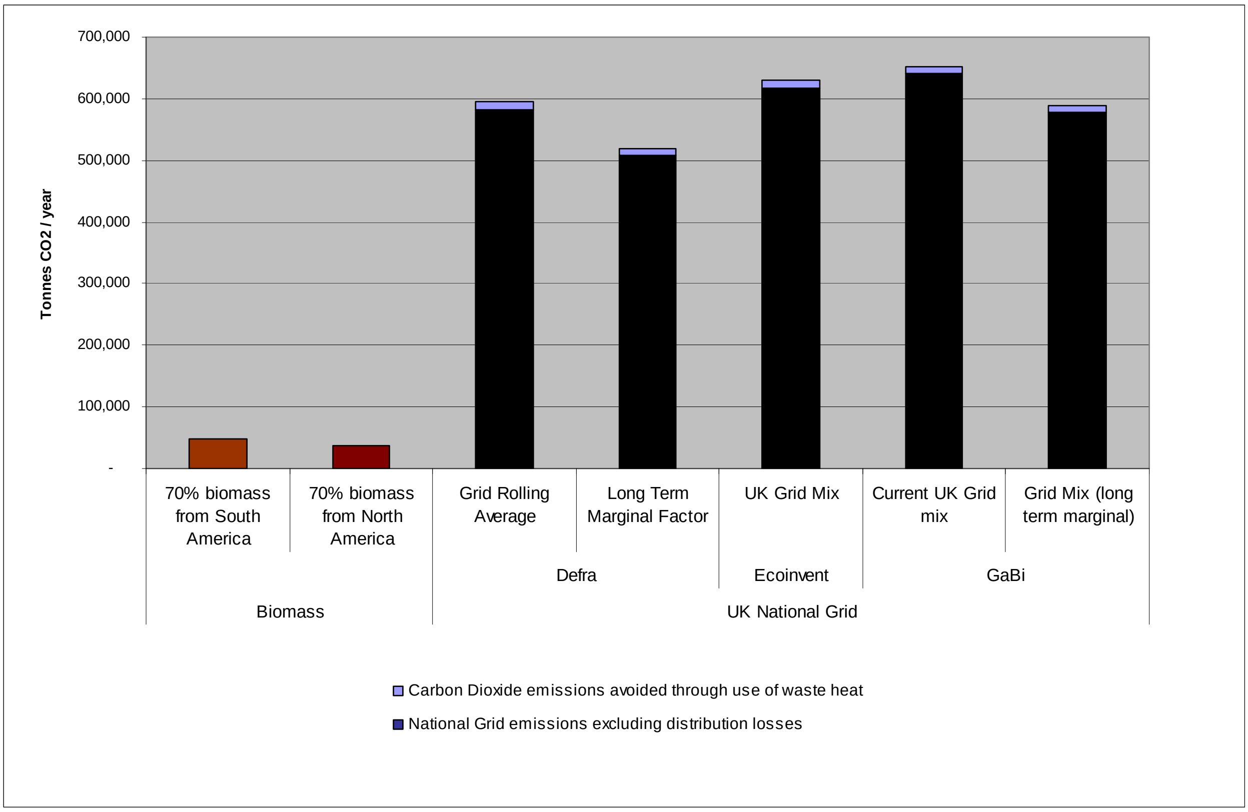


Figure 4.5. Overall Emissions – Scenario 1 (Industrial application of waste heat)

E.ON has also specified a potential residential application for the waste heat. In this option, the heat demand of a nearby urban extension is likely to be in the order of 25.7MW for six months of the year. Using waste heat in this application would avoid 24,039 tonnes CO_2 per year. The overall impact of these avoided emissions on the performance of the base case is displayed in Figure 4.6.

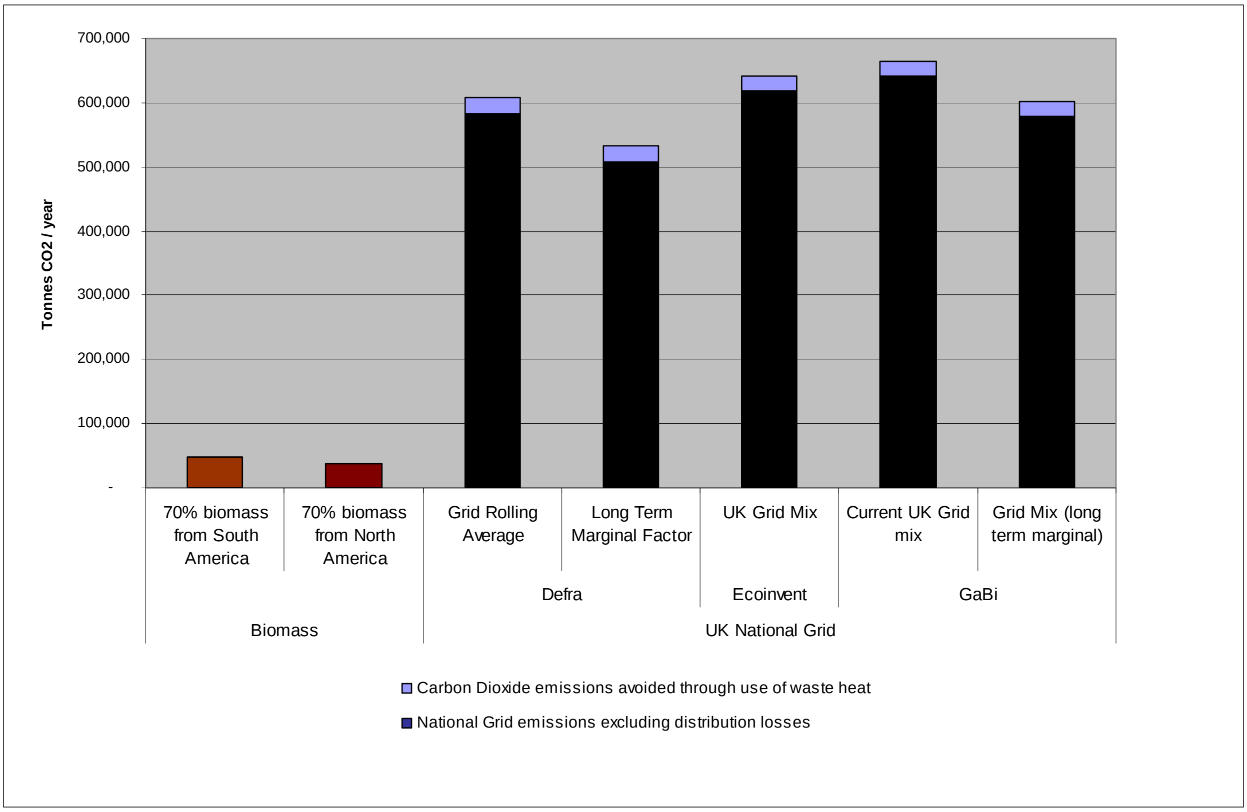


Figure 4.6. Overall Emissions – Scenario 1 (Residential application of waste heat)

The above scenario does not take into account any CO_2 emissions that may be associated with the distribution of the heat to the end user. Equally, the scenario assumes that the specified waste heat demands could be met by the proposed Renewable Energy Plant.

5 Conclusions and Recommendations

Base Case

The proposed Portbury Dock Renewable Energy Plant compares favourably from a CO_2 emission perspective when compared to emissions arising from the same generation capacity of the National Grid. The emissions arising from the Renewable Energy Plant have been assessed relative to a range of grid emissions factors. Of most relevance are the Defra long term marginal factor and the GaBi emissions factor for the UK national grid. The Renewable Energy Plant presents savings of 450,000 tonnes per year and around 600,000 tonnes per year respectively when compared with these two figures.

The scenario where the 70% forestry products fuel stream is sourced from North America results in over 20% less CO_2 emissions then when biomass is sourced from South America. The variance arises primarily from the relative differences in transport distances. A significant portion (greater than 70%) of both carbon footprints arises from transport emissions and the results are strongly influenced by the assumptions made in relation to transport in both the UK and overseas. As a result, there will be particular sensitivity in the results in relation to:

- Approach to transport management in the UK and overseas;
- Transport distances;
- Assumed lorry utilisation rates; and
- Shipping distances.

E.ON should investigate opportunities to maximise the proportion of locally sourced biomass fuels where possible and minimise fuel transport distances.

This study has not considered the implications of potential land use changes to support forestry operations within this study. Within the PAS 2050 carbon footprinting guidance, CO_2 emissions are apportioned to land use changes to support forestry operations where the change has occurred since 1990. This CO_2 'cost' recognises the requirement to avoid destruction of natural habitat in order to facilitate forestry operations. Arup recommends that further work is undertaken to ensure that E.ON's fuel sourcing policies and procedures ensure that the procurement of biomass fuel does not take place from sources where there is the potential for land use change to have occurred. The ongoing sustainable management of the fuel sources is equally important. In addition to the CO_2 implications of this issue, there exists a strong reputational risk to E.ON in this area of fuel sourcing.

As a result, it is important to note that woodchip should be sourced from long-established forestry operations to realise calculated carbon savings presented in this report.

Scenario 1: Use of waste heat

The use of waste heat for the specified industrial and residential applications has been modelled. There is some benefit to the relative position of the proposed Renewable Energy Plant when compared to the national grid.

Arup recommends that E.ON investigates further opportunities to use waste heat within the biomass site to pre-dry the woodchips on site with the potential benefit of increasing calorific value of fuel into the boiler.

Throughout this study, it has been assumed that the calorific value and moisture content of all wood fuels is constant. This assumption has been suggested by E.ON. It is likely that the carbon footprint results would be influenced by changes in both of these values.

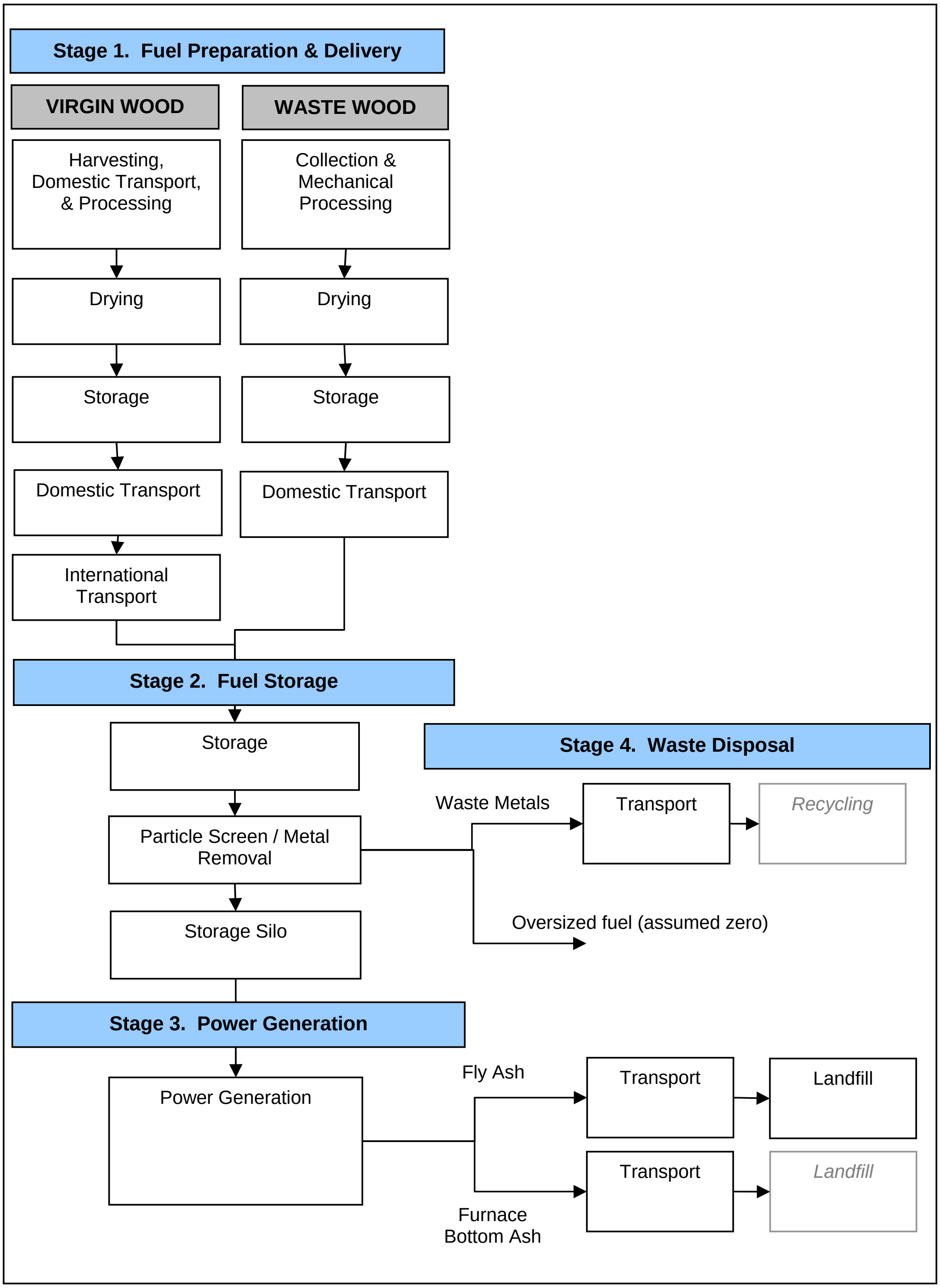
Arup recommends that further studies are undertaken to assess the availability for biomass fuel stocks within the UK with a view to, over the long term, maximising local procurement.

Appendix A

Assumptions used in the Study

A1 Assumptions

A1.1 Base Case



Stage 1 – Fuel Preparation & Delivery

Forestry Products Fuel

Harvesting, domestic transport from forest to mill, mechanical processing

- Emissions include growing, cultivation, sawing, lifting, transport, chipping of wood.
- Density of woodchip is 545kg/m (calculated average).

Drying

- No GHG emissions occur during drying - natural drying

Storage

- No GHG emissions occur during storage

Domestic Transport – Wood processing plant to dock

- The distance from mill to the port in both North America and South America is 250km. This is the equivalent of Pinheiros (North Espirito Santo, Atlanta Forest) to Vitoria (Brazil).
- The South American truck is based on: Average 40t truck in Brazil (with average load, including running empty). Emissions factor = 0.875 kgCO_2/km, Fuel consumption = 0.35 litres/km
- The North American truck is based on: Average 40t truck in Canada (with average load, including running empty). Emissions factor = 0.8 kgCO_2/km. Fuel consumption = 0.32 litres/km
- Supply of diesel for the trucks is from a North American refinery.

International Transport

South America

- Assumed wood from South America is originating in Brazil.
- Distance from Brazil to Bristol is the equivalent of Vitoria, Brazil to Bristol Port, UK.
- Ship used is: Bulk carrier ocean 100,000-200,000 dead weight tons (dwt) pay load capacity.
- Ship emits 0.002391 kgCO_2 / t.km and uses heavy fuel oil obtained from a US refinery

North America

- Assumed wood from North America is originating in Canada.
- Distance from Canada to Bristol is equivalent of Halifax, Canada to Bristol Port, UK.
- Ship used is: Bulk carrier ocean 100,000-200,000 dead weight tons (dwt) pay load capacity.
- Ship emits 0.002391 kgCO_2 / t.km and uses heavy fuel oil obtained from a US refinery

Waste wood (UK)

Mechanical Processing

- Mobile chipper used to chip waste wood
- All waste wood chipped includes metal waste

Drying

- No CO_2 emissions occur during drying – natural drying

Storage

- No CO_2 emissions occur during storage

Transport to Biomass Plant - UK

- Wood chippings are transported by an articulated lorry with 40t total weight according to EURO 3 emission limit. Maximum payload of lorry is 27t but it is assumed to carry 20 tonnes (based on 60 deliveries per day, 6 days a week, to carry 360,000 tonnes).
- All waste wood transported from within 80km radius with a return empty journey.

Stage 2 – Fuel Storage

Storage (Receiving Hopper)

- No CO_2 emissions occur during storage

Particle Screen / Metal Removal

- Included in overall Renewable Energy Plant figure as assumed minimal

Stage 3 – Power Generation

Renewable Energy Plant

- The anticipated generating capacity for the proposed Renewable Energy Plant is 150MW. A margin of plus or minus 10% has been applied to this figure for modelling purposes. As a result, this carbon footprinting study considers the maximum generating capacity of 165MW (i.e. 150MW plus 10%) as the basis for all calculations and comparisons to reflect a ‘worst case’ scenario for CO_2 emissions arising from the biomass renewable energy plant. The comparable grid emissions have been calculated based on a 150MW output to ensure the emissions reductions achieved by the proposed biomass renewable energy plant are not overstated.
- Comparisons between the Renewable Energy Plant and the national grid are based on the generation of 150MW (by the grid). This is to ensure that the potential CO_2 savings arising from the renewable energy plant when compared with equivalent national grid emissions are not overstated.
- Efficiency of the Biomass Plant is 31%

On-site vehicles

- Negligible

Auxillary Boiler

- No Auxillary Boiler

Stage 4 – Waste Disposal

Transport (Bottom Ash)

- Waste is transported by an articulated lorry with 40t total weight according to EURO 3 emission limit. Payload of lorry is 27t with a return empty journey.

Transport (Fly Ash)

- Waste is transported by an articulated lorry with 40t total weight according to EURO 3 emission limit. Payload of lorry is 27t with a return empty journey.

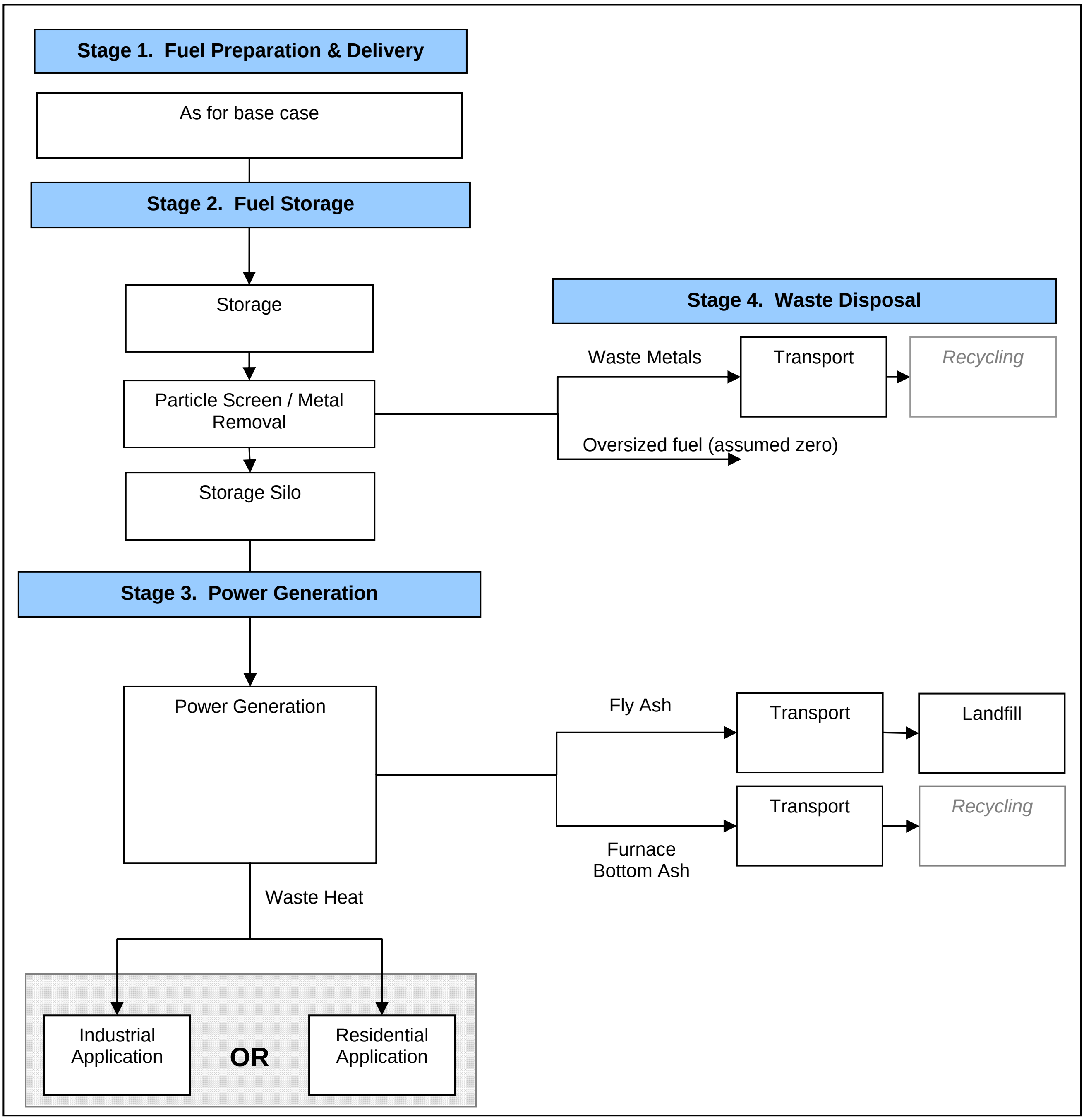
Transport (Waste Metals)

- Metal waste quantities based on 0.2% of waste wood.
- Waste is transported by an articulated lorry with 40t total weight according to EURO 3 emission limit. Payload of lorry is 27t with a return empty journey.
- Recycling of waste metals has not been included within this study.

Transport (Rejected wood)

- Oversized particles are negligible

A1.2 Scenario 1 – Base Case with waste heat re-use



Appendix B

Data Quality Matrix

B1 Data Quality Matrix

The following matrix has been used as the basis for the qualitative data quality assessment:

	High (H)	**Medium (M)**	**Low (L)**
Accuracy / Precision *(Acc)*	Data collected for specific process/supply chain from industry and compiled by LCA practitioners / process experts	Data from publicly available database or database for which a user licence is required	Data from bibliographic references, for which boundaries and assumptions not clear
Representativeness *(Repres)*	Recent (< 5 years) with appropriate geographical/technological scope	Data of intermediate age (5-10 years) based on an alternative geographical area/technology, but which are applicable to the study	Old data (>10 years) or representing a geographical/technological scope that is not directly applicable to the study
Consistency *(Con)*	Study methodology consistently applied for all processes	Study methodology applied consistently to key processes such that variation in methodology unlikely to be material	Study methodology not applied consistently
Reproducibility *(Reprod)*	Data from a publicly available database e.g. European life cycle database (ELCD)	Data from a database / produced by a database company, for which a licence is required to access data	Data relating to significant parts are confidential

Appendix C

Data Quality Assessment

C1 Data Quality Assessment

This study concentrates on the secondary (supporting) data.

C1.1 Secondary Data

GaBi 4[12] has been used as a source of secondary data. The software contains life cycle based emissions factors for processes including those being developed for the emerging European Life Cycle Database (ELCD). Additionally sources of data have been websites, the International Road Transport Union and the Carbon Trust:

- Wood chip production;
- Waste disposal;
- Transport (truck and ship);
- Fuel (diesel);
- Wood density.

C1.2 Method for Data Quality Assessment

All data used are listed in the accompanying tables. Where possible, information about the source of data, age and geographical coverage, is provided. The data have been assessed using the Data Quality Matrix in Appendix B under the following categories:

- Accuracy / precision (Acc);
- Representativeness (Repres);
- Consistency (Con);
- Reproducibility (Reprod).

Based on the results of the assessment under these criteria, an overall assessment has been provided based on the following matrix:

Results of Individual DQA's	Overall DQA
3 - 4 H's	H
3 – 4 M's	M
3 – 4 L's	L
2 H's, 2 M's or 2H's, M & L	H/M
2 H's, 2 L's	M
2 M's, 2 L's	M/L
2 M's, H & L	M
2 L's, H & M	M/L

These criteria are as set out in the ISO 14040 Life Cycle Assessment standards, part of the ISO 14000 Environmental Management standards.

[12] GaBi 4 is the proprietary life cycle assessment (LCA) software tool of PE International GmBH.

C2 Secondary Data

Process/Product	Source	Geographic Coverage	Year	Acc	Repres	Con	Reprod	Total
Woodchip production from Cradle to Gate (inc. chipping)								
Bark chips, softwood, u=140%, at forest road	Ecoinvent	Europe	2001	M	M	M	M	M
Mechanical Processing								
Wood chopping mobile chopper in forest	Ecoinvent	Europe	2002	M	M	H	M	M
Plant Wastes								
Landfill for Fly Ash and Bottom Ash (Inert waste in a landfill with surface and base sealing, using materials such as clay, mineral coating and PE film)	PE International	Germany	2005	M	H	H	M	H/M
Transport								
Articulated Lorry (40t) inc. fuel	ELCD	Europe	2005	H	H	H	H	H
Articulated Lorry (40t)	International Road Transport Union	South America	2008	L	H	M	L	M/L
Articulated Lorry (40t)	International Road Transport Union	North America	2008	L	H	M	L	M/L
Container ship ocean incl fuel	ELCD	Europe	2005	H	H	H	H	H
Port Distances	Maritimechain.com	Worldwide	2008	M	H	H	H	H
Diesel at Refinery (US)	PE International	US	2003	M	M	H	M	M
Diesel at Refinery (UK)	PE International	Europe	2003	M	M	H	M	M
Density of diesel	Carbon Trust: Energy and carbon conversions	Global	2006	H	H	H	H	H
Density of wood	valuecreatedreview.com/softwood.htm	Canada	-	L	H	H	L	M

C3 Summary of Data Quality Assessment

A summary of data quality statistics, based on the overall assessment made in the "Total" column in Section C2 above, are provided below for secondary data.

Data Quality Assessment Category	% of Total Assessment (Secondary Data)
High	33
High/Medium	8
Medium	42
Medium/Low	17

Based on this analysis, 41% or above of secondary data used have been assessed as being of either high or high/medium quality. Overall data quality falls into the High/Medium range. Therefore we conclude that data quality of secondary data used is of acceptable quality for the project and its aims.