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Shoalhaven Starches

Report for Ethanol Plant Upgrade

Greenhouse Gas Assessment

August 2008

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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1. Summary

1.1 Methodology

A greenhouse gas assessment of the proposed ethanol plant upgrade was conducted in accordance with:

» The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard developed by the World Business Council for Sustainable Development;

» Life Cycle Assessment principles (ISO 14040 series); and

» The Commonwealth Department of Climate Change (DCC) National Greenhouse Accounts (NGA) Factors, 2008).

The assessment included Scope 1, 2 and 3 emissions from all stages of production, including:

» The preparation and acquisition of raw materials;

» Transfer of major raw materials (including grains and sugar) to Bomaderry by truck;

» Energy and fuel used on site for the production of ethanol and any other co-products and by-products, including grid electricity, natural gas, petroleum, diesel, etc;

» Storage of products on site;

» Waste disposal and wastewater treatment;

» Transport of products from site to depots and distributors; and

» Usage of ethanol products.

1.2 Results

The proposed upgrade to the ethanol plant is estimated to produce net greenhouse gas emissions of 230,016 t CO2-e/a. The predicted greenhouse intensity is 0.96 t CO2-e/ kL ethanol, which is lower than the industry average of 1.3 t CO2-e/ kL ethanol (based on National Greenhouse Accounts data).

The three highest net emission sources are natural gas, flour production and wheat production, which account for more than 95% of total positive emissions.

1.3 Energy Efficiency

A number of energy and greenhouse efficient measures will be incorporated into the design of the ethanol plant including:

» The proposed plant will mainly use natural gas as the primary fuel source, which has lower greenhouse emissions than other fuels;

» Use of a natural gas fired cogeneration plant;

» Biogas recovery from the wastewater treatment plant; and

» Use of energy efficient equipment.

1.4 Disclaimer

This report has been prepared at the request of Shoalhaven Starches Pty Ltd and is for the sole purpose of evaluating the greenhouse gas emissions associated with the proposed ethanol upgrade at Shoalhaven Starches Bomaderry plant.

This report is not for use by any related or third party or for any other project. The information and recommendations are to be read and considered as a whole and the content is not to be used selectively as this may misrepresent the content of the report and provide erroneous project or decision outcomes.

The recommendation, opinions, assessments, analyses and summaries presented in this report are based on information, data, assumptions and advice provided and verified by Shoalhaven Starches Pty Ltd. This information has not been independently verified by GHD Pty Ltd and where assumptions are identified and recommendations made these need to be verified and tested.

As GHD has been unable to independently verify the input information, data, assumptions and advice provided by Shoalhaven Starches Pty Ltd, GHD does not represent, warrant or guarantee the assessment provided in this report.

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2. Introduction

2.1 Background

Shoalhaven Starches propose to increase ethanol production at the Bomaderry Plant from the current approved 126 million litres per year to 300 million litres per year.

The proposal would involve the installation of a range of additional plant within the existing Shoalhaven Starches factory site; alterations to the existing and approved wet weather storage ponds on the company's environmental farm to accommodate components of a new wastewater treatment system; as well as the provision of a new gas pipeline extending from the Eastern Gas Pipeline to the west of the Princes Highway to the site.

The project components include:

» A gas fired cogeneration plant;

» A wastewater treatment plant to treat condensate, wash-down water and wastewater, including biogas capture and combustion;

» Additional fermentation tanks and associated cooling towers;

» Additional dryers;

» Additional evaporators; and

» Related infrastructure.

2.2 Greenhouse Gas Assessment Scope

The scope of this assessment has been based on the Director-General's requirements for the environmental assessment of the Proposed Ethanol Expansion Project:

» A full greenhouse gas assessment, including a quantitative analysis of the scope 1, 2 and 3 emissions of the project, and a qualitative analysis of the impacts of these emissions, in accordance with the requirements of the Australian Greenhouse Office's Factors and Methods Workbook 2006;

» Evaluate the feasibility of measures to reduce and/or offset emissions, including an analysis of energy use.

The Director-General's requirements and the specific requirements of NSW Department of Environment and Climate Change are given in Appendix A.

The methodology for conducting the assessment has been based on the Department of Planning's *Guidelines Energy and Greenhouse in EIA,* August 2002 (the 'Guidelines'). The Guidelines set out a systematic approach to the assessment of the energy and greenhouse impacts associated with a proposal.

The purpose of the greenhouse assessment is to calculate the emissions of greenhouse gases associated with the proposed development, and to compare these to the baseline scenario. In order to obtain a comprehensive estimate, emission sources were considered (both direct and indirect), associated with:

» The construction of the new plant;

- The preparation and acquisition of raw materials;
- Transfer of major raw materials (including wheat) to Bomaderry by truck or train;
- Energy and fuel used on site for the production of ethanol, starch, gluten and other products, including grid electricity, natural gas, petroleum, diesel, etc;
- Storage of products on site;
- Waste disposal and wastewater treatment;
- Transport of products from Shoalhaven Starches to depots, distributors and consumers;
- Usage of ethanol blend fuels; and
- Final plant decommissioning.

The emissions from these life cycle stages were then aggregated and compared to the no-change scenario of continuing to operate the current Shoalhaven Starches facility (without upgrade).

2.3 Methodology

The greenhouse assessment was prepared in accordance with the general principles of:

- The recognised international standard – *The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard* developed by the World Business Council for Sustainable Development (GHG Protocol);
- Life Cycle Assessment principles (ISO 14040 series); and
- The Department of Climate Change (DCC) *National Greenhouse Accounts (NGA) Factors,* 2008 (which replaces the Australian Greenhouse Office (AGO) Factors and Methods Workbook).

These are considered to represent best practice in Australian greenhouse gas accounting.

In accordance with the Guidelines, where the proposal is modifying or augmenting an existing operation or activity, the net greenhouse emissions are calculated, where:

- Net project emissions = Gross project emissions minus Baseline emissions;
- Baseline emissions = greenhouse emissions of the existing plant; and
- Gross project emissions = greenhouse emissions of the proposal (existing plus new plant).

2.4 Abbreviations

Table 1 Abbreviations

a	Annum
AGO	Australian Greenhouse Office
CO2-e	Carbon dioxide equivalent emissions (emissions of other greenhouse gases are multiplied by their GWP so that their effects can be compared to emissions of carbon dioxide)
COD	Chemical Oxygen Demand
DCC	Department of Climate Change
DEFRA	UK Department of Environment, Food and Rural Services
EF	Emission Factor
EIA	Environmental Impact Assessment
EPA	Environment Protection Authority
G	Giga (x 1,000,000,000)
GHG	Greenhouse Gas
ISO	International Standards Organisation
kg	kilogram
kL	kilolitre
km	kilometre
kWh	kilowatt hour
LCA	Life Cycle Assessment
M	Mega (x 1,000,000)
NA	Not Applicable
NGA	National Greenhouse Accounts
t	Tonnes

3. Greenhouse Gas Assessment

3.1 Level of assessment required

The Department of Planning's *Guidelines Energy and Greenhouse in EIA,* (Guidelines) indicate two possible levels of assessment:

1. Level 1 Assessment – A simplified assessment based on a limited number of energy sources and methane generation potential; and
2. Level 2 Assessment – A more detailed assessment including all Scope 1 and 2 emissions and 'upstream' and 'downstream emissions.

A Level 2 Assessment is required for proposals with projected emissions above a threshold of 20,000 t CO2-e per annum. Table 13 of the Guidelines indicate that this threshold would be exceeded by an ethanol plant of 20,000 kL/a. Since the proposed upgrade will have a total capacity of 300,000 kL/a (an increase of 174,000 kL/a over current capacity), the threshold will be exceeded and a Level 2 assessment is required.

3.2 Boundary of the Assessment

3.2.1 Life cycle stages for the product

The life cycle stages for the products are:

» Construction – Energy embodied in construction materials and fuels used during construction;

» Raw materials – Products, energy and materials required to produce each of the major raw materials, including wheat grain, wheat flour and chemicals;

» Delivery of raw materials to the site at Bomaderry, including water;

» Manufacture of a range of products – Use of utilities, such as electricity, natural gas, coal, fuels, refrigerants, and the generation of wastes, including solid waste and recycling, wastewater and gaseous emissions from the site;

» Manufacture and delivery of packaging materials, such as plastic and paper bags;

» Transportation of products from the factory to points of sale, in Australia and overseas;

» Usage – Emissions associated with the use of the products, including those from combusting ethanol blend fuels (as opposed to 100% petroleum derived fuels); and

» Decommissioning – Fuels used during demolition and/or decommissioning, disposal of wastes and credits for recycling/reuse of materials.

The emissions sources (material and energy flows) that fall under each of these life cycle stages are illustrated in Figure 1.

Figure 1: Life Cycle stages for the Shoalhaven Starches proposed upgrade

Note: Since the ethanol blend fuel is thoroughly combusted, there is no "disposal" life cycle stage to consider.

3.2.2 System boundaries and geographic limitations

The system boundary is the inputs and outputs of each of the identified life cycle stages, including transportation and support services. This includes the manufacture of products and raw materials, the use of energy and utilities and the treatment of solid, liquid and gaseous wastes generated.

The assessment covers emissions generated from the manufacture, use and disposal of the products, packaging, and associated services. It does not include:

» The carbon sequestered by the growth of grain crops, and subsequently released during the fermentation process to produce ethanol. The carbon dioxide released in fermentation is greenhouse neutral (since emissions are of biogenic origin only, i.e. carbon is absorbed in the growing of grains, and is released within a short time period), and it is therefore excluded from the inventory;

» Emissions arising from the environmental farm adjacent to the Bomaderry site. Activities on the farm are not anticipated to change (since the farm area and the number of cattle will remain the same), so there is unlikely to be a significant change in associated emissions. The treatment of wastewater which is subsequently used for farm irrigation has been considered, however, all other aspects of the farm are excluded;

» The end of life impacts of process and construction by-products and wastes that are used as raw materials for the manufacture of other products. This type of industrial synergy is similar to recycling, which the DCC considers to be greenhouse neutral (since it is a method of resource and energy conservation). Once the by-product has entered the manufacturing phase of the secondary product, it is no longer considered to be the responsibility of Shoalhaven Starches; and

» Emissions arising from the transportation of the product from the main distribution centre (e.g. State Capital city or international country capital city) to point of use.

3.2.3 Aspects of energy use considered

The following aspects of energy use have been considered for the products:

» Energy required to produce and prepare raw materials for product manufacture;

» Energy required for operations at the factory, including electricity, coal, diesel and natural gas, and to maintain equipment in working order;

» Energy required for transportation of raw materials and the end products between their points of production and points of manufacture and sale, respectively;

» Energy used to dispose or recycle waste products from each life cycle stage; and

» Energy credits if materials are recycled and incorporated into another product.

3.2.4 Greenhouse gases considered

The greenhouse gases considered in this assessment are:

» Carbon dioxide;

» Nitrous oxides; and

» Methane.

Shoalhaven Starches does not use, store or generate any perfluorocarbons or sulphur hexafluoride, and uses only negligible quantities of hydrofluorocarbons for refrigeration. These gases have therefore been excluded.

3.3 Data Collection and Calculation Procedures

Emission factors that are used in the LCA calculations are outlined in Appendix B. Where possible, factors have been sourced from the *National Greenhouse Accounts (NGA) Factors,* 2008. If factors have been sourced elsewhere then source references have been provided in Tables 2 and 3 below.

Wherever possible, estimates with high accuracy were used to calculate greenhouse gas emissions. For example, electricity consumption figures measured from current operations can be multiplied by the NGA emission factors to calculate greenhouse gas emissions with a high degree of accuracy. When data is unavailable, assumptions and approximations were made in order to obtain a reasonable estimate. For example, emissions factors for some of the materials used in ethanol manufacture were not readily available, and these were estimated based on the best available information. Recognised standards, such as the World Business Council Greenhouse Gas Protocol, were used to assist in these estimations whenever appropriate.

All energy consumption and emissions data has been converted into quantities of carbon dioxide equivalent for each life cycle stage of the project, as shown in Appendix B. The emission values for each life cycle stage have been summed to reach an estimate of the total greenhouse gas emissions over the entire life cycle.

3.4 Exclusions and Assumptions

3.4.1 Exclusions

The life cycle stages and emissions sources and energy consumption that have been omitted from the study are identified below:

» Acquisition of, and energy embodied in, existing physical assets required to manufacture and deliver the product, including processing equipment, office and factory buildings, fixtures, fittings, ancillary equipment and furniture. Section 3.3 of the Guidelines indicates that it is not considered appropriate or feasible to consider all embedded energy in material or other inputs to projects. Note that energy embodied in the materials and equipment required for the upgrade, and in the major raw materials (wheat grain, wheat flour, chemicals, packaging materials and water) is included in the assessment;

» Emissions associated with the extraction and processing of trace materials, including enzymes, minor chemical additives and cleaning agents. These ingredients are currently used in quantities not greater than 600 tonnes per year. The transportation of these ingredients to the factory is included in the assessment, since they are manufactured internationally or interstate, and therefore require long-distance transportation.

» Energy used to manufacture and supply consumables needed for the service provision, such as office paper and stationary, marketing and promotional materials as only small quantities of individual items are used;

- Energy required for business travel as part of the product's support services (including staff air travel, ground transport (taxis, hire cars, public transport, personal vehicles and company vehicles) and accommodation);
- Emissions associated with staff commuting to and from work by personal vehicle or public transport.
- Emissions associated with visitors/clients/consultants commuting to and from the factory by any mode of transport; and
- Fugitive emissions of refrigerants from office refrigerators and air conditioning systems.

The materiality of the omitted emission sources is difficult to accurately establish. From experience, it is expected that of the exclusions, the energy embodied in buildings, equipment, fixtures and fittings have the largest associated greenhouse gas emissions. However, if these emissions are annualised over the lifetimes of the relevant equipment or buildings, they are unlikely to be significant compared to the major annual emission sources, such as electricity consumption. This assumption is supported by the fact that the annualised construction and decommissioning emissions for the upgrade are only approximately 0.1% of the net annual operating emissions. The discrepancies in the total emissions inventory due to the exclusions and limitations of the assessment are therefore anticipated to be non-material.

3.4.2 Assumptions

Energy use

Assumptions used in estimating the energy use from the baseline operations and future ethanol plant are listed in Table 2.

Table 2 Energy use assumptions

Parameter measured	Assumptions	
	Baseline	**Proposed plant**
Electricity (plant)	Quantity based on 2006/07 consumption data. Emission Factor (EF) from Table 5 of the DCC NGA Factors publication (2008) for NSW (Scopes 2 and 3).	Quantity estimated by Shoalhaven Starches engineering calculations (based on itemised list of equipment to be installed). Note that most electricity for the plant will be supplied by the natural gas fired cogeneration plant. The total electricity purchased from the grid will be significantly lower for the proposed plant than the current plant. EF same as for baseline.
Electricity (farm)	Quantity based on 2006/07 consumption data. EF from Table 5 of the DCC NGA Factors publication (2008) for NSW (Scopes 2 and 3).	Quantity estimated by Shoalhaven Starches engineering calculations and included in total electricity purchases above. EF same as for baseline.
Electricity (WWTP)	NA – not used in existing plant	Quantity estimated by Shoalhaven Starches engineering calculations and included in total electricity purchases above. EF from Table 5 of the DCC NGA Factors publication (2008) for NSW (Scopes 2 and 3).

Parameter measured	Assumptions	
	Baseline	**Proposed plant**
Natural gas	Quantity based on 2006/07 consumption data. EF from Table 2 of the DCC NGA Factors publication (2008) for NSW (Scopes 1 and 3).	Quantity estimated by Shoalhaven Starches engineering calculations. EF same as for baseline.
Coal	Quantity based on 2006/07 consumption data. EF from Table 1 of the DCC NGA Factors publication (2008) for black coal (Scopes 1 and 3).	Quantity estimated by Shoalhaven Starches engineering calculations (based on current usage and not anticipated to change significantly). EF same as for baseline.
Diesel (on site)	Quantity based on 2006/07 consumption data. EF from Table 3 of the DCC NGA Factors publication (2008) for automotive diesel combustion (Scopes 1 and 3).	Quantity estimated by Shoalhaven Starches engineering calculations (based on current usage and not anticipated to change). EF same as for baseline.
Ethanol fuel	Quantity based on 2006/07 production data. Approximately 65% ethanol is used for fuel blending and the rest for industrial/beverage production. It is assumed that the use of ethanol fuel (either unmixed or in ethanol blend fuel) will replace the equivalent volume of petroleum fuel (based on energy content), resulting in an emissions credit – rather than simply increasing the total volume of fuels used. The credit EF is based on NGA Factors energy content data for ethanol and petrol (Tables 1 and 3, respectively) and petrol emission factors (Scopes 1 and 3) from Table 3. The EF is expressed as t CO2-e saved per kL of ethanol fuel used to replace petrol (or *negative emissions* per kL ethanol fuel).	Quantity based on design capacity of plant. Shoalhaven Starches estimate that 90% of the design capacity will be used for fuel production with the remainder used for industrial applications. EF (credit) same as for baseline.

Greenhouse emissions

Assumptions used in estimating the greenhouse emissions from the baseline operations and future ethanol plant are listed in Table 3.

Table 3 Greenhouse emissions assumptions

Parameter measured	Assumptions	
	Baseline	**Proposed plant**
Raw materials		
Wheat grain	Quantity based on 2006/07 purchase data. EF sourced from SimaPro (licensed Life Cycle Assessment (LCA) software which contains several databases of environmental information relating to various products or services, including greenhouse gas emissions). The wheat EF was based on comprehensive Australian studies of the fuel and energy used and fugitive emissions associated with growing and processing the grains and are considered to be the most accurate figures available.	Quantity estimated by Shoalhaven Starches engineering calculations. EF same as for baseline.
Wheat flour	Quantity based on 2006/07 purchase data. EF sourced from SimaPro, based on Australian data for flour manufacture.	Quantity estimated by Shoalhaven Starches engineering calculations. EF same as for baseline.
Sugar	NA – not used in existing plant	Quantity based on estimated quantity for ethanol production. EF derived from data from the Australian Sugar Milling Council, *Submission to the Task Group on Emissions Trading*, March 2007, including published emissions from growing, harvesting, transporting and processing sugar cane, cane production and sugar yield. The EF takes into account that bagasse produced during the processing of sugar cane is often used to generate electricity which is fed into the grid system – resulting in an emissions credit (since it replaces coal generated electricity). This credit is equal to approximately one third of the emissions associated with the product, and therefore significantly reduces the associated emissions.
Millfeed	NA – not used in existing plant	Quantity estimated by Shoalhaven Starches engineering calculations. Millfeed EF is assumed to be equivalent to wheat flour (on a per tonne basis), since both are products of flour milling. EF sourced from SimaPro and is based on Australian data.
Filter aid	Quantity based on 2006/07 purchase data. The extraction and processing method	The consumption of chemicals used in the starch and glucose plants, such as Filter aids, will not increase substantially, and the quantity is therefore the same as for the

Parameter measured	Assumptions	
	Baseline	**Proposed plant**
	for diatomaceous filter powder is similar to that of gypsum plaster. The EF for filter aid was based on the embodied energy for gypsum plaster	baseline. EF same as for baseline.
Lime Sulfuric acid Ammonia	Quantities based on 2006/07 purchase data. EF for lime sourced from SimaPro and is based on Australian data for calcined lime. EF for acid sourced from SimaPro and is based on Australian data for sulphuric acid. EF for ammonia sourced from SimaPro and is based on Australian data.	Quantities of chemical usage following the upgrade have been estimated based on the current usage figures, which have been extrapolated according to the increased production of ethanol (which will increase to 3.45 times the volume currently produced). The consumption of chemicals used in the starch and glucose plants will not increase substantially, however lime, ammonia & sulfuric acid are not used in these plants. EFs same as for baseline.
Caustic Sodium hypochlorite Hydrochloric acid	Quantities based on 2006/07 purchase data. EF for caustic sourced from SimaPro and is based on Australian data for 50% sodium hydroxide in water. EF for sodium hypochlorite sourced from SimaPro and is based on data for 15% sodium hypochlorite solution. EF for Hydrochloric acid sourced from SimaPro and is based on Australian data.	The consumption of chemicals used in the starch and glucose plants will not increase substantially. A large proportion of the caustic, hydrochloric acid & sodium hypochlorite is used in these plants, and this quantity will not change. The remainder (used in other parts of the manufacturing process) will increase according to the increase in ethanol production (by 3.45 times). EFs same as for baseline.
Paper packaging materials	Quantity based on 2006/07 purchase data. EF from an EPA Victoria publication *"EPA Ecological Footprint Calculator: Technical Background Paper"* (Publication 972, February 2005) for non-recycled paper.	Quantity based on Shoalhaven Starches estimated quantity and the assumption that all packaging for the gluten product is paper-based. EF same as for baseline.
Plastic packaging materials	Quantity based on 2006/07 purchase data. EF sourced from SimaPro and is based on Australian data for low-density polyethylene.	Quantity based on Shoalhaven Starches estimates. EF same as for baseline.
Mains water	Quantity based on 2006/07 consumption data. EF has been derived based on Sydney Water Corporation electricity consumption data published for the 2005/06 period for water provision, and the NSW EF for electricity use in NSW.	Quantity based on Shoalhaven Starches engineering estimates. EF same as for baseline.

Parameter measured	Assumptions	
	Baseline	**Proposed plant**
Raw water	Quantity based on 2006/07 consumption data. Raw water is pumped from the river a distance of 2.5 km. The power required for pumping is calculated based on standard engineering equations and assuming a pump efficiency of 40%. An EF (in t CO2-e/ML) has been derived from the pumping power requirement, volume of water pumped and the EF for electricity use in NSW.	Quantity based on Shoalhaven Starches projected consumption. Same EF as for baseline.
Transport to site		
Wheat grain	Supplier locations provided by Shoalhaven Starches – 95% from NSW and 5% from SE QLD. Grain is transported by rail from the supplier to Bomaderry. It has been assumed that a third of the NSW grain is sourced from each of Manildra, Narrandera and Gunnedah (where Manildra has its flour mills). The 5% from SE QLD is assumed to come from Toowoomba. The distances from these locations to Bomaderry were estimated using the website: www.whereis.com. Emissions for train transport sourced from SimaPro for Australian bulk rail transport (in kg CO2-e/t.km). The specific wheat transport EF was derived from the SimaPro factor and the weighted average distance from the supplier locations to Bomaderry.	Supplier locations provided by Shoalhaven Starches and are not anticipated to change. EF same as for baseline.
Wheat flour	Supplier locations provided by Shoalhaven Starches – 38% from Manildra, 31% from Gunnedah and 31% from Narrandera. Flour is transported by rail from the supplier locations to Bomaderry. The distances from these locations to Bomaderry were estimated using the website: www.whereis.com. Emissions for train transport sourced from SimaPro for Australian bulk rail transport (in kg CO2-e/t.km). The specific flour transport EF was derived from the SimaPro factor and the weighted average distance from the supplier locations to Bomaderry.	Supplier locations provided by Shoalhaven Starches – 55% from Manildra, 22% from Gunnedah and 23% from Narrandera. Specific EF derived in the same way as for baseline.

Parameter measured	Assumptions	
	Baseline	**Proposed plant**
Millfeed	NA – not used in existing plant	Shoalhaven Starches anticipates that 100% of the millfeed will be sourced from the Manildra flour mill, and will be transported to Bomaderry by train. The distance from Manildra to Bomaderry was estimated using the website: www.whereis.com. Emissions for train transport sourced from SimaPro for Australian bulk rail transport (in kg CO2-e/t.km). The specific millfeed transport EF was derived from the SimaPro factor and the distance from the supplier location to Bomaderry.
Sugar	NA – not used in existing plant	Assumed that sugar will be transported from North QLD (Innisfail) by road in large trucks (40 tonne). The distance from Innisfail to Bomaderry was estimated using the website: www.whereis.com. Emissions for 40 tonne truck transport sourced from SimaPro for road transport (in kg CO2-e/t.km). The SimaPro EFs take several factors into consideration – including the infrastructure required for product transportation, vehicle maintenance, and "back haulage"- the fuel used by empty trucks on the return journey. The emission factor used for 40 tonne trucks is 0.165 kg CO2-e/t.km and for 20 tonne trucks 0.248 kg CO2-e/t.km. The *Sima Pro* factors are the most comprehensive and accurate factors available. The specific sugar transport EF was derived from the SimaPro factor and the distance from the supplier location to Bomaderry.
Coal	Coal is sourced from a supplier in Lithgow, NSW and transported to Bomaderry by 40 tonne truck. The distance from Lithgow to Bomaderry was estimated using the website: www.whereis.com. Emissions for 40 tonne truck transport sourced from SimaPro for road transport (in kg CO2-e/t.km). The specific coal transport EF was derived from the SimaPro factor and the distance from the supplier location to Bomaderry.	Shoalhaven Starches anticipate that coal required following the development will be sourced from the same location and transported by the same means. EF same as for the baseline.
Diesel	Diesel is sourced from a supplier in Albion Park, NSW and transported to Bomaderry by 15 kL tanker.	There is no change in the quantity and supplier location for diesel following the upgrade.

Parameter measured	Assumptions	
	Baseline	**Proposed plant**
	The distance from Albion Park to Bomaderry was estimated using the website: www.whereis.com. EF for 15 kL road tanker transport sourced from SimaPro for Australian road transport and is assumed to be equivalent to a 15 tonne rigid vehicle (in kg CO2-e/t.km). The specific coal transport EF was derived from the SimaPro factor and the distance from the supplier location to Bomaderry.	EF same as for baseline.
Chemicals	Chemicals purchased in 2006/07 were sourced from many suppliers, both in Australia and internationally. It was assumed that all chemicals from oversees were transported to Australia by cargo ship (to Port Botany in Sydney) and are then transported by road to Bomaderry in medium trucks. It was assumed that all chemicals from Australian suppliers were transported by road from the supplier location to Bomaderry in medium trucks. International shipping distances were estimated using the website: http://www.indo.com/cgi-bin/dist/ Australian road distances were estimated using the website: www.whereis.com. EF for medium truck and cargo ship transport sourced from SimaPro for Australian road transport and international freight shipping, respectively (in kg CO2-e/t.km). The specific transport EF for each chemical was derived based on the shipping and road transport distances and the SimaPro transport factors.	While the quantities of chemicals used following the upgrade will increase according to the increase in ethanol production, Shoalhaven Starches anticipates that the suppliers and modes of transportation will not change. The EF for each chemical will therefore be the same as the baseline.
Paper packaging	Paper packaging is currently sourced from a supplier in Sydney. It is assumed that it is transported by medium truck from the supplier to Bomaderry. The distance from Sydney to Bomaderry was estimated using the website: www.whereis.com. EF for medium truck transport sourced from SimaPro for Australian road transport (in kg CO2-e/t.km). The specific paper packaging transport	While the quantity of paper packaging materials used will change following the upgrade, the supplier locations and modes of transport for will remain the same. EF same as for baseline.

Parameter measured	Assumptions	
	Baseline	**Proposed plant**
	EF was derived from the SimaPro factor and the distance from the supplier location to Bomaderry.	
Plastic packaging	Plastic packaging is currently sourced from two suppliers. 90% is from a supplier in China, with the remaining 10% from a supplier in Sydney. It was assumed that the packaging from China was transported by cargo ship to Port Botany in Sydney and is then transported by road to Bomaderry in medium trucks. It was assumed that the packaging from the Sydney supplier was transported by road to Bomaderry in medium trucks. The international shipping distance was estimated using the website: http://www.indo.com/cgi-bin/dist/. The Australian road distance was estimated using the website: www.whereis.com. EF for medium truck and cargo ship transport sourced from SimaPro for Australian road transport and international freight shipping, respectively (in kg CO2-e/t.km). The specific plastic packaging transport EFs were derived from the SimaPro factors and the distance from the supplier locations to Bomaderry.	While the quantity of plastic packaging materials used will change following the upgrade, the supplier locations and modes of transport for will remain the same. EFs are the same as for baseline.
Manufacture		
Waste disposal	Quantity of waste produced estimated by Shoalhaven Starches based on 4 trips per week to the landfill at 3 tonnes per trip. EF from Table 20 of the DCC NGA Factors publication (2008).	Waste quantity is anticipated by Shoalhaven Starches to remain the same following the upgrade. EF same as for baseline.
Wastewater treatment	Quantity based on measured volumes of wastewater, condensate, wash down water and measured COD load for each wastewater stream. The EF is based on the NGA emission equations for industrial wastewater treatment using default factors from NGA Table 23. Wastewater is currently not treated, and its storage in ponds on the environmental farm is assumed to be equivalent to “unmanaged aerobic” treatment.	Following the upgrade a wastewater treatment plant will be installed, and Shoalhaven Starches estimates that 100% of the biogas produced will be captured and combusted for energy recovery. No greenhouse gases are emitted as a result of wastewater treatment since the resulting biogas is captured. The carbon dioxide that is created as a result of the combustion is biogenic in origin (since all the carbon is derived from the organic materials used as raw materials) – EF is therefore zero.

Parameter measured	Assumptions	
	Baseline	**Proposed plant**
Transport from site		
General (starch, gluten, glucose, Gemspray, brewer's syrup, stillage, liquid CO2)	Production data for 2006/07 was analysed and grouped into like products to obtain product quantities. All product exports are transported by rail to Botany Bay, then shipped to the final destination. Local distribution is by road (large truck) to major population centres (except distribution to Tasmania is by road/ferry). Distances by road, rail and ship were estimated for each of the 39 product destinations. EF for large truck and cargo ship transport sourced from SimaPro for road transport and Australian international freight shipping, respectively (in kg CO2-e/t.km). Ferry EF was sourced from a document published by DEFRA, UK in 2005 titled *"Guidelines for Company Reporting on Greenhouse Gas Emissions"* The international shipping distances were estimated using the website: http://www.indo.com/cgi-bin/dist/. The Australian road distances were estimated using the website: www.whereis.com. Distribution to Australian states is assumed to be to the capital city only (and in the case of Northern Territory, split between Alice Springs and Darwin according to population). The specific transport EF for each product was derived based on the shipping and road transport distances and the SimaPro (and other) transport factors.	Production quantity for each item based on Shoalhaven Starches estimates. The destination, distribution patterns and mode of transport will not change significantly from current operations, only the quantities will increase. Distribution EF for each product the same as for baseline.
Ethanol fuel & Industrial/ Beverage use	Quantity based on 2006/07 production data. Approximately 65% ethanol is used for fuel blending and the rest for industrial/beverage production. All product exports are transported by rail to Botany Bay, then shipped to the final destination. Local distribution is by road (large truck) to major population centres. Distances by road, rail and ship were estimated for each of the 10 product destinations. EF for large truck and cargo ship transport sourced from SimaPro for road transport and Australian international freight shipping,	Quantity based on design capacity of plant. Following the upgrade, Shoalhaven Starches estimates that 90% of the ethanol manufactured will be used for fuel, with the remaining 10% used for industrial uses. Shoalhaven Starches anticipates all of the fuel ethanol to be transported to Sydney by 15 kL road tankers. The distribution emission factor has been derived based on the road distance from Bomaderry to Sydney and the SimaPro EF for Australian road transport, assumed to be equivalent to a 15 tonne rigid vehicle (in kg CO2-e/t.km). For industrial ethanol, the destination, distribution patterns and mode of transport

Parameter measured	Assumptions	
	Baseline	**Proposed plant**
	respectively (in kg CO2-e/t.km). The international shipping distances were estimated using the website: http://www.indo.com/cgi-bin/dist/. The Australian road distances were estimated using the website: www.whereis.com. Distribution to Australian states is assumed to be to the capital city only (and in the case of Northern Territory, split between Alice Springs and Darwin according to population). The specific transport EF for each ethanol product was derived based on the shipping and road transport distances and the SimaPro transport factors.	will not change significantly from current operations, only the quantity will change. The EF is the same as for the baseline.
Construction		
Construction materials	NA – only calculated for proposed plant	The approximate quantity in tonnes of construction materials required for each of the proposed new plant areas was estimated by Shoalhaven Starches (including a breakdown into reinforced concrete, steel, stainless steel, roof material, piping and racking, electrical cabling and manufactured process equipment). The specific EF for each construction material was based on SimaPro emission factors. Total emissions were annualised over a 30 year plant life, as estimated by Shoalhaven Starches.
Construction equipment	NA – only calculated for proposed plant	The approximate number of hours of operation of construction equipment required for each of the proposed new plant areas was estimated by Shoalhaven Starches (including a breakdown into cranes, trucks, forklifts, access towers and earthmoving equipment). All equipment was assumed to run on diesel. The EF for each piece of equipment (in kg CO2-e/h) was based on fuel consumption data from "Spoon's Civil Engineering and Highway Works Price Book" (Davis, Langdon and Everest). Total emissions were annualised over a 30 year plant life.
Decommissioning		
Materials recycled	NA – only calculated for proposed plant	Approximately 70% of process equipment

Parameter measured	Assumptions	
	Baseline	**Proposed plant**
		would be sold as used equipment, 95% of steel and stainless steel would be recycled, and 60% of concrete would be recycled. Credits were given for recycled materials. The credit EF for concrete was from SimaPro based on Australian conditions. The credit EF for steel and stainless steel were from Grant, T et al. (2001) "Stage 2 Report for Life Cycle Assessment for Paper and Packaging Waste Management Scenarios in Victoria", EcoRecycle Victoria (pp82 -112 main report). The materials disposed via landfills are non-putrescible and would therefore not generate any greenhouse gas emissions in the form of landfill gas. Equipment sold second-hand following decommissioning is assumed to have zero emissions (i.e. no disposal emissions or recycling credits) since there is no certainty as to what will happen to it at its eventual end of life. Total emissions were annualised over a 30 year plant life.
Decommissioning equipment	NA – only calculated for proposed plant	The approximate number of hours of operation of demolition equipment required for decommissioning each of the proposed new plant areas was estimated by Shoalhaven Starches (including a breakdown into cranes, trucks, forklifts, access towers, shears, concrete breakers and earthmoving equipment). All equipment was assumed to run on diesel. The EF for each piece of equipment (in kg CO2-e/h) was based on fuel consumption data from "Spoon's Civil Engineering and Highway Works Price Book" (Davis, Langdon and Everest). Total emissions were annualised over a 30 year plant life.

3.5 Emission Scopes

Scope 1, 2 and 3 emissions are defined in the *"Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard"* developed by the World Business Council for Sustainable Development and the World Resources Institute. This document is considered the global standard for emissions accounting and reporting, and as a result, the concept of scope 1, 2 and 3 emissions has been carried over into Australian publications, such as those produced by the Department of Climate Change and the draft guidelines that are applicable to this greenhouse gas assessment (Department of Planning's *Guidelines Energy and Greenhouse in EIA,* August 2002). These guidelines specifically require emissions to be

expressed in terms of Scope 1, 2 and 3. For this greenhouse gas assessment, the scopes are defined as follows:

» Scope 1: Direct greenhouse gas emissions produced within the boundaries of the Shoalhaven Starches site at Bomaderry (or in equipment owned and operated as part of the site's normal operation). Scope 1 emissions therefore include the combustion of natural gas, coal and diesel for stationary energy, heat, cogeneration, transport, or any other application. The fugitive emissions of methane and nitrous oxide from wastewater stored in ponds on the farm (prior to the construction of the wastewater treatment plant) are also Scope 1.

» Scope 2: Indirect emissions associated with the combustion of fuels in power stations to generate electricity taken from the grid for use at the site.

» Scope 3: All other indirect emissions. These are associated with the production and transportation of raw materials, transportation of materials and products, waste disposal, and the combustion of ethanol blend fuels (credit). Scope 3 emissions are generally produced by a third party and Shoalhaven Starches does not have a direct control over them.

Scope 1 emissions are produced by the combustion of fuels such as coal, diesel and natural gas, at the Bomaderry site, and by vehicles and plant equipment over which Shoalhaven Starches owns and has operational control. Note that only the direct combustion of the fuels is considered as Scope 1. Scope 2 emissions arise from the consumption of electricity at the Bomaderry site, in plant equipment that is owned and operated by Shoalhaven Starches. Emissions arising from the extraction, processing and transportation and distribution of fuels and electricity are classified as Scope 3, since these activities are not within the operational control of the end user. The breakdown between Scope 1 or 2 emissions and Scope 3 emissions associated with the consumption of electricity are given in Appendix B.

All other emissions associated with the project are defined as Scope 3, since they are produced outside the Bomaderry site, and Shoalhaven Starches does not have operational control of the facilities from which they originate. Shoalhaven Starches does not own or operate any of the vehicles that transport raw materials to the site, or distributes products manufactured at the site to customers. As such, the emissions resulting from the combustion of fuels for this transportation are classified as Scope 3.

4. Energy and Greenhouse Analysis

4.1 Energy Use Results

Baseline, gross and net energy used during operation are summarised in Table 4. Full details of baseline and proposed energy uses are included in Appendix B.

Total energy use at the Shoalhaven Starches site will increase by 2.7 times current levels. The analysis shows that the primary energy source is the combustion of natural gas (responsible for 94% of net energy use). The proposed ethanol plant upgrade will include a cogeneration facility that will be powered by natural gas and biogas captured from wastewater treatment. The large increase in natural gas consumption will be offset to some extent by a reduction in purchased electricity from the grid. Following the upgrade, purchased electricity consumption will be cut to 11% of baseline usage.

Transport energy use for raw materials and products account for 6% and 4% net energy use respectively. The small increase in coal use for the proposed plant only accounts for 2% of net energy use.

Table 4 Energy use summary

Energy Source	Energy Content	Units	Baseline Energy Use			Gross Energy Use			Net Energy Use		
			Consumption	Units	GJ/a	Consumption	Units	GJ/a	Consumption	Units	GJ/a
Scope 1											
Coal	27.0	GJ/t	105,000	t/a	2,835,000	109,000	t/a	2,943,000	4,000	t/a	108,000
Natural Gas	-		168,536	GJ/a	168,536	6,800,000	GJ/a	6,800,000	6,631,464	GJ/a	6,631,464
Diesel - On-site	38.6	GJ/kL	660	kL/a	25,476	660	kL/a	25,476	0	kL/a	0
Scope 2											
Electricity (total)	0.0036	GJ/kWh	129,910,812	kWh/a	467,679	14,000,000	kWh/a	50,400	–115,910,812	kWh/a	–417,279
Scope 3											
Diesel - Raw material transport	38.6	GJ/kL	3,105	kL/a	119,834	14,870	kL/a	573,970	11,765	kL/a	454,136
Diesel - Product transport	38.6	GJ/kL	13,315	kL/a	513,952	21,263	kL/a	820,740	7,948	kL/a	306,788
Total					**4,130,478**			**11,213,586**			**7,083,109**

4.2 Greenhouse Emissions Results

The results from the greenhouse assessment, separated by life cycle stage and emissions scope, are presented in Table 5 below. The total emissions inventory is given in Appendix B for the baseline and the proposed plant.

Table 5: Greenhouse gas emissions assessment results by life cycle stage and scope

Life Cycle Stage	Baseline Emissions[1]	Gross Emissions[2]	Net Emissions[3]	
Units	**t CO2-e/a**	**t CO2-e/a**	**t CO2-e/a**	**Uncertainty**
Construction (annualised over 30 years)	0	302	302	High
Raw material supply	174,335	421,284	246,949	Moderate
Raw material transport to Bomaderry	9,003	43,122	34,119	Moderate
Manufacture at Bomaderry	445,969	736,709	290,740	Low
Product transportation	38,613	61,662	23,049	Moderate
Product usage	-96,730	-461,842	-365,112	Low
Decommissioning (annualised over 30 years)	0	-31	-31	High
Total Emissions	***667,920***	***1,263,088***	***749,257***	
Total Credits	***-96,730***	***-461,882***	***-519,241***	
Total[4]	**571,190**	**801,206**	**230,016**	
Scope 1 emissions component of total	292,136	611,097	318,962	
Scope 2 emissions component of total	115,621	12,460	-103,161	
Scope 3 emissions component of total	163,433	177,649	14,215	

Notes:

Listed figures may not sum exactly to the totals due to rounding.

1. Baseline emissions of the existing Shoalhaven Starches plant
2. Gross emissions of the existing and new plant
3. Net Emissions is calculated as gross emissions minus baseline emissions
4. Total annual emissions based on annual Scope 1, 2 and Scope 3 emissions (including annualised construction and decommissioning emissions).

4.2.1 Baseline Emissions

The total baseline emissions for the existing plant, based on the 2006/07 period, amount to 571,190 t CO2-e per annum. These emissions include the Scope 1, 2 and 3 emissions associated with the production of ethanol and other products at the Shoalhaven Starches site at Bomaderry, and the upstream and downstream impacts. Construction and decommissioning are not applicable. If the

proposed plant expansion were not to go ahead, the emissions associated with the baseline would continue into the future.

4.2.2 Total gross emissions

Total gross annual emissions are calculated based on annual Scope 1, 2 and Scope 3 emissions, including annualised construction and decommissioning emissions.

Total gross annual emissions amount to 801,206 tonnes CO2-e compared to 571,190 tonnes CO2-e for the existing plant – an increase of 230,016 tonnes CO2-e (40%). This compares well with the total increase in energy usage of 2.7 times current levels and indicates that lower greenhouse intensity fuels are being used for the proposed plant.

4.2.3 Total (net) project emissions

The greenhouse assessment, as shown in Table 5, indicates total (net) project emissions of 230,016 tonnes of CO2-e per year, including annualised emissions from the construction and decommissioning stages of the project. Total estimated emissions from the construction and decommissioning stages have been annualised over a 30 year period.

The project will result in a net increase of greenhouse gas emissions, even when the downstream reduction as a result of replacing petroleum fuels with bioethanol is taken into account (i.e. the increased greenhouse gas emissions of the project will not be completely offset by the reduced downstream emissions). The use of lower emissions fuels at the plant will result in the products manufactured at the site having lower associated emissions intensities than they have currently (however the larger volumes to be produced mean that the total emissions will increase).

Table 5 shows the total emissions and total credits associated with the no change (baseline) scenario, the proposed development (gross) scenario and the difference between them (net). The total emissions figure is the sum of all of the positive emissions associated with the production across the life cycle. Positive emissions arise from the combustion of fuels, waste disposal, fugitive emissions of greenhouse gases, etc. The total credits figure is the sum of all the emissions credits throughout the life cycle. Emissions credits arise from activities that result in a reduction of greenhouse gas emissions, such as the combustion of ethanol instead of petroleum fuel, the reuse or recycling of resources instead of using virgin materials, etc. In the same way that the total emissions consider the upstream and downstream greenhouse gas emissions associated with the activities undertaken by Shoalhaven Starches at Bomaderry, the total credits figure considers any upstream and downstream reduction in greenhouse gas emissions. As such, the total credits are subtracted from the total emissions to calculate the total emissions associated with the production at Bomaderry, for each of the three considered scenarios.

The Guidelines indicate that the uncertainty associated with emissions should be stated. A qualitative assessment of uncertainty has been included in Table 5, based on the perceived accuracy of the data and emissions factors for each life cycle stage. The most accurate emission data is associated with manufacture.

The most emissions intensive stage of the project is manufacturing at the Bomaderry production site.

Total annual NSW emissions for 2006/2007 are 158.2 Mega-tonnes CO2-e (based on AGO ‘State and Territory Greenhouse Gas Inventories 2005’ March 2007). The estimated additional annual emissions from the project would account for approximately 0.15% of the state’s total emissions.

4.2.4 Fuel Combustion

Emissions due to product use are negative since they displace emissions due to combustion of petrol, as indicated in Table 6.

Table 6 Combustion emissions (Transportation)

Parameter	Value	Units
Ethanol energy content*	23.4	GJ/kL
Energy content petrol*	34.2	GJ/kL
Petrol Emission Factor*:		
Scope 1	2.3	t CO2-e/kL
Scope 3	0.2	t CO2-e/kL
Full Fuel Cycle	2.5	t CO2-e/kL
1 kL ethanol replaces	0.684	kL petrol
Emissions eliminated		
Scope 1	-1.574	t CO2-e/kL ethanol
Scope 3	-0.137	t CO2-e/kL ethanol
Full Fuel Cycle	-1.711	t CO2-e/kL ethanol

* Source: NGA Factors, Table 3

4.2.5 Major emission sources

The top ten annual net emission sources are listed in Table 7. It can be seen that the three highest emission sources are:

1. Natural gas combustion (58% of positive emissions)
2. Flour production (15% of positive emissions)
3. Grain production (9% of positive emissions)

These emission sources are responsible for 82% of positive emissions. The total for the ten highest sources captures 97% of positive emissions.

Table 7 Top 10 net emission sources

Ranking	Source	Emissions (t CO2-e)	Fraction of net positive emissions
1	Natural Gas	434,361	58.0%
2	Flour production	115,208	15.4%
3	Grain production	66,949	8.9%
4	Millfeed production	29,880	4.0%
5	Sugar transportation	28,632	3.8%

Ranking	Source	Emissions (t CO2-e)	Fraction of net positive emissions
6	Lime production	16,293	2.2%
7	Sugar production	12,512	1.7%
8	Coal combustion	10,055	1.3%
9	Starch distribution	7,775	1.0%
10	Stillage distribution	4,738	0.6%
Total		**721,666**	**97.0%**

The top 3 credits in the net emissions inventory are:

1. Replacement of petroleum with ethanol fuels
2. Reduction in electricity consumption
3. Wastewater treatment biogas capture

These emission sources are responsible for credits of 517,288 tCO2-e/a. The total of all the credits is equivalent to 519,241 tCO2-e/a.

4.2.6 Greenhouse intensity

Greenhouse intensity is normally expressed as the emissions per unit of production for operational emissions only (based on current practice with DCC Greenhouse Challenge reporting requirements). The greenhouse intensity can be used to benchmark against an organisation's previous performance or across an industry sector.

It is difficult to calculate the greenhouse intensity of products from the Shoalhaven Starches facility at Bomaderry, since a range of different products are manufactured there, with varying degrees of energy and utility inputs. In Life Cycle Assessment, the most common way to apportion emissions and other environmental impacts between co-products of the same process is according to the relative economic value of the products. This method recognises that the manufacture of the most valuable products are the economic drivers for the process, and that the less valuable products are essentially by-products of the process. This allows the relative importance of the products to be captured in the assessment.

For Shoalhaven Starches, only the production tonnages for the various products were available (not their relative economic values). Apportioning emissions based on production tonnages means that the emissions intensity of ethanol is equivalent to the emissions intensity of starch, gluten and liquid carbon dioxide, despite their different embodied energies and production processes. Calculating emissions intensities on the basis of production tonnages will provide an indication of the order of magnitude, however, there is great uncertainty associated with the calculations. Insufficient data was available to calculate emissions intensities more accurately.

Emissions intensities for ethanol manufacture at Bomaderry are given in Table 8.

Table 8 Emissions Intensity for Ethanol Manufacture

Scenario	Operational Emissions (Scopes 1&2)[1]	Total LCA Emissions (Scopes 1,2&3)[2]	Total LCA Emissions excluding fuel combustion credit[3]
	t CO2-e/kL	t CO2-e/kL	t CO2-e/kL
Baseline emissions (2006/07 production)	0.75	1.06	1.24
Gross emissions (following upgrade)	0.54	0.69	1.09
Net emissions (additional emissions attributed to additional production)	0.35	0.37	0.96
Industry average ethanol emissions based on manufacture from waste wheat starch and/or molasses[4]	*Unavailable*	*Unavailable*	1.3

Notes:

1. Operational emissions only include Scope 1 & 2 emissions (based on current practice with DCC Greenhouse Challenge reporting requirements).
2. Total emissions include the full Scope 1, 2 & 3 life cycle emissions, including credits for ethanol fuel combustion.
3. Total emissions include the full Scope 1, 2 & 3 life cycle emissions, excluding credits for ethanol fuel combustion.
4. Industry average greenhouse intensity for ethanol manufactured from waste wheat starch and/or molasses (Source: NGA Factors Table 3)

Despite the uncertainty associated with apportioning emissions based on production tonnages, a large fraction of the additional production tonnages from the upgrade are from the increased volumes of ethanol to be manufactured. Therefore, the net emissions intensity for ethanol is relatively accurate. It can be seen that the net emissions intensity is lower than both the gross and baseline emissions intensities. When compared to NGA average values for ethanol production, the Shoalhaven Starches values are considerably lower. The current production emission intensity value is approximately 5% lower, and following the upgrade the intensity will be 16% lower. The net emissions intensity is approximately 26% lower than the Australian average value. These differences should be considered indicative only, since they fall within the uncertainty of the emissions intensity values.

4.2.7 Best Practice Ethanol Emissions

In Australia, fuel ethanol can be manufactured from a number of sources, including wheat, sugar cane, molasses and wood waste, however, at present it is only manufactured on a commercial scale from the fermentation of sugars from wheat and molasses. A large fraction of the total life cycle emissions associated with the production of fuel ethanol arises from the production and processing of the major raw material inputs. Significant savings are therefore achieved when a waste material from another process is utilised, rather than an agricultural input that is grown for the purpose.

CSIRO (and partners) published a report in 2003 titled “Final Report (EV45A/2/F3C) to the Australian Greenhouse Office on the Stage 2 study of Life-cycle Emissions Analysis of Alternative Fuels for Heavy Vehicles” which used life cycle assessment principles to compare environmental indicators for a number of fuels that are produced and used in Australia. Table 9 presents the emissions intensities of ethanol produced in Australia from a range of feedstocks.

Table 9: Emissions intensity of ethanol produced from different feedstocks

Ethanol Production Feedstock	**Emissions Intensity (excluding combustion)[5]**
Units	**(t CO2-e/kL)**
Molasses[6]	1.0 to 1.7
Wheat starch waste	0.9
Wheat	1.6
Wheat, fired by wheat straw	0.8
Wood waste	0.2

Notes:

5. Figures derived from data within the publication: Beer, T et al. (2003) “Final Report (EV45A/2/F3C) to the Australian Greenhouse Office on the Stage 2 study of Life-cycle Emissions Analysis of Alternative Fuels for Heavy Vehicles” published by CSIRO and partners. Figures correspond to anhydrous ethanol, which is comparable to the ethanol produced by Shoalhaven Starches at Bomaderry.

6. Variation in emissions from molasses is due to the LCA assessment methodology used.

Best practice fuel ethanol production uses wood waste as the major raw material, as can be seen in Table 9. Although ethanol produced from wood waste has a much lower emissions intensity than any of the other feedstocks, the production of ethanol in this way is still largely in the research and development stage, and there are no facilities in Australia that produce ethanol in this way on a mass scale.

The next best technology options are associated with the fermentation of wheat starch and wheat starch waste. Best practice in this sector also involves heat recovery from wheat straw, with an emissions intensity of 0.8 t CO2-e/kL.

The process currently undertaken by Shoalhaven Starches uses wheat starch waste as the feedstock, although the proposed expansion will also ferment wheat grain and refined sugar to produce ethanol. The emissions intensity of ethanol produced at Bomaderry following the upgrade will be 0.96 t CO2-e/kL. Although the Shoalhaven Starches process does not include (or propose to include) heat recovery from the combustion of wheat waste, these materials are sold as a useful product (animal feed), and are not wasted.

Until ethanol production from wood waste becomes a commercial option, production from wheat and wheat starch waste, such as the process carried out by Shoalhaven Starches at Bomaderry, will represent the lowest emissions option in Australia.

International processes and production have not been included in this assessment because growing conditions, and the markets for raw materials and process products and by products vary considerably from Australian conditions, and as such, are not considered to be comparable.

5. Greenhouse Emission Reduction

5.1 Direct greenhouse gas minimisation

Direct greenhouse gas emissions (ie: those generated on site) can be minimised at the Shoalhaven Starches site by:

- Adoption of best available technology for fuel combustion;
- Greenhouse gas capture and destruction; and
- Switching from high-emissions to low-emissions fuels.

5.1.1 Adoption of best available technology

The proposed plant will incorporate a gas fired cogeneration plant. This represents best available technology economically achievable to meet the heat and energy needs of the proposed plant.

Additional equipment for the proposed plant, such as fermentation tanks, cooling towers, dryers, evaporators, etc will be designed to minimise operational energy use.

5.1.2 Greenhouse gas capture

The existing plant sends wastewater to a series of treatment ponds, where anaerobic decomposition generates methane. This methane is not captured from the system and contributes to greenhouse gas emissions (approximately 5% of current positive emissions).

The proposed plant incorporates a new wastewater treatment system where 100% of biogas generated is captured for energy generation. This will effectively reduce greenhouse emissions by 31,000 tonnes per annum, and will recover 260 TJ annually, further reducing Shoalhaven Starches' consumption of fossil fuels.

Emissions savings resulting from the energy recovery from biogas are taken into account in the calculations. The combustion of the biogas has an emissions factor of zero tonnes of CO2-e per GJ and the fugitive emissions from the wastewater treatment plant are also zero. If the biogas capture and energy recovery were not undertaken, emissions would be considerably higher, since more natural gas would need to be purchased to meet energy needs, and methane would be released from the wastewater treatment plant. These avoided emissions result in the products from the plant having lower emissions intensities than they would otherwise.

5.1.3 Fuel use switching

Natural gas

The proposed plant will mainly use natural gas as the primary fuel source (refer to Table 4). Natural gas produces much lower greenhouse emissions than the amount of coal of equivalent energy. Using natural gas in the proposed plant instead of coal saves approximately 187,680 t CO2-e/a.

Coal

Following the plant expansion, 109 kt of coal will be used at Bomaderry (gross). Coal is a very emissions intensive fuel, and its use will create approximately 274,000 t CO2-e, or 34% of all gross emissions. If

the existing coal-fired boiler was replaced with a natural gas fired boiler, emissions could be reduced by around 81,000 t CO2-e (a reduction of 30% compared to the coal emissions, and 10% of the total gross emissions). Replacement of the coal-fired boiler has not been included in the current budget for the proposed plant.

Diesel

Shoalhaven Starches uses 660 kL of diesel fuel annually, and this volume will not change following the upgrade. This results in annual emissions of approximately 1,910 t CO2-e. By switching to a biodiesel blend, emissions could be reduced. A 10% biodiesel (canola) blend would result in total emissions of 1,880 t CO2-e, a reduction of 30 t CO2-e annually, or 0.004% of gross emissions. Any changes would be insignificant.

5.2 Indirect greenhouse gas minimisation

Indirect greenhouse gas emissions (ie: those generated off site as a result of ethanol production, such as electricity use) can be minimised at the Shoalhaven Starches site by:

» Purchase of renewable energy (GreenPower); and

» Using alternative feedstock.

5.2.1 Purchasing 100% GreenPower

As shown in Table 4 and Appendix B, current electricity consumption is 130 GWh. Following the upgrade, Shoalhaven Starches will reduce electricity consumption to 14 GWh purchased from the grid. 14 GWh accounts for 14,840 t CO2-e, or 1.8% of total gross emissions. Purchasing 100% accredited renewable energy, such as GreenPower would remove these emissions from the inventory. GreenPower is, however, considerably more expensive than standard grid electricity, and is considerably more expensive than purchasing external greenhouse emissions offsets:

» GreenPower costs approximately an additional 5 cents per kWh, which equates to an abatement cost of $47/ t CO2-e for NSW electricity; and

» There are a number of external greenhouse gas emissions offsets available on the market, which range in price from less than $10/ t CO2-e to more than $30/ t CO2-e. An average cost is approximately $15/t CO2-e.

Following the proposed upgrade, switching to 100% GreenPower would cost an estimated $0.7 million annually for the entire site (plant, farm and wastewater treatment plant). Offsetting electricity emissions through the purchase of offsets would cost an estimated $0.2 million annually (based on an assumed cost of $15/t CO2-e).

While the purchase of external offsets can be counted against emissions from any source, the use of GreenPower is limited to emissions associated with the use of electricity only. The cost to purchase GreenPower has not been included in the current budget for the proposed plant.

5.2.2 Alternative feedstock

Out of the top ten emission sources shown in Table 7, five are due to embodied energy in raw materials (flour, grain, millfeed, lime and sugar), which account for 32% of net positive emissions. Other possible grain-based feedstocks will have similar order of magnitude emissions. The only feasible way to

significantly reduce raw material emissions is by replacing grain and other premium agricultural products with waste products, which have much lower greenhouse intensities. It is highly unlikely that there would be sufficient agricultural waste products available to manufacture 3 ML of ethanol. Importing waste products to Bomaderry would also increase transportation emissions, since they would need to be sourced more widely that the proposed raw materials, and since they are less effective, a greater quantity would be required. It is not feasible to switch process feedstocks.

5.3 Offset residual emissions

Opportunities to offset residual greenhouse gas emissions are:

» Purchase of greenhouse offsets; and

» Establishment of offset projects such as plantation sinks.

5.3.1 Greenhouse offsets purchase

Net greenhouse emissions amount to 230,016 t CO2-e/a. These emissions could be offset by purchasing greenhouse offsets or credits. There are a number of offset/credit providers in the current marketplace, with an average offset cost of around $15/ t CO2-e. Costs to offset 100% net emissions amount to approximately $3.5 million annually. The cost to purchase offsets has not been included in the current budget for the proposed plant.

5.3.2 Plantation sinks

Another alternative is for Shoalhaven Starches to establish a tree plantation to offset emissions at a nearby or remote location. Approximately four trees per year are required to offset one tonne of CO2-e, so a one million tree plantation (over 1,000 hectares) would be required to offset the net emissions from the proposed plant per year. This option is not really feasible for Shoalhaven Starches as it is outside of core business and would be more cost effective to purchase offsets from existing plantation providers that are accredited under the DCC Greenhouse Friendly program or NSW Greenhouse Gas Reduction Scheme.

Approximately 4,000 trees have been planted on the environmental farm, and an additional 4,000 are planned, however, the order of magnitude of these plantings is far too small to have a significant impact on Shoalhaven Starches' net emissions.

Appendix A

Director-General Greenhouse Assessment Requirements

1. Director-General's Requirements (extract)
2. DECC Requirements (extract)

Appendix B

Emissions calculations

a) Baseline Inventory
b) Gross Inventory

Baseline Emissions Inventory - No Change from 2006/07 Scenario

Data	Value	Units	Scope 1 EF	Scope 2 EF	Scope 3 EF	Total EF	Units	Scope 1 Emissions	Scope 2 Emissions	Scope 3 Emissions	Total Emissions	Proportion of Total Inventory
	(Q)					(EF)		(t CO2-e)	(t CO2-e)	(t CO2-e)	(t CO2-e/a)	%
Raw Materials												
Wheat Grain (12% moisture)	66,089	t/a			0.299	0.299	t CO2-e/t grain	0	0	19,761	19,761	3.46%
Wheat Flour (12% moisture)	425,188	t/a			0.332	0.332	t CO2-e/t flour	0	0	141,162	141,162	24.71%
Mains Water	1,787	ML/a			0.2756	0.2756	t CO2-e/ML	0	0	492	492	0.09%
Raw Water	787	ML/a			0.02	0.02	t CO2-e/ML	0	0	14	14	0.003%
Sugar	0	t/a			0.18	0.18	t CO2-e/t	0	0	0	0	0.000%
Millfeed	0	t/a			0.33	0.33	t CO2-e/t	0	0	0	0	0.000%
Paper Packaging Materials	1	t/a			2.727	2.727	t CO2-e/t paper	0	0	4	4	0.001%
Plastic Packaging Materials	182	t/a			2.25	2.25	t CO2-e/t	0	0	410	410	0.07%
Ammonia 25%	977	t/a			0.758	0.758	t CO2-e/t	0	0	741	741	0.13%
Filter Aid	1,222	t/a			0.2842	0.2842	t CO2-e/t	0	0	347	347	0.06%
Hydrochloric Acid 33%	2,150	t/a			0.0923	0.0923	t CO2-e/t	0	0	198	198	0.03%
Lime	4,058	t/a			1.64	1.64	t CO2-e/t	0	0	6,655	6,655	1.17%
Liquid Caustic	3,875	t/a			0.845	0.845	t CO2-e/t	0	0	3,274	3,274	0.57%
Sodium Hypochlorite 13%	1,428	t/a			0.832	0.832	t CO2-e/t	0	0	1,188	1,188	0.21%
Sulphuric Acid 98%	770	t/a			0.0795	0.0795	t CO2-e/t	0	0	61	61	0.01%
Sulphuric Acid 50%	337	t/a			0.0795	0.0795	t CO2-e/t	0	0	27	27	0.005%
Total Raw Materials										**174,335**	**174,335**	**30.52%**
Transport to Bomaderry Site												
Wheat Grain (12% moisture)	66,089	t/a			6.43	6.43	kg CO2-e/t	0	0	425	425	0.07%
Wheat Flour (12% moisture)	425,188	t/a			6.02	6.02	kg CO2-e/t	0	0	2,560	2,560	0.45%
Millfeed	0	t/a			5.13	5.13	kg CO2-e/t	0	0	0	0	0.00%
Sugar	0	t/a			409.04	409.04	kg CO2-e/t	0	0	0	0	0.00%
Coal	105,000	t/a			45.05	45.05	kg CO2-e/t	0	0	4,730	4,730	0.83%
Diesel	660	kL/a			14.38	14.38	kg CO2-e/kL	0	0	9	9	0.00%
Chemicals transport	16,636	t/a			76.14	76.14	kg CO2-e/t	0	0	1,267	1,267	0.22%
Paper Packaging Materials	1	t/a			39.68	39.68	kg CO2-e/t	0	0	0.1	0.1	0.00001%
Plastic Packaging Materials	182	t/a			63.14	63.14	kg CO2-e/t	0	0	11	11	0.002%
Total Transportation to Bomaderry										**9,003**	**9,003**	**1.58%**

Data	Value	Units	Scope 1 EF	Scope 2 EF	Scope 3 EF	Total EF	Units	Scope 1 Emissions	Scope 2 Emissions	Scope 3 Emissions	Total Emissions	Proportion of Total Inventory
	(Q)					(EF)		(t CO2-e)	(t CO2-e)	(t CO2-e)	(t CO2-e/a)	%
Manufacture at Bomaderry												
Electricity (plant)	128,495,869	kWh/a		0.89	0.17	1.06	kg CO2-e/kWh	0	114,361	21,844	136,206	23.85%
Electricity (farm)	1,414,943	kWh/a		0.89	0.17	1.06	kg CO2-e/kWh	0	1,259	241	1,500	0.26%
Electricity (WWTP)	0	kWh/a		0.89	0.17	1.06	kg CO2-e/kWh	0	0	0	0	0.00%
Natural Gas	168,536	GJ	51.3		14.2	65.5	kg CO2-e/GJ	8,646	0	2,393	11,039	1.93%
Coal	2,835,000	GJ/a	88.5		4.6	93.1	kg CO2-e/GJ	250,898	0	13,041	263,939	46.21%
Diesel (transportation)	660	kL/a	2.7		0.2	2.9	t CO2-e/kL	1,782	0	132	1,914	0.34%
Waste Disposal (Comingled)	624	t/a			0.9	0.9	t CO2-e/t waste	0	0	562	562	0.10%
Wastewater Treatment	14,490,500	kg COD/a	2.13			2.13	kg CO2-e/kg COD	30,810	0	0	30,810	5.39%
Total Manufacture at Bomaderry								**292,136**	**115,621**	**38,213**	**445,969**	**78.08%**
Transportation of Products, By-Products and Wastes												
Starch	119,673	t/a			113.40	113.40	kg CO2-e/t	0	0	13,571	13,571	2.38%
Gluten	60,131	t/a			74.92	74.92	kg CO2-e/t	0	0	4,505	4,505	0.79%
Glucose	37,373	t/a			107.29	107.29	kg CO2-e/t	0	0	4,010	4,010	0.70%
Gemspray	1,703	t/a			64.09	64.09	kg CO2-e/t	0	0	109	109	0.02%
Brewers' syrup	16,107	t/a			143.93	143.93	kg CO2-e/t	0	0	2,318	2,318	0.41%
Ethanol - Fuel	44,394	t/a			162.51	162.51	kg CO2-e/t	0	0	7,215	7,215	1.26%
Ethanol - Industrial	24,939	t/a			114.15	114.15	kg CO2-e/t	0	0	2,847	2,847	0.50%
Stillage	105,612	t/a			33.99	33.99	kg CO2-e/t	0	0	3,590	3,590	0.63%
Liquid CO2	16,562	t/a			26.07	26.07	kg CO2-e/t	0	0	432	432	0.08%
Solid Waste	624	t/a			26.20	26.20	kg CO2-e/t	0	0	16	16	0.00%
Total Product Transportation										**38,613**	**38,613**	**6.76%**
Usage - Fuel Ethanol												
Ethanol Fuel Blend Combustion	56,550	kL/a			-1.71	-1.71	t CO2-e/kL			-96,730	-96,730	-16.93%
Total Usage										**-96,730**	**-96,730**	**-16.93%**
Total Greenhouse Gas Emissions								**292,136**	**115,621**	**163,433**	**571,190**	

Gross Emissions Inventory - Following Upgrade
Operational Emissions Including Construction and Decommissioning

Data	Value	Units	Scope 1 EF	Scope 2 EF	Scope 3 EF	Total EF	Units	Scope 1 Emissions	Scope 2 Emissions	Scope 3 Emissions	Total Emissions	Proportion of Total Inventory
	(Q)					(EF)		(t CO2-e)	(t CO2-e)	(t CO2-e)	(t CO2-e/a)	%
Raw Materials												
Wheat Grain (12% moisture)	290,000	t/a			0.299	0.299	t CO2-e/t grain	0	0	86,710	86,710	10.82%
Wheat Flour (12% moisture)	772,200	t/a			0.332	0.332	t CO2-e/t flour	0	0	256,370	256,370	32.00%
Mains Water	2,080	ML/a			0.276	0.276	t CO2-e/ML	0	0	573	573	0.07%
Raw Water	800	ML/a			0.018	0.018	t CO2-e/ML	0	0	15	15	0.002%
Sugar	70,000	t/a			0.179	0.179	t CO2-e/t	0	0	12,512	12,512	1.56%
Millfeed	90,000	t/a			0.332	0.332	t CO2-e/t	0	0	29,880	29,880	3.73%
Paper Packaging Materials	1,200	t/a			2.727	2.727	t CO2-e/t paper	0	0	3,272	3,272	0.41%
Plastic Packaging Materials	7	t/a			2.250	2.250	t CO2-e/t	0	0	16	16	0.00%
Ammonia 25%	3,369	t/a			0.758	0.758	t CO2-e/t	0	0	2,554	2,554	0.32%
Filter Aid	1,222	t/a			0.284	0.284	t CO2-e/t	0	0	347	347	0.04%
Hydrochloric Acid 33%	2,946	t/a			0.092	0.092	t CO2-e/t	0	0	272	272	0.03%
Lime	13,992	t/a			1.640	1.640	t CO2-e/t	0	0	22,947	22,947	2.86%
Liquid Caustic	5,099	t/a			0.845	0.845	t CO2-e/t	0	0	4,309	4,309	0.54%
Sodium Hypochlorite 13%	1,445	t/a			0.832	0.832	t CO2-e/t	0	0	1,202	1,202	0.15%
Sulphuric Acid 98%	2,653	t/a			0.080	0.080	t CO2-e/t	0	0	211	211	0.03%
Sulphuric Acid 50%	1,163	t/a			0.080	0.080	t CO2-e/t	0	0	92	92	0.01%
Total Raw Materials								**0**	**0**	**421,284**	**421,284**	**52.58%**
Transport to Bomaderry Site												
Wheat Grain (12% moisture)	290,000	t/a			6.4	6.4	kg CO2-e/t	0	0	1,866	1,866	0.23%
Wheat Flour (12% moisture)	772,200	t/a			5.8	5.8	kg CO2-e/t	0	0	4,458	4,458	0.56%
Millfeed	90,000	t/a			5.1	5.1	kg CO2-e/t	0	0	462	462	0.06%
Sugar	70,000	t/a			409.0	409.0	kg CO2-e/t	0	0	28,632	28,632	3.57%
Coal	109,000	t/a			45.0	45.0	kg CO2-e/t	0	0	4,910	4,910	0.61%
Diesel	660	kL/a			14.4	14.4	kg CO2-e/kL	0	0	9	9	0.001%
Chemicals transport	37,859	t/a			72.3	72.3	kg CO2-e/t	0	0	2,736	2,736	0.34%
Paper Packaging Materials	1,200	t/a			39.7	39.7	kg CO2-e/t	0	0	48	48	0.01%
Plastic Packaging Materials	7	t/a			63.1	63.1	kg CO2-e/t	0	0	0.4	0.4	0.0001%
Total Transportation to Bomaderry								**0**	**0**	**43,122**	**43,122**	**5.38%**

Data	Value	Units	Scope 1 EF	Scope 2 EF	Scope 3 EF	Total EF	Units	Scope 1 Emissions	Scope 2 Emissions	Scope 3 Emissions	Total Emissions	Proportion of Total Inventory
	(Q)					(EF)		(t CO2-e)	(t CO2-e)	(t CO2-e)	(t CO2-e/a)	%
Manufacture at Bomaderry												
Electricity (plant)	14,000,000	kWh/a		0.89	0.17	1.06	kg CO2-e/kWh	0	12,460	2,380	14,840	1.85%
Electricity (farm)	0	kWh/a		0.89	0.17	1.06	kg CO2-e/kWh	0	0	0	0	0.00%
Electricity WWTP	0	kWh/a		0.89	0.17	1.06	kg CO2-e/kWh	0	0	0	0	0.00%
Natural Gas	6,800,000	GJ	51.3		14.2	65.5	kg CO2-e/GJ	348,840	0	96,560	445,400	55.59%
Coal	2,943,000	GJ/a	88.5		4.6	93.1	kg CO2-e/GJ	260,456	0	13,538	273,993	34.20%
Diesel (transportation)	660	kL/a	2.7		0.2	2.9	t CO2-e/kL	1,782	0	132	1,914	0.24%
Waste Disposal (Comingled)	624	t/a			0.9	0.9	t CO2-e/t waste	0	0	562	562	0.07%
Wastewater Treatment	3.1	ML/day	0.00			0	t CO2-e/ML	0	0	0	0	0.00%
Total Manufacture at Bomaderry								**611,078**	**12,460**	**113,171**	**736,709**	**91.95%**
Transportation of Products, By-Products and Wastes												
Starch	188,240	t/a			113.4	113.4	kg CO2-e/t	0	0	21,346	21,346	2.66%
Gluten	109,652	t/a			74.9	74.9	kg CO2-e/t	0	0	8,216	8,216	1.03%
Glucose	60,000	t/a			107.3	107.3	kg CO2-e/t	0	0	6,437	6,437	0.80%
Gemspray	1,703	t/a			64.1	64.1	kg CO2-e/t	0	0	109	109	0.01%
Brewers' syrup	16,000	t/a			143.9	143.9	kg CO2-e/t	0	0	2,303	2,303	0.29%
Ethanol - Fuel	213,030	t/a			49.7	49.7	kg CO2-e/t	0	0	10,580	10,580	1.32%
Ethanol - Industrial	24,916	t/a			114.2	114.2	kg CO2-e/t	0	0	2,844	2,844	0.35%
Stillage	245,000	t/a			34.0	34.0	kg CO2-e/t	0	0	8,329	8,329	1.04%
Liquid CO2	56,841	t/a			26.1	26.1	kg CO2-e/t	0	0	1,482	1,482	0.18%
Solid Waste	624	t/a			26.2	26.2	kg CO2-e/t	0	0	16	16	0.002%
Total Product Transportation								**0**	**0**	**61,662**	**61,662**	**7.70%**
Usage - Fuel Ethanol												
Ethanol Fuel Blend Combustion	270,000	kL/a			-1.71	-1.71	t CO2-e/kL	0	0	-461,842	-461,842	-57.64%
Total Usage								**0**	**0**	**-461,842**	**-461,842**	**-57.64%**
Construction of Plant Expansion ***Materials and EFs are for total construction. Scope 1, 2 and 3 emissions have been annualised over 30 years.***												
Materials												
Concrete and Reinforcement	3,480	t			0.142	0.142	t CO2-e/t	0	0	16	16	0.002%
Structural Steel	1,260	t			1.72	1.72	t CO2-e/t	0	0	72	72	0.01%
Stainless Steel	455	t			3.67	3.67	t CO2-e/t	0	0	56	56	0.01%

Data	Value	Units	Scope 1 EF	Scope 2 EF	Scope 3 EF	Total EF	Units	Scope 1 Emissions	Scope 2 Emissions	Scope 3 Emissions	Total Emissions	Proportion of Total Inventory
	(Q)					(EF)		(t CO2-e)	(t CO2-e)	(t CO2-e)	(t CO2-e/a)	%
Roof Material	22	t			1.72	1.72	t CO2-e/t	0	0	1	1	0.0002%
Piping and Racking	375	t			2.935	2.935	t CO2-e/t	0	0	37	37	0.005%
Electrical Cabling	87	t			5.58	5.58	t CO2-e/t	0	0	16	16	0.002%
Processing Equipment	1,270	t			2.17	2.17	t CO2-e/t	0	0	92	92	0.01%
Equipment Use												
Cranes	3,850	hrs	27.0		2.0	29.0	kg CO2-e/hr	3	**0**	0.3	4	0.0005%
Trucks	2,010	hrs	81.0		6.0	87.0	kg CO2-e/hr	5	**0**	0.4	6	0.001%
Forklifts	1,360	hrs	6.8		0.5	7.3	kg CO2-e/hr	0.3	**0**	0.02	0.3	0.00004%
Access Towers	1,760	hrs	8.1		0.6	8.7	kg CO2-e/hr	0.5	**0**	0.04	1	0.0001%
Earthmoving equipment	1,320	hrs	28.4		2.1	30.5	kg CO2-e/hr	1	**0**	0.1	1	0.0002%
Total Construction								**11**	**0**	**291**	**302**	**0.04%**
Decommissioning of Plant Expansion ***Materials and EFs are for total construction. Scope 1, 2 and 3 emissions have been annualised over 30 years.***												
Material Disposal												
Concrete and Reinforcement recycling	2,088	t			-0.0125	-0.0125	t CO2-e/t	**0**	**0**	-1	-1	-0.0001%
Structural Steel recycling	882	t			-0.98	-0.98	t CO2-e/t	**0**	**0**	-29	-29	-0.004%
Stainless Steel recycling	319	t			-0.98	-0.98	t CO2-e/t	**0**	**0**	-10	-10	-0.001%
Equipment Use												
Cranes	770	hrs	27.0		2.0	29.0	kg CO2-e/hr	1	**0**	0.1	1	0.0001%
Trucks	1,710	hrs	81.0		6.0	87.0	kg CO2-e/hr	5	**0**	0.3	5	0.001%
Forklifts	540	hrs	6.8		0.5	7.3	kg CO2-e/hr	0.1	**0**	0.01	0.1	0.00002%
Access Towers	590	hrs	8.1		0.6	8.7	kg CO2-e/hr	0.2	**0**	0.01	0.2	0.00002%
Shears	1,320	hrs	6.2		0.5	6.7	kg CO2-e/hr	0.3	**0**	0.02	0.3	0.00004%
Concrete Breakers	740	hrs	28.4		2.1	30.5	kg CO2-e/hr	1	**0**	0.1	1	0.0001%
Earthmoving Equipment	2,180	hrs	28.4		2.1	30.5	kg CO2-e/hr	2	**0**	0.2	2	0.0003%
Total Decommissioning								**9**	**0**	**-39**	**-31**	**-0.005%**
Total Greenhouse Gas Emissions								**611,097**	**12,460**	**177,649**	**801,206**	

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Document Status

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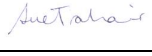
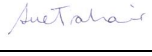
Draft	F Orton	S Trahair		S Trahair		26/3/08
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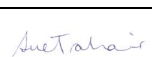
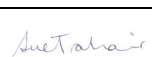
Revised Final	F Orton	S Trahair		S Trahair		1/8/08