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Report

on

Life Cycle Assessment

for

Bealiba Victoria

June 2010

file 437A

Life Cycle Assessment of GeoBrick product range and comparison with traditional clay fired bricks.

Prepared for:
GeoBrick and Sustainability Victoria

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Disclaimer
We have endeavoured to make our analysis transparent and to make clear where data and other inputs have been sourced.
Where results are derived from data provided by the client or referenced authorities, the accuracy of the results will rely on the accuracy of that source data.
This document reports on the comparison of the life cycle impacts of the manufacture of the GeoBrick range of bricks and typical traditional fired clay bricks. This report does not recommend GeoBricks or traditional bricks for any particular application. Anyone needing to select building materials and products for a specific application should seek appropriate professional advice which considers the particular circumstances of the building project.

Feedback
We will be happy to receive feedback regarding the data, analysis and conclusions in this report (email to genesis@genesisnow.com.au or phone 1800 22 99 11).

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Executive Summary

The aim of this paper is to determin the greenhouse gas emissions of the GeoBrick Geo12 brick, calculate the expected LCA emissions for GeoBrick Geo16 and compare these figures with a traditional kiln fired brick..
A detailed analysis of the GeoBrick operations was undertaken to measure its natural resource inputs and associated environmental emissions due to its operations. Measurements were taken and then converted into greenhouse gas emissions and recorded.

The system boundary is cradle-to-gate which starts with the extraction of raw materials on-site to the storage of final products ready for transport to the building site.

The comparison with traditional kiln fired bricks relies on data have been collected from public documents including LCA assessments and published greenhouse emission factors.

GeoBrick bricks are similar in size, mass, strength, colour and cost to traditional bricks, but differ in manufacture. The GeoBrick brick is not kiln fired and relies on a stabiliser that allows the brick to dry naturally under the sun.
Life Cycle Assessment (LCA) has been used to determine and compare the potential environmental impacts of a GeoBrick brick and a traditional kiln fired brick.

LCA is an internationally accepted approach that provides detailed and independent environmental information on the life-cycle of products to stakeholders. LCA is also widely used as a basis for determining the consequential carbon dioxide emissions (that contribute to global warming) associated with the provision of a product or service.

The main objective of this paper was to calculate the environmental impacts (in particular greenhouse gas emissions) associated with the production of a brick made from GeoBricks unique operations, so that its environmental performance may be compared fairly with that of a traditional kiln fired brick.

Further objectives of this paper are:

- to compare against other GeoBrick types. (Geo2, 4, 8, 12 & 16)
- potentially to identify areas within the production of a GeoBrick that could be improved further.

Conclusions

The final results table per Standard Brick Equivalent (SBE) are:

Brick Type	**kg CO_2.e per (SBE)**	**% Reduction**	**litres of water per (SBE)**	**% Reduction**
GeoBrick16	0.41	33	0.28	44
Traditional Brick	0.61		0.5	

Table 1 Embodied CO_2 and water, GeoBrick 16 and traditional kiln-fired brick

The GeoBrick Geo16 type brick has 33 % less CO_2e emissions per brick than a traditional kiln fired brick.

Methodology

The methodology followed in this report is consistent with the ISO14040 series of standards. The following steps were undertaken:

1. Develop the goal and scope definition of the analysis
2. Establish the function, functional unit and reference flows
3. Clearly identify the system boundary
4. Identify the data quality requirements
5. Discuss the data collection method
6. Clearly show all data calculations
7. Discuss any allocation of flows and releases
8. Identify any limitations
9. Interpret the findings of the inventory analysis and impact assessments
10. Report on the findings
11. Critically review the methodology

Figure 1 View of the GeoBrick office at their operations in Bealiba, Central Victoria.

1. Introduction

Embodied Energy in Building Materials

CSIRO has concluded that the embodied energy in the materials and appliances used in housing can equal 12 – 20 years of operating energy for the dwelling[1].

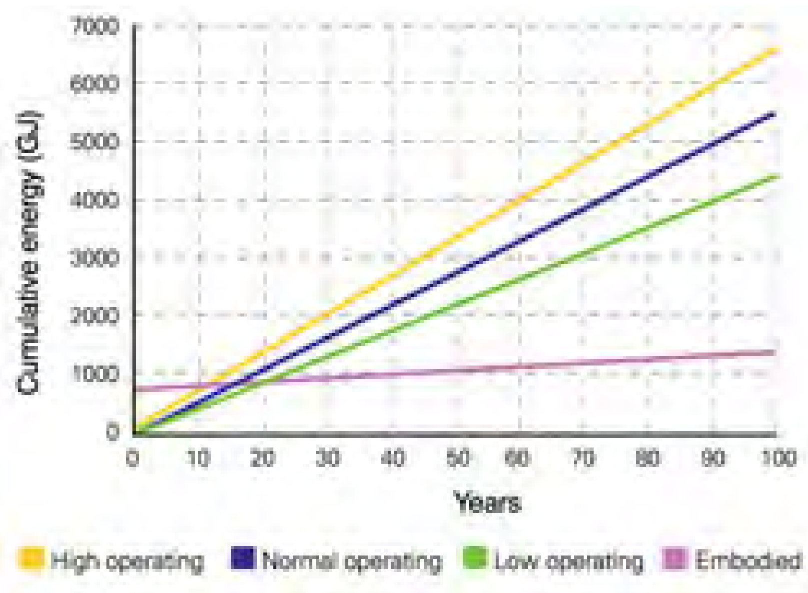

Figure 2 Embodied and operational energy of housing

Since this analysis was conducted, the community has focused on reducing operational energy in housing, but the following trends have tended to increase the embodied energy:

- increasing dwelling size,
- shorter dwelling life, as higher land prices encourage the demolition and replacement of dwellings, and
- decreasing number of people per dwelling (though in 2010 there was a slight reversal in this trend).

[1] see www.yourhome.gov.au/technical/fs52.html, accessed June 2010.

1.1 Background

Product description & function

Description of the product:	A brick for use in residential construction

Company background

Geo Brick reflects the owners' love of the Australian bush and passionate concerns about global warming.

The Company's quarries and brickworks sit astride Puzzle Flat reef in the historic goldfields of Central Victoria, at Bealiba, not far from Dunolly. Here, in 1857, Australia's largest gold nugget was discovered - the Welcome Stranger.

"For years we've wanted to make an environmentally friendly brick, and one which captures the subtle colours of the clays here - soft ochres, grey-pinks, mauves, grey-greens and straw - the colours you see in the old gold country here and which is reflected in the trees and wildflowers of the district and all over Australia."

The Company backs up its environmental concerns by an extensive re-afforestation program on all its quarry sites.

"We want to lead the way. I hope we can make a significant contribution to a more sustainable future, and provide Australian suburbs and townscapes with attractive dwellings which blend naturally and beautifully with our natural environment."

Geo Brick produce bricks suitable for the domestic housing market. All raw materials are extracted on-site. Crushing, mixing and brick pressing then storage are carried out on-site.

Geo Brick is clearly demonstrating sustainable brick manufacturing practices. This report assesses the environmental inputs to the manufacturing process.

Geo Brick produce several types of bricks. Geo 2, 4, 8, 12 & 16. The stabiliser in the brick is cement. Geo 16 has the highest quantity of cement and hence reflects the highest embodied emissions.

1.2 Process Description

Geo Brick extracts raw materials from an old gold mining site located approx 0.5 km from the brick works. Contractors are engaged to extract the raw material as it is needed using excavators and bulldozers. The operations are currently running batches of bricks dependent on orders.

The raw materials are then crushed and screened. The material is then mixed with cement, water and water repellent into specific batch sizes. The bricks are then pressed, stacked and stored on-site for one month before they are ready for transport to the building site.

Figure 3 View of the GeoBrick batch mixing machinery at their operations in Bealiba.

The GeoBrick process can be visualised by the simple flow diagram shown in Figure 1 shown on the following page.

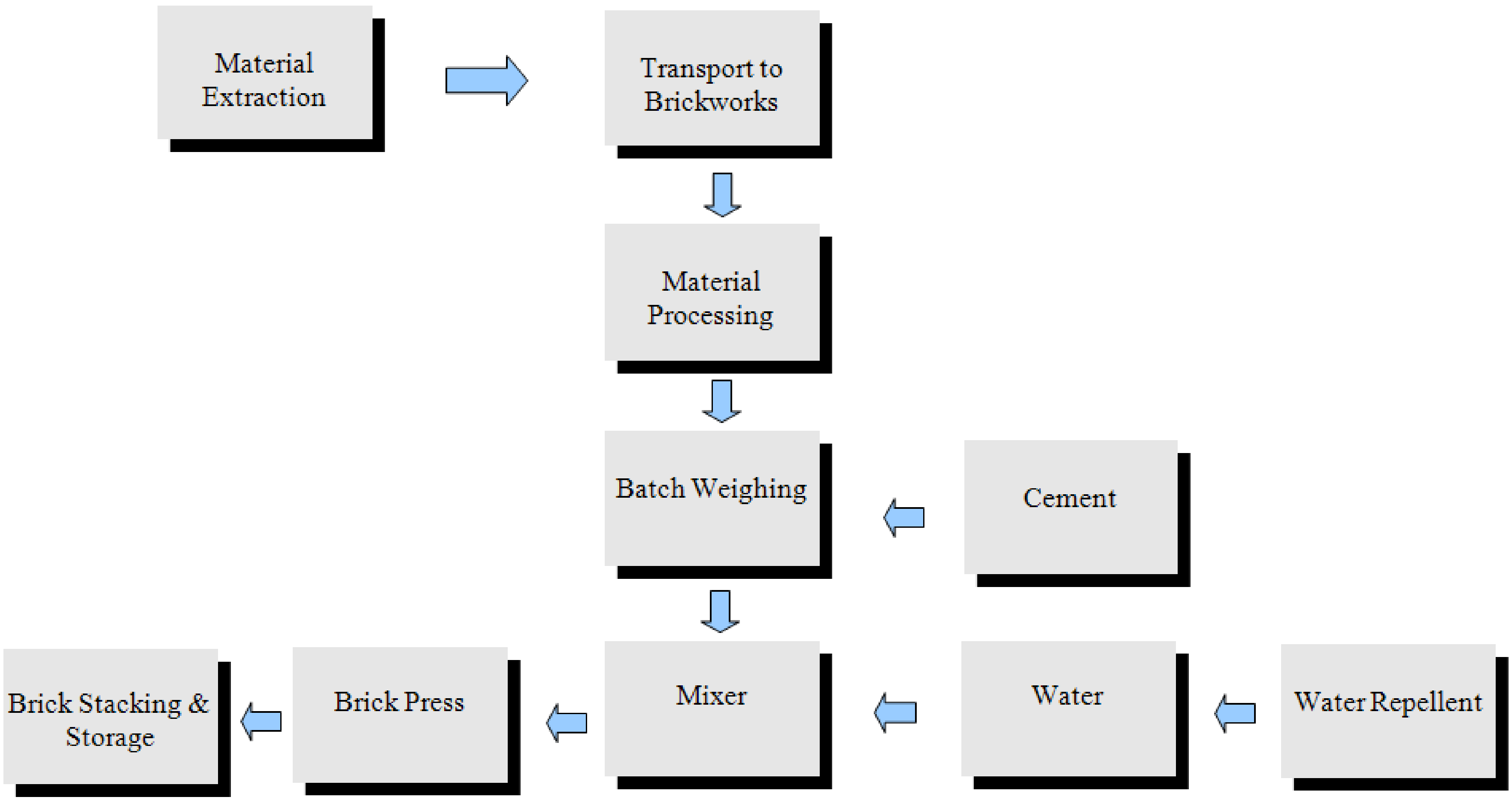

Figure 4 Flow diagram of the GeoBrick process

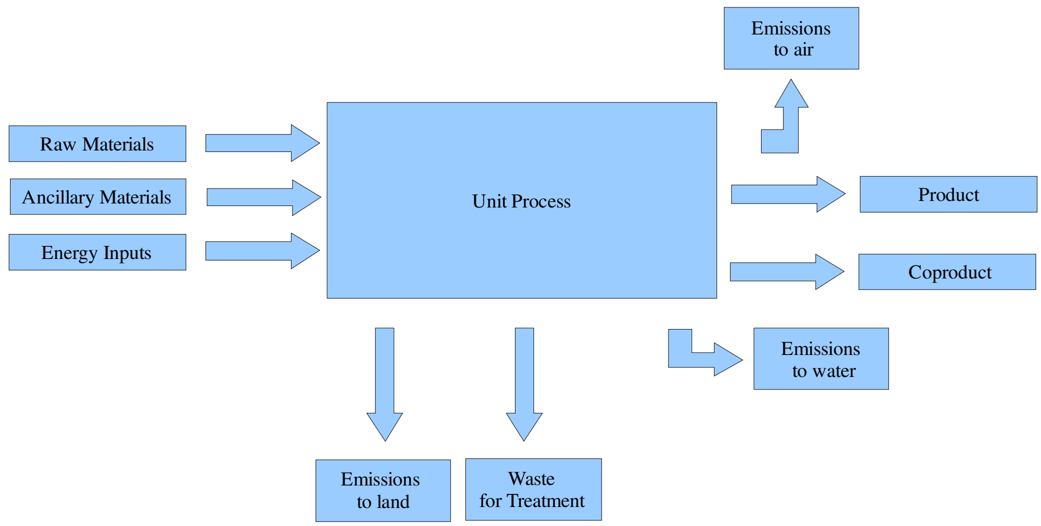

Figure 5 Process Inputs/Outputs

Figure 2 shows the basic flow of materials through the GeoBrick process.

The quantities for each flow is shown in Table 1 below:

NB: A batch is 27,147 bricks. The brick type was a Geo12.

Input	Material Category	Unit	Quantity per batch of 27,147 bricks
Raw Materials	Product from other system	kg	81,429
Cement	Product from other system	kg	8,550
Pallets	Product from other system	kg	1700
Electricity	Intermediate Product.	kW.h	268
Diesel (Materials)	Intermediate Product	litres	43.95
Diesel (Operations)	Intermediate Product	litres	27.15
Water Repellent	Product from other system	litres	41
Black Plastic	Product from other system	kg	25
Water	Product from other system	kilolitres	7.64
Output			
Brick	Intermediate Product	SBE	10,000
Carbon Dioxide; Emission to atmosphere	Elementary Flow	kg	7600

Table 2 Material Flow Quantities

2. Life Cycle Assessment

The aim of the LCA is to identify and quantify all greenhouse gas emissions attributable to the brick manufacturing operations. This includes those from the production of raw materials, their transport to the site, all direct and indirect emissions from manufacture.

The LCA has been prepared in accordance with the general framework, principles and requirements for conducting and reporting LCA studies outlined in the current Australian Standard for LCA in the ISO 14040 series.

Abbreviations

Table 3 Abbreviations

CO_2-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)
EF	Emission Factor
HFCs	Hydrofluorocarbons
ISO	International Standards Organisation
kg	kilogram
kL	kilolitre
kW.h	kilowatt hour
LCA	Life Cycle Assessment
LPG	Liquefied Petroleum Gas
MPa	Million Pascals. Measure of force per unit area.
MJ	Mega Joule
ML	Megalitre
NGA	National Greenhouse Accounts, (Factors June 2009)
SBE	Standard Brick Equivalent

2.1 Scope of the LCA

Life Cycle of the Product

This LCA analysis examines the emissions associated with the production of raw materials, their transport to the processing and manufacturing site, all direct and indirect emissions from manufacture. The scope of this analysis stops at the factory gate, i.e. it excludes the transport of bricks from the factory to the customer.[2] The analysis is a cradle-to-gate assessment. Scope 2 & 3 embodied emissions due to the use of utilities and input products have been included where applicable.

The assessment is based on a typical brick suitable for the domestic housing market.

Dimensions = 76mm x 110mm x 230mm

Mass = 3.4 kg

MPa = 25

Figure 6 Photo of a GeoBrick brick.

The assessment is based on a Standard Brick Equivalent (1 SBE). A lot of 10,000 SBE's is also included to represent a standard domestic house size.

The Geo 16 brick is to be compared against the traditional kiln fired brick. Considerations will also be made for the other products. Geo2, 4, 8 & 12.

[2] Transport has been excluded mainly because there is insufficient data on the distance which traditional bricks are transported from factory to customer. The distance can vary widely, depending on the brick type purchases and where that brick is produced. Brick manufacturers with multiple factories may offer bricks made in their factories which are not the closest factory to the customer, and so can transport bricks thousands of kilometres. (We understand the industry is working to reduce this practice, by reducing the range of bricks offered in each region). As Geo Brick services mainly Melbourne and closer customers, we believe that it is reasonable to assume Geo Bricks have no greater transport requirements than traditional bricks.

Life cycle stages for the product

The life cycle stages for the service considered in this LCA are:

- Raw materials – Products, energy and materials required to extract the raw materials;
- Delivery of raw materials to the site;
- Manufacture of the brick and associated input resources;
- Manufacture and delivery of packaging and storage materials;
- Manufacture of cement.

The emissions sources (material and energy flows) that fall under each of these life cycle stages are illustrated below : Life Cycle Stages for production

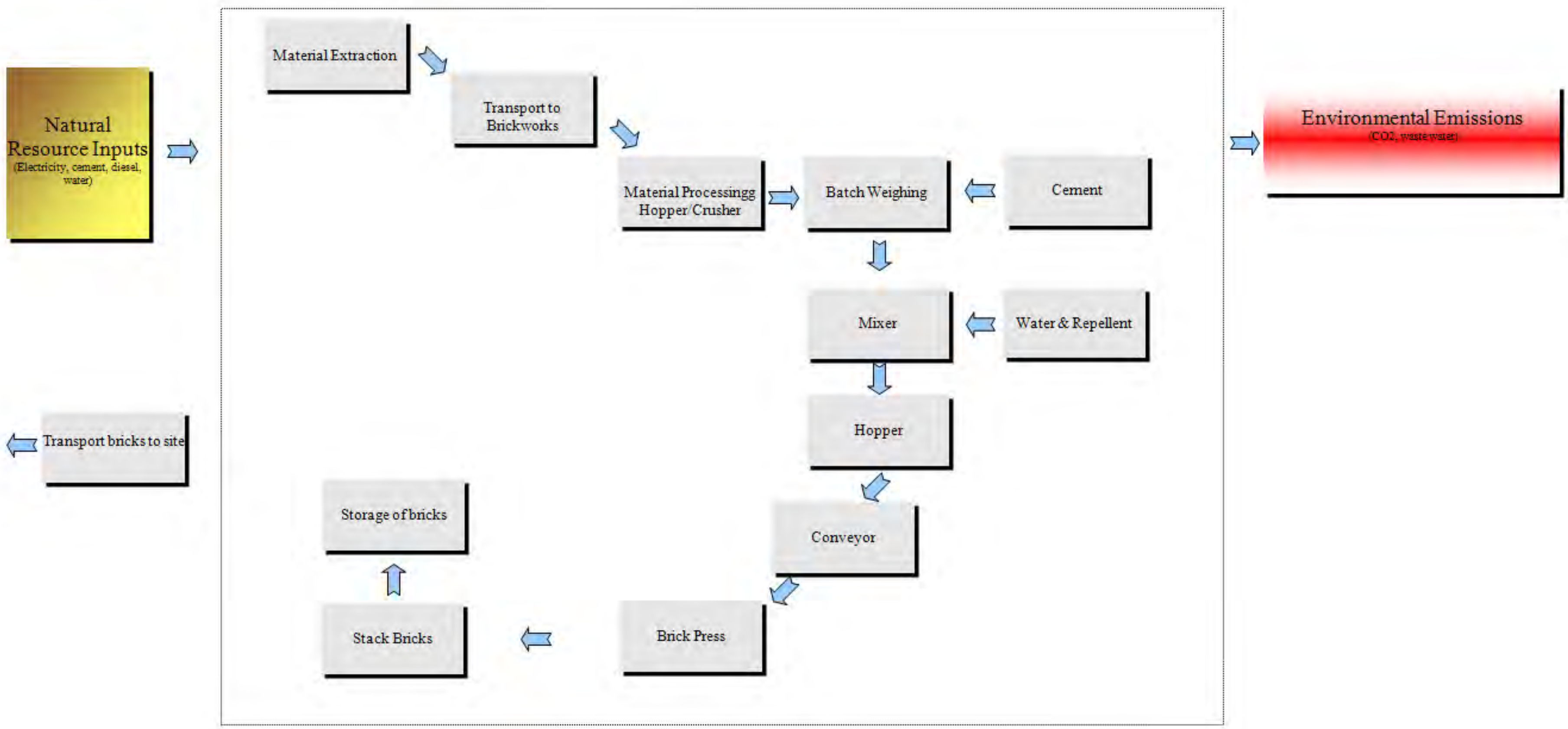

Figure 7 Emission sources and material flows

LCA Boundaries

System boundaries and geographic limitations

The system boundary is the inputs and outputs of each of the identified life cycle stages.

The identified life cycle stages include:

Raw Material Extraction

Transport to brickworks

Bunker

Material processing

- Loader to bunker
- Collection in a hopper
- Conveyor
- Crusher
- Stockpile

Loader to Hopper

Batch weighing

- Cement addition

Mixer

- Water & Repellent addition

Hopper

Conveyor

Brick Press

Forklift

Brick Storage

Material Extraction and Processing

1 Raw Material Extraction
2 Transport to brickworks
3 Material processing
4 Collection in a hopper
5 Crusher
6 Conveyor
7 Stockpile
8 Loader to Bunker
9 Bunker Storage

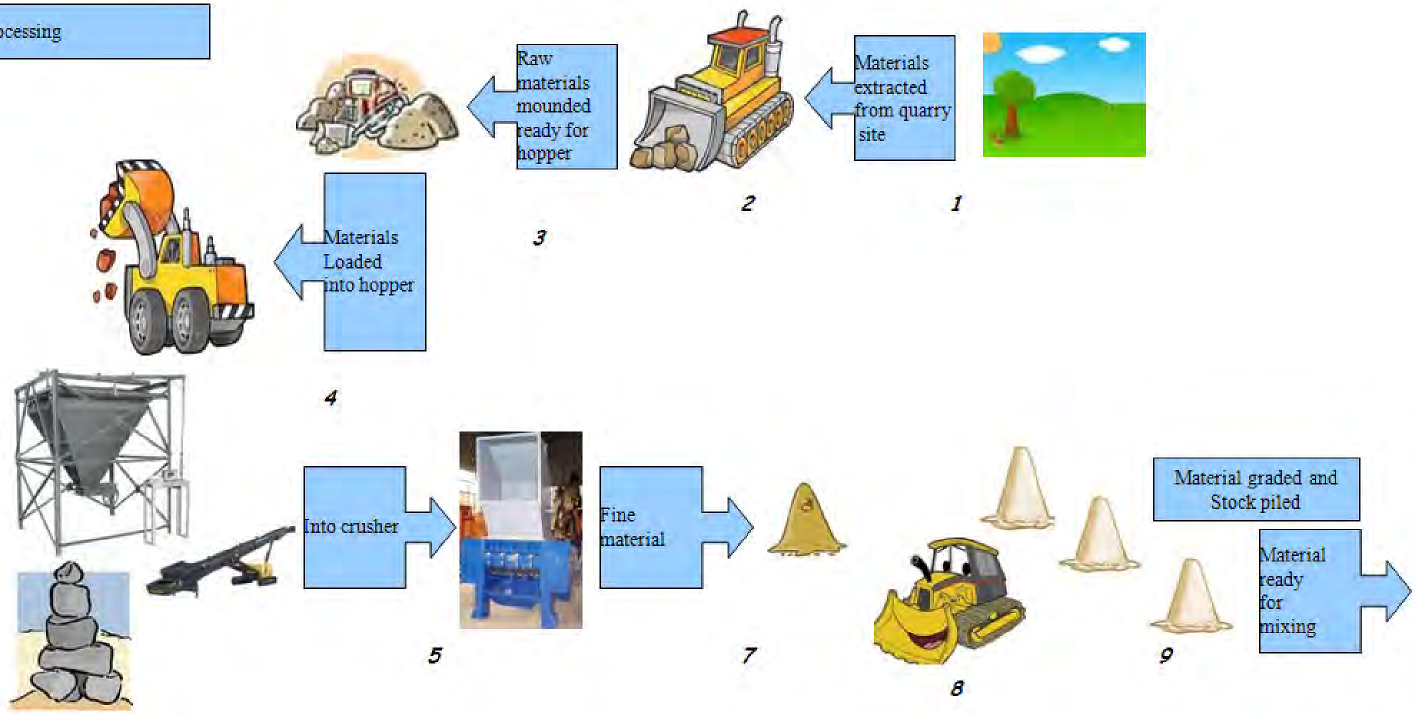

Figure 8 GeoBrick process flow (Material Extraction and Processing)

Figure 9 GeoBrick process flow (Brick Making)

Aspects of energy use to be considered

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

- Energy required to produce and prepare raw materials for product manufacture;
  - Diesel use
- Energy required for operations at the brick works;
  - Electricity use
  - Diesel use
- Energy required for storage (moving bricks)
  - Diesel use
- Embodied energies in the resources brought into the operations.
  - Cement
  - Plastic
  - Wooden Pallets

Measurable parameters

The measurable parameters that will be used and justification for inclusion are set out in Table 2.

Table 4Measurable parameters included in the LCA

Emission source	Reason for inclusion
Raw Materials	
Cement	Used as a stabiliser in the brick. Emissions are associated with the manufacture of this product.
Pallets	Used to store and transport bricks to building site. (Reused 10 times)
Water Repellent	Used to protect brick from moisture once installed.
Black Plastic LDPE	Plastic is used to help protect the bricks from rain when stored on-site. (Reused 8 times)
Site Inputs and Utilities	
Mains water	Electricity is required to deliver mains water to the brickworks.
Electricity	Scope 2 and 3 as per NGA guidelines and is used to operate the majority of the machinery on-site.
Transportation of Materials and Product	
Transportation of raw materials to brick works and product around facility	Diesel plant is used in extracting the raw materials and vehicles delivering to the brick works. Movement within the brickworks also includes diesel plant consumption.

The LCA boundaries and measurable parameters are thus consistent with the AS/NZS ISO 14040 family of standards.

Greenhouse gases considered

The greenhouse gases considered in this LCA are:

- Carbon dioxide;
- Nitrous oxides;
- Methane;
- Hydrofluorocarbons (HFCs).
- perfluorocarbons
- sulphur hexafluoride

Exclusions and Limitations

Exclusions

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

- Embodied energies and resource use in the manufacture and supply of any capital assets on-site
- Embodied energies and resource use in the manufacture and supply of the machinery on-site
- Emissions associated with employees/contractors attending work site
- Emissions associated with the manufacture, supply and operation of the domestic house located on-site
- Emissions from the large collection of wood stored on-site by previous owners.
- Transport emissions from delivering bricks to the building site
- Emissions due to land clearing for raw material extraction.

Critical Review

ISO 14044 states that critical reviews on LCA studies by internal or external experts should be undertaken when "the results are intended to be used to support a comparative assertion intended to be disclosed to the public".

Several reviews have been undertaken for this paper.

Preparation and commissioning by Glenn MacMillan, GenesisNow.

Client review by Rory Stainton, GeoBrick

Stakeholder review by Rodney Pugh/Andrew Haus, Sustainability Victoria

Independent Internal Review by Phil Pomaroff & Geoff Andrews, GenesisNow

2.2 Inventory Analysis

Data Collection and Calculation Procedures

A full description of data collection procedures, by life cycle stage as described in Section 2 "Scope" is given below for each measurable parameter:

Emission factors that are used in the LCA calculations are outlined in Appendix 1. Where possible, factors have been sourced from the most current *Department of Climate Change NGA Factors* (June 2009). If factors have been sourced elsewhere then evidence, references and documentation to demonstrate that the factors are relevant and accurate have been provided.

All energy consumption data has been converted into quantities of carbon dioxide equivalent emissions for each life cycle stage of the service, as shown in Appendix 1. 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.

Uncertainties have been estimated on the basis of the following matrix:

Data Collection / Calculation Methodology	Low	Medium	High
Low	5%	10%	15%
Medium	10%	15%	20%
High	15%	20%	25%

Table 5 Uncertainties matrix

All uncertainties are then combined in the Emissions Calculator using the following equation[3]:

$$U_{total} = \frac{\sqrt{(U_1 \bullet x_1)^2 + (U_2 \bullet x_2)^2 + \ldots + (U_n \bullet x_n)^2}}{x_1 + x_2 + \ldots + x_n}$$

Where:

U_{total} is the percentage uncertainty in the sum of the quantities (half the 95% confidence interval divided by the total (i.e. mean) and expressed as a percentage); and

x_i and U_i are the uncertain quantities and the percentage uncertainties associated with them, respectively.

[3] Equation 6.3, IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas inventories,

Data Collection Methodology

Data has been collected on a batch basis. A batch consists of extracting raw materials, processing materials, mixing cement and water then pressing the bricks for a specific order. The following table outlines the quantities of each variable. The functional unit, 10,000 SBE's has simply been proportioned from the total bricks produced from one batch run. The batch under assessment is for a Geo12 brick.

Item	Description	Unit	Quantity	Per SBE	Per 10,000 bricks
1	Bricks Produced	SBE	27,147	1.000	10000
2	Processed Raw Materials	kg	81,429	2.999	29996
3	Electricity	W.h	268000	9.87	98722
4	Cement	kg	8,550	0.315	3150
5	Water Repellent	litres	41	0.0015	15.1
6	Diesel (Materials)	litres	43.49	0.0016	16.02
7	Diesel (Operations)	litres	27.15	0.0010	10
8	Water	litres	7635	0.28	2812.47
9	Black Plastic (LDPE)	kg	25	0.00042	9.21
10	Pallets	each	68	0.0025	25.05

Table 6 Material input quantities for a Geo12 brick.

Raw Materials

Cement

Data collection method	Production methodology and records
Period of data collection	A batch run of 27,147 bricks 1st December 2009 to 1st February 2010
Units	kg
Representativeness	High
Exclusions and assumptions	Assume emission factor for cement is 0.82 kg CO_2e / kg cement. Reference Sources: http://www.asa-inc.org.au/Doc/Heidrich,c.pdf Green House Gas Emissions due to Concrete Manufacture* David J. M. Flower and Jay G. Sanjayan** Department of Civil Engineering, Monash University, Clayton, VIC 3800, Australia
Calculation method	Emissions (kg CO_2-e) = Quantity of cement (kg) x EFcement = Quantity of cement (kg) x 0.82
Geographical representativeness	Australia
Uncertainty: 10% ◗ Data collection ◗ Calculation methodology	 Low Medium

Pallets

Data collection method	Production methodology and records
Period of data collection	A batch run of 27,147 bricks 1st December 2009 to 1st February 2010
Units	kg
Representativeness	High
Exclusions and assumptions	Assume a pallet is 25kg of which is made of hard wood. Assume manufacture of pallet (cutting & construction) is negligible. Assume emission factor for hardwood = 0.03 kg CO_2-e/kg of hardwood. Reference Source: http://www.tastimber.tas.gov.au/species/pdfs/embodied.pdf
Calculation method	1 kg of hard wood = 0.03 kg CO2e. 1 Pallet = 0.75 kg CO2e Emissions (kg CO_2-e) Pallet = 25 kg x EFhardwood / number of uses x pallets = 0.75 kg CO_2-e / 10 x pallets = 0.075 x quantity pallets
Geographical representativeness	Australia
Uncertainty: 25% ◗ Data collection ◗ Calculation methodology	 High High

Water Repellent

Data collection method	Production methodology and records
Period of data collection	A batch run of 27,147 bricks 1st December 2009 to 1st February 2010
Units	Litres
Representativeness	High
Exclusions and assumptions	No data available. It is estimated that this will have minimal impact on the LCA. A previous study references 2.8 MJ / kg. Tech – dry the manufacturer states 50% is water and the process is predominately electricity. Source: Ecologically Sustainable Development:- Approaches in the Construction Industry. Robert Omahen, Faculty of Economics, University of Regensburg, Germany. 2002. http://horizonshidc.com/downloads/thesis_ecologically_sustainable_development.pdf
Calculation method	Emissions (kg CO2-e/ litre) = 0.5 x 2.8 / 3.6 x 1.35 = 0.525
Geographical representativeness	Australia
Uncertainty: 25% ◗ Data collection ◗ Calculation methodology	 Low Moderate

Diesel

Data collection method	Production methodology and records
Period of data collection	A batch run of 27,147 bricks 1st December 2009 to 1st February 2010
Units	Litres
Representativeness	High
Exclusions and assumptions	
Calculation method	Emissions (kg CO_2-e) diesel = 2.7 kg CO_2-e x litres diesel Source: NGA Factors Workbook., 38.6 x 69.2 /1000 = 2.7 kg CO_2-e /l
Geographical representativeness	Australia
Uncertainty: 5% ◗ Data collection ◗ Calculation methodology	 Low Low

Black Plastic (LDPE)

Data collection method	Production methodology and records
Period of data collection	A batch run of 27,147 bricks 1st December 2009 to 1st February 2010
Units	kg
Representativeness	High
Exclusions and assumptions	Assume 1kg of Black Plastic emissions are 2.74 kgCO_2e. The plastic is reused 8 times. Reference Source: Public information available in **Sima Pro calculation -** http://simapro.rmit.edu.au/LCA/datadownloads.html
Calculation method	Emissions (kg CO_2-e) LDPE = EF LDPE x quantity LPDE(kg) / number uses = 2.74 / 8 x quantity LDPE (kg) = 0.343 x quantity LDPE (kg)
Geographical representativeness	Australia
Uncertainty: 10% ◗ Data collection ◗ Calculation methodology	 Low Medium

Water (Delivery)

Data collection method	Production methodology and records
Period of data collection	A batch run of 27,147 bricks 1st December 2009 to 1st February 2010
Units	litres
Representativeness	High
Exclusions and assumptions	Assume Coliban Water deliver water to the site at 1.5 GJ per ML of water. Reference Source: Public information available. **- Victorian Water Review 2005/2006** http://www.vicwater.org.au/index.php?sectionid=659
Calculation method	Emissions (kg CO_2-e) Litre = EF water x quantity Water(litre) = 1.5 x 1000 / 3.6 * 1.35 / 1,000,000 x quantity LDPE (kg) = 0.0005625x quantity Water (Litres)
Geographical representativeness	Australia
Uncertainty: 15% ◗ Data collection ◗ Calculation methodology	 Low Medium

Electricity

Data collection method	Production methodology and records
Period of data collection	A batch run of 27,147 bricks 1^{st} December 2009 to 1^{st} February 2010
Units	kW.h
Representativeness	High
Exclusions and assumptions	Electricity consumed from Victorian Grid
Calculation method	Emissions (kg CO_2-e) for electricity = EF electricity x quantity of electricity (kW.h) = 1.35 x quantity of electricity (kW.h) Source: NGA Factors Workbook, 1.35 kg CO_2-e / kW.h (scope 2 & 3)
Geographical representativeness	Victoria
Uncertainty: 5% ◗ Data collection ◗ Calculation methodology	 Low Low

2.3 LCA Results

Emissions

The LCA indicates 7.6 tonnes of CO_2-e for a complete batch run of 27,147 Geo12 bricks.

The table below shows the underlying calculations.

The emissions for a SBE are 0.28 kg $CO_{2\text{-}}$e

The emissions for 10,000 bricks (house lot) are 2.8 tonnes $CO_{2\text{-}}$e

The following table is for the 'Geo12' brick.

Item	Description	Units	kgCO2e/ unit	Quantity Total	Quantity per SBE	Quantity per 10,000 bricks	kgCO2e Total	kgCO2e/ SBE	kgCO2e/ 10,000 bricks	Uncertainty	Of Lot	Squared
1	Electricity	kW.h	1.35	268	0.0099	98.72	361.8	0.0133	133.27	5%	6.66	44.4
2	Cement	kg	0.82	8547.06	0.3148	3148.44	7008.59	0.2582	2581.72	10%	258.17	66652.7
3	Water Repellent	litres	0.525	41	0.0015	15.1	21.53	0.0008	7.93	25%	1.98	3.9
4	Diesel (Materials)	litres	2.7	43.56	0.0016	16.05	117.62	0.0043	43.33	5%	2.17	4.7
4a	Diesel (Operations)	litres	2.7	27.15	0.0010	10	73.3	0.0027	27	5%	1.35	1.8
5	Water	litres	0.001	7635	0.2813	2812.5	4.29	0.0002	1.58	15%	0.24	0.1
6	Plastic	kg	0.343	25	0.0009	9.21	8.58	0.0003	3.16	10%	0.32	0.1
7	Pallet	kg	0.075	68	0.0025	25.05	5.1	0.0002	1.88	25%	0.47	0.2
	Total						**7600.80**	**0.28**	**2799.87**	Total		66707.9
										Square root	+/-	258.3
											+/-	9.2%

Table 7 Geo12 Brick emission results

Water

The total water consumption for the site is 16.28 kl for the period of the brick run. This includes water use in the home.

The following calculation can be used to estimate the water use in the brick works.

One mix is 128 bricks.

A mix has 435kg of materials. (388kg raw material + 47kg cement).

36 litres of water is added to the mix.

Resulting in 36 litres of water for 128 bricks. Or 0.28 litres per SBE. Or 2812.5 litres for 10,000 bricks.

For 27,147 bricks this equates to 7.635 kl.

This leaves 8.584 kl for the domestic house.

2 people using 150 litres per day each for 14 days equals 8.4 kl. So this quantification is reasonable.

2.4 Calculations

The following cement quantities have been used in calculating the greenhouse emissions for the manufacture of the other Geobrick products. The % cement 16, 8, 4 & 2 have been used to determine the amount of cement in each mix.

GeoBrick Product	Cement content	Batch, mass of cement and other raw materials
Geo16	16%	435 kg = 375kg Raw Materials + 60 kg Cement (60/375*100=16%)
Geo8	8%	435kg = 403kg Raw Materials + 32 kg Cement (32/403*100=8%)
Geo4	4%	435kg = 418kg Raw Materials + 17 kg Cement (17/418*100=4%)
Geo2	2%	435kg = 426kg Raw Materials + 9 kg Cement (9/426*100=2%)

Table 8 Geobrick material mix

The individual batch of 27,147 Geo12 bricks investigated used a slightly lower cement content of 10.5%.

Geo12: 424 kg = 384kg Raw Materials + 40 kg Cement (40/384*100=10.5%)

The following 3 tables shows the material quantities for 1 SBE , 10,000 bricks and 27,147 bricks.

			Mass (kg's)			
Brick Type	Mass	# Bricks	RAW Materials	Cement	Total Mix	Water (litres)
Geo16	3.4	1	2.93	0.47	3.4	0.2813
Geo12	3.4	1	3	0.31	3.32	0.2813
Geo8	3.4	1	3.15	0.25	3.4	0.2813
Geo4	3.4	1	3.27	0.13	3.4	0.2813
Geo2	3.4	1	3.33	0.07	3.4	0.2813

Table 9 Material Quantities for 1 SBE

			Mass (kg's)			
Brick Type	Mass	# Bricks	RAW Materials	Cement	Total Mix	Water (litres)
Geo16	34000	10000	29296.88	4687.5	33984.38	2812.5
Geo12	34000	10000	30007.81	3148.44	33156.25	2812.5
Geo8	34000	10000	31484.38	2500	33984.38	2812.5
Geo4	34000	10000	32656.25	1328.13	33984.38	2812.5
Geo2	34000	10000	33281.25	703.13	33984.38	2812.5

Table 10 Material Quantities for 10,000 bricks or 1 house lot.

			Mass (kg's)			
Brick Type	Mass	# Bricks	RAW Materials	Cement	Total Mix	Water (litres)
Geo16	92299.8	27147	79532.23	12725.16	92257.38	7635
Geo12	92299.8	27147	81462.21	8547.06	90009.27	7635
Geo8	92299.8	27147	85470.63	6786.75	92257.38	7635
Geo4	92299.8	27147	88651.92	3605.46	92257.38	7635
Geo2	92299.8	27147	90348.61	1908.77	92257.38	7635

Table 11 Material Quantities for the batch run between 1 Dec 2009 and 1st Feb 2010

Emission results for the complete GeoBrick range of products Geo2, 4, 8, 12 and 16 are shown in the following five tables.

Item	Description	Units	kgCO2e/ unit	Quantity Total	Quantity per SBE	Quantity per 10,000 bricks	kgCO2e Total	kgCO2e/ SBE	kgCO2e/ 10,000 bricks	Uncertainty	Of Lot	Squared
1	Electricity	kW.h	1.350	268	0.0099	98.72	361.8	0.0133	133.27	5%	6.66	44.4
2	Cement	kg	0.820	12725.16	0.4688	4687.5	10434.63	0.3844	3843.75	10%	384.38	147744.1
3	Water Repellent	litres	0.525	41	0.0015	15.1	21.53	0.0008	7.93	25%	1.98	3.9
4	Diesel (Materials)	litres	2.700	42.53	0.0016	15.67	114.83	0.0042	42.3	5%	2.12	4.5
4a	Diesel (Operations)	litres	2.700	27.15	0.0010	10	73.3	0.0027	27	5%	1.35	1.8
5	Water	litres	0.001	7635	0.2813	2812.5	4.29	0.0002	1.58	15%	0.24	0.1
6	Plastic	kg	0.343	25	0.0009	9.21	8.58	0.0003	3.16	10%	0.32	0.1
7	Pallet	kg	0.075	68	0.0025	25.05	5.1	0.0002	1.88	25%	0.47	0.2
	Total						**11024.05**	**0.41**	**4060.87**	Total		147799.1
										Square root	+/-	384.4
											+/-	9.5%

Table 12 Geo16 emission results

Item	Description	Units	kgCO2e/ unit	Quantity Total	Quantity per SBE	Quantity per 10,000 bricks	kgCO2e Total	kgCO2e/ SBE	kgCO2e/ 10,000 bricks	Uncertainty	Of Lot	Squared
1	Electricity	kW.h	1.35	268	0.0099	98.72	361.8	0.0133	133.27	5%	6.66	44.4
2	Cement	kg	0.82	8547.06	0.3148	3148.44	7008.59	0.2582	2581.72	10%	258.17	66652.7
3	Water Repellent	litres	0.525	41	0.0015	15.1	21.53	0.0008	7.93	25%	1.98	3.9
4	Diesel (Materials)	litres	2.7	43.56	0.0016	16.05	117.62	0.0043	43.33	5%	2.17	4.7
4a	Diesel (Operations)	litres	2.7	27.15	0.0010	10	73.3	0.0027	27	5%	1.35	1.8
5	Water	litres	0.001	7635	0.2813	2812.5	4.29	0.0002	1.58	15%	0.24	0.1
6	Plastic	kg	0.343	25	0.0009	9.21	8.58	0.0003	3.16	10%	0.32	0.1
7	Pallet	kg	0.075	68	0.0025	25.05	5.1	0.0002	1.88	25%	0.47	0.2
	Total						**7600.80**	**0.28**	**2799.87**	Total		66707.9
										Square root	+/-	258.3
											+/-	9.2%

Table 13 Geo12 emission results

Item	Description	Units	kgCO2e/ unit	Quantity Total	Quantity per SBE	Quantity per 10,000 bricks	kgCO2e Total	kgCO2e/ SBE	kgCO2e/ 10,000 bricks	Uncertainty	Of Lot	Squared
1	Electricity	kW.h	1.35	268	0.0099	98.72	361.8	0.0133	133.27	5%	6.66	44.4
2	Cement	kg	0.82	3605.46	0.1328	1328.13	2956.48	0.1089	1089.06	10%	108.91	11860.6
3	Water Repellent	litres	0.525	41	0.0015	15.1	21.53	0.0008	7.93	25%	1.98	3.9
4	Diesel (Materials)	litres	2.7	47.41	0.0017	17.46	128	0.0047	47.15	5%	2.36	5.6
4a	Diesel (Operations)	litres	2.7	27.15	0.0010	10	73.3	0.0027	27	5%	1.35	1.8
5	Water	litres	0.001	7635	0.2813	2812.5	4.29	0.0002	1.58	15%	0.24	0.1
6	Plastic	kg	0.343	25	0.0009	9.21	8.58	0.0003	3.16	10%	0.32	0.1
7	Pallet	kg	0.075	68	0.0025	25.05	5.1	0.0002	1.88	25%	0.47	0.2
	Total						**3559.07**	**0.13**	**1311.04**	Total		11916.7
										Square root	+/-	109.2
											+/-	8.3%

Table 14 Geo4 emission results

Item	Description	Units	kgCO2e/ unit	Quantity Total	Quantity per SBE	Quantity per 10,000 bricks	kgCO2e Total	kgCO2e/ SBE	kgCO2e/ 10,000 bricks	Uncertainty	Of Lot	Squared
1	Electricity	kW.h	1.35	268	0.0099	98.72	361.8	0.0133	133.27	5%	6.66	44.4
2	Cement	kg	0.82	6786.75	0.2500	2500	5565.14	0.2050	2050	10%	205.00	42025.0
3	Water Repellent	litres	0.525	41	0.0015	15.1	21.53	0.0008	7.93	25%	1.98	3.9
4	Diesel (Materials)	litres	2.7	45.71	0.0017	16.84	123.41	0.0045	45.46	5%	2.27	5.2
4a	Diesel (Operations)	litres	2.7	27.15	0.0010	10	73.3	0.0027	27	5%	1.35	1.8
5	Water	litres	0.001	7635	0.2813	2812.5	4.29	0.0002	1.58	15%	0.24	0.1
6	Plastic	kg	0.343	25	0.0009	9.21	8.58	0.0003	3.16	10%	0.32	0.1
7	Pallet	kg	0.075	68	0.0025	25.05	5.1	0.0002	1.88	25%	0.47	0.2
	Total						**6163.13**	**0.23**	**2270.28**	Total		42080.7
										Square root	+/-	205.1
											+/-	9.0%

Table 15 Geo8 emission results

Item	Description	Units	kgCO2e/ unit	Quantity Total	Quantity per SBE	Quantity per 10,000 bricks	kgCO2e Total	kgCO2e/ SBE	kgCO2e/ 10,000 bricks	Uncertainty	Of Lot	Squared
1	Electricity	kW.h	1.35	268	0.0099	98.72	361.8	0.0133	133.27	5%	6.66	44.4
2	Cement	kg	0.82	1908.77	0.0703	703.13	1565.19	0.0577	576.56	10%	57.66	3324.2
3	Water Repellent	litres	0.525	41	0.0015	15.1	21.53	0.0008	7.93	25%	1.98	3.9
4	Diesel (Materials)	litres	2.7	48.31	0.0018	17.8	130.45	0.0048	48.05	5%	2.40	5.8
4a	Diesel (Operations)	litres	2.7	27.15	0.0010	10	73.3	0.0027	27	5%	1.35	1.8
5	Water	litres	0.001	7635	0.2813	2812.5	4.29	0.0002	1.58	15%	0.24	0.1
6	Plastic	kg	0.343	25	0.0009	9.21	8.58	0.0003	3.16	10%	0.32	0.1
7	Pallet	kg	0.075	68	0.0025	25.05	5.1	0.0002	1.88	25%	0.47	0.2
	Total						**2170.24**	**0.08**	**799.44**	Total		3380.5
										Square root	+/-	58.1
											+/-	7.3%

Table 16 Geo2 emission results

2.5 Comparison with a traditional brick.

The next stage of the LCA is to compare the Geo Brick range of products against a traditional kiln fired brick.

Table 15 shows the comparison between the traditional brick and Geo bricks variants.

Special attention is needed when comparing which GeoBrick is to be substituted for a traditional brick.

While information exists for the MPa ratings of traditional bricks, there does not seem to be a standard MPa requirement, as such. All that exists is a specification for the wall strength, on which the mortar has a significant (reducing) influence.

We recommend that Table 15 be used as an indication of what a Geo brick MPa ratings are as compared with a traditional brick. Selection of either of these bricks for the particular application will need to be determined by the brick purchaser, depending on the application and requirements. This will clearly vary from application to application, and is beyond the scope of this investigation.

On the basis of tested brick strength as a selection criterion, the Geo16 bricks which have a strength of >25MPa could be used in the place of traditional bricks with a strength of 15 – 35 MPa in many applications.

This report does not recommend GeoBricks or traditional bricks for any particular application. Anyone needing to select building materials and products for a specific application should seek appropriate professional advice which considers the particular circumstances of the building project.

This report has focused on the Geo16 which has a tested strength within the range of the strength of traditional bricks but with 33% less CO_2.e. However, the suitability of Geo2, Geo4, Geo8 and Geo12 bricks should also be considered (upon suitable engineering certification). A Geo2 brick can reduce CO_2.e emissions by 86%, which equates to almost 5 tonnes of CO_2.e for every 10,000 bricks (house lot).

Product	MPa Rating	Reduced Total kg CO2e vs Traditional Brick (27,147)	kg CO2e/ SBE	% Reduction in kg CO2e	t CO2e/ 10,000 bricks	Litres of water / SBE	% Reduction in Water	kilolitres of water / 10,000 bricks
Geo Brick (Geo16)	> 25	5535.62	0.4061	33.43	4.0609	0.28	43.75	2.81
Geo 12	>18	8958.87	0.2800	54.10	2.7999	0.28	43.75	2.81
Geo 8	>12	10396.54	0.2270	62.78	2.2703	0.28	43.75	2.81
Geo 4	>6	13000.6	0.1311	78.51	1.3110	0.28	43.75	2.81
Geo2	>3	14389.43	0.0799	86.89	0.7994	0.28	43.75	2.81
Traditional Brick	> 25	16559.67	0.6100	0.00	6.1000	0.5	0	5

Table 17 Comparison between Geo bricks and the traditional brick.

The traditional brick emission factor (kg CO_2.e per SBE) has been sourced from:

A recent LCA report published by Thinkbrick Australia. Details can be found at http://blog.thinkbrick.com.au/sustainability/lca/

Traditional brick water use has been calculated from using the % moisture content in a pre kiln fired dried brick. A typical finished fired brick is 3.2 kg of which would have 15% moisture prior to firing. Results in 0.5 kg water. Assume 1 kg water = 1 litre. 0.5 litres per SBE.

Traditional Kiln Fired Brick Description

This Figure depicts the process involved in the manufacture of a traditional kiln fired brick.

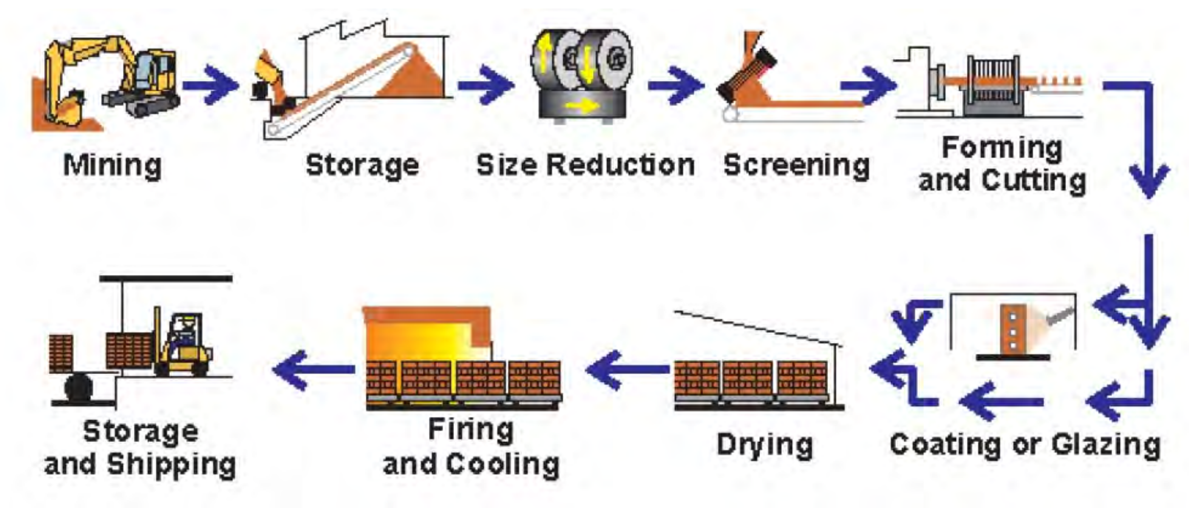

Figure 10 Traditional kiln fired brick process.

When this traditional brick process is compared with the GeoBrick natural earth brick process, the two major differences are in the manufacture of the GeoBrick:

- does not entail 'Firing & Cooling' stage. See Figure 6.
- includes the addition of cement powder

This 'Firing & Cooling' stage is predominately powered by natural gas or electricity.

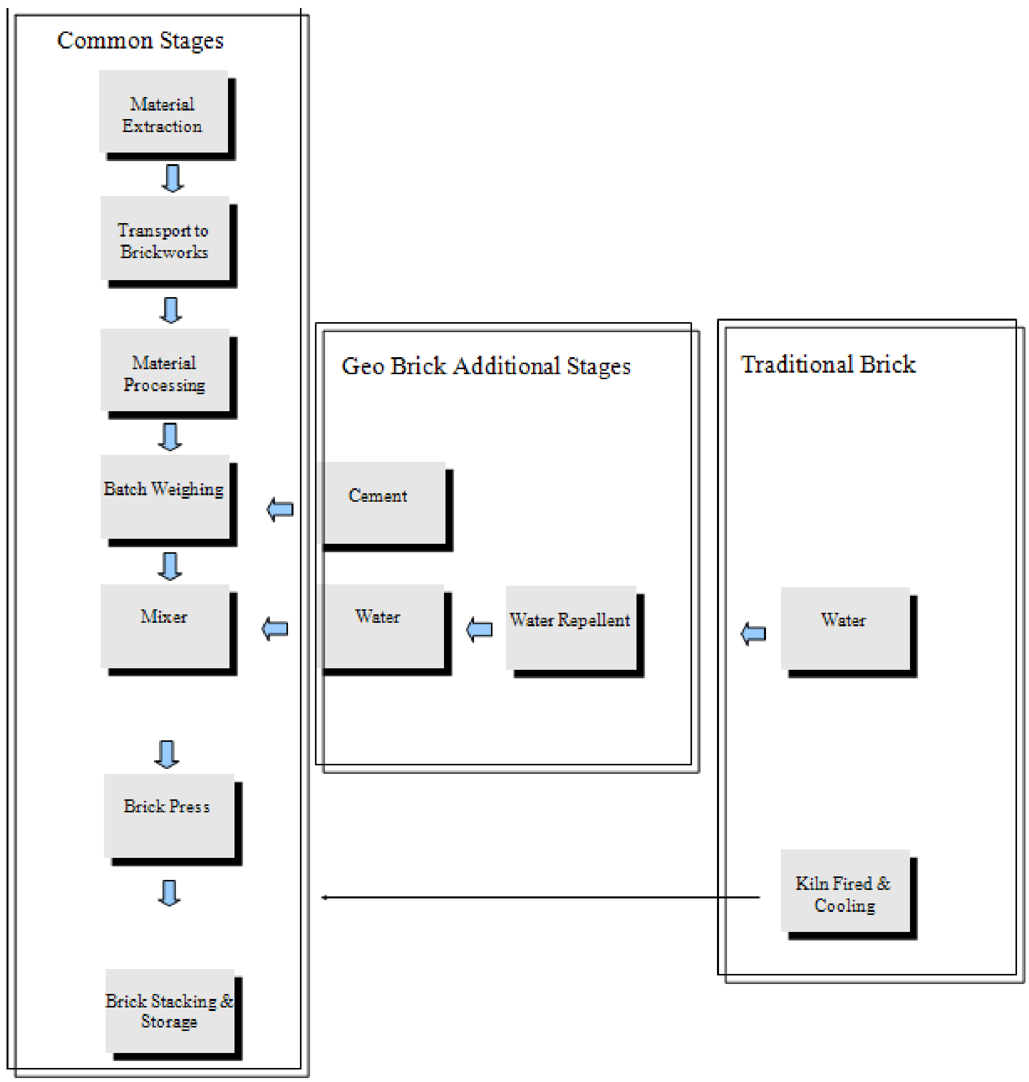

Figure 11 Comparison between a Geo Brick and a Traditional brick process.

2.6 Other calculation considerations:

Electricity consumption has been taken from retailer bills. Meter readings before and after the batch run were recorded. The house and office electricity are taken from a separate reading. The electricity for the office is minimal, with only a computer, two compact fluorescent lights and a fax.

Diesel use has been broken into two sections. Fuel for raw material extraction and fuel for the operations. Exact fuel figures were used for the raw material extraction, however this raw material was not used for the batch run under assessment. A litres of Diesel per tonne of raw material was calculated (0.534).

The operations diesel use has been calculated based on using 5 litres per 5000 bricks. This is an estimate given by the operator.

Pallets are used to store the bricks on. Each pallet holds 400 bricks. This equates to 68 pallets. Each pallet is reused 10 times. A pallet weighs 25 kg and is made of hardwood. The emissions have been calculated by multiplying the emissions for 1 kg of hardwood by 25. The overall emissions for the pallets have been then divided by 10 to accommodate for the reuse.

Black plastic is also used to help in drying. This plastic is also reused and adjusted in the figures accordingly.

Water is provided by mains. The embodied energy to deliver the water to the site has been included.

The only other raw material is a water repellent. For 27,147 bricks 41 litres was used. After discussing with the manufacturer of the material and researching available data it was quickly understood that very low embodied emissions go into the making of this product.

Cement Emissions

The main material worth extra explanation is the calculation of the emissions associated with the use of cement in the Geo brick.

Cement makes up approximately 95% of the total emissions of a Geobrick. The scope of this LCA was not broad enough to investigate and report on the emission factors for the manufacture of cement in great detail.

However, a detailed literature search and expert consultation has been undertaken to ensure the information we have sourced is as accurate and recent as possible.

A range of emission factors of between 0.5 and 1 kg CO_2-e / kg cement has been identified.

The main component of these emissions is the reduction of limestone which takes place in the cement kiln. This figure is about 0.5 kg CO_2 / kg cement (i.e. 50% - 65% of the total embodied emissions of the manufacture of cement). The portion of total emissions from chemical reduction of limestone increases as cement manufacturers increase the energy efficiency of the cement production process.

This study has relied on a figure of 0.82 kg CO_2e / kg cement.

The reason for a wide range can be attributed to different efficiency improvements over the years in cement production plants. The source of their energy and mix of renewable energy can influence this figure.

2.7 Discussion

This LCA has clearly identified that the Geo brick range of products can be compared favourably against a traditional kiln fired brick in terms of reduced greenhouse gas emissions and water consumption.

As a result of this study data collection methods can be improved to assist the manufacturer understand sources of emissions in their production. The data for this LCA has been collected from one run of bricks from the 1st of December 2009 and 1st February 2010. Data errors are common with this approach and further improvements will occur once more regular brick runs are undertaken.

It is a finding of this report that the avoidance of using a kiln clearly reduces greenhouse gas emissions. However, Geobrick still has a significant greenhouse burden from the use of traditional Portland cement in each brick they manufacture.

The future for the kiln fired brick is to explore cleaner methods of manufacturing a brick. Over the years we have seen plants convert from coal powered to electricity to now natural gas fired. There is no reason this industry will not continue to become more efficient and in terms of greenhouse gas emissions, when financially viable, their main source of emissions (kiln) could be reduced significantly when they begin to use more renewable energy.

It is for this reason that the full range of Geo bricks should be considered. The lower % of cement products such as Geo8, 4 and 2 bring significant greenhouse gas savings.

While outside the scope of this LCA new binding agents are beginning to enter the market that demonstrate a significant reduction in emissions. 'Green Concrete' and low carbon cement is certainly the future for Geobrick to assist in reducing their emissions further.

