Climate Change Impact Assessment
Cenin Cement Replacement Products

Report presented to: Cenin

By: Energy for Sustainable Development

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Project	Climate Change Assessment
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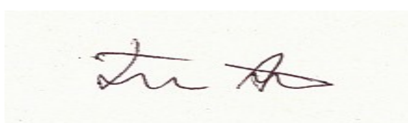

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CONTENTS

Tables

Figures

Climate Change Impact Assessment – Cenin Cement Replacement Products

Executive Summary

Background

This assessment estimates the CO_2 emissions associated with the manufacture of a range of cement replacement products produced by Cenin. The products assessed include: Cenin 1; Cenin 2; Cenin 3 70/30; Cenin 3 60/40 and; Cenin 3 50/50.

The scope of the assessment is 'cradle to gate' *plus* product distribution.

Summary of Emissions

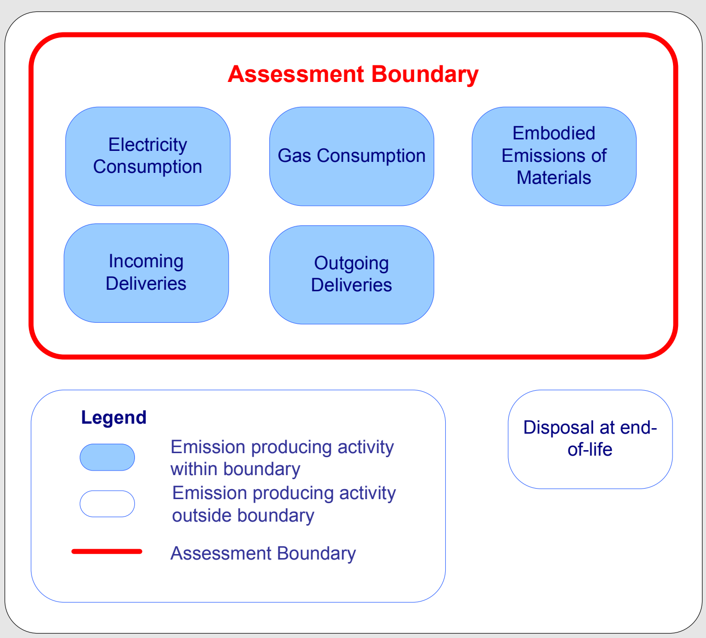
The CO_2 emissions associated with each of the Cenin products assessed are shown in the table and graph below.

Source of emissions	CO_2 emitted (kg/tonne cement)
Cenin 1	72
Cenin 2	26
Cenin 3: 70/30	608
Cenin 3: 60/40	525
Cenin 3: 50/50	442

Scope and Methodology

The assessment methodology follows the reporting principles and guidelines provided by the WBCSD Greenhouse Gas Protocol.

The scope of the assessment includes: incoming delivery of raw materials; energy consumed during material processing and product manufacture; embodied emissions of materials and; product distribution (as shown below).



1. Introduction

1.1 Background

Climate change presents a serious challenge for responsible business leaders in the 21st century. Most scientists now agree that rising atmospheric concentrations of greenhouse gases (GHGs), particularly carbon dioxide (CO_2), threaten to have severe impacts on food production, natural ecosystems and human health over the next 100 years. Industrialised and rapidly industrialising countries are the main sources of greenhouse gases. However, the greatest impacts will be felt by people in developing countries, particularly those in low lying coastal regions and marginal agricultural areas.

Figure 1. Flooding in Bangladesh

In response to the threat of climate change, the Kyoto Protocol was adopted in December 1997. Under the Protocol, industrialised countries have a legally binding commitment to reduce their collective greenhouse gas emissions by at least 5% compared to 1990 levels by the period 2008-2012. Russia ratified the Kyoto Protocol on 18th November 2004 and as a result it came into force on February 16th 2005. In November 2006 at the UN Climate Change Conference in Nairobi, the parties agreed on a work plan detailing the steps needed to reach an agreement on a new set of post 2012 commitments.

Figure 2. Kyoto Ratification -The UN Secretary General Kofi Annan receives Russia's instrument of ratification. Allowing the Kyoto Protocol to enter into force in early 2005. Picture taken from http://unfccc.int/2860.php.

The UK ratified the Kyoto Protocol in May 2002 as part of a joint ratification by European Union countries. The UK commitment is for a 12.5% reduction in Kyoto greenhouse gases, however the UK Government has pledged to reduce CO_2 emissions by 20% of their 1990 level by 2010. Total UK GHG emissions for 2005 for all sources (fossil fuel combustion, industrial processes and land use change and forestry) were 653,800,000 tonnes of CO_2 equivalent, 15.4% below 1990 levels (Baggott *et al* 2007). The 2003 UK Government's Energy White Paper set an aspiration for the UK to reduce carbon emissions by 60%, and create a low carbon economy by 2050.

1.2 Why carry out a Climate Change Impact Assessment?

National governments and the EU are taking a variety of steps to reduce GHG emissions including emissions trading schemes, voluntary reduction and reporting programs, carbon or energy taxes, and regulations and standards on energy efficiency and emissions. Increasingly, companies will need to understand and manage their GHG risks in order to maintain their license to operate, to ensure long-term success in a competitive business environment, and to comply with national or regional policies aimed at reducing corporate GHG emissions (WBCSD/WRI 2004).

ESD helps to install and run the systems needed to understand and control the climate change impact from organisations, events and products. A Climate Change Impact Assessment is the first step in the carbon management process.

A Climate Change Impact Assessment provides the basis for further initiatives such as public reporting, target setting and implementation of mitigation activities. Mitigation activities may include energy efficiency measures, sourcing of energy from renewable supplies and offsetting irreducible emissions through offset schemes.

1.3 Client and Product Details

Cenin specialises in the manufacture of cement replacement products using industrial wastes and co-products.

Cenin use only renewable power in the production of their cement replacement products. This power is produced from an on site biogas plant and wind turbine. The biogas plant uses cereal residues as its feedstock, sourced from the local area.

2. Assessment Methodology

2.1 General Procedure

The assessment methodology used here follows the reporting principles and guidelines provided by the Greenhouse Gas Protocol published by the World Business Council for Sustainable Development and the World Resources Institute (WBCSD/WRI Protocol). The methodology is also consistent with the Carbon Trust's draft 'Specification for the embodied greenhouse gas emissions of products and services' (2007).

In line with the WBCSD/WRI Protocol, ESD uses the following procedure to undertake a Climate Change Impact Assessment:

1. Establishment of the assessment boundaries (including the selection of: greenhouse gases, project boundaries).
2. Collection of client data.
3. Evaluation of data quality and of client data sources.
4. Calculation of emissions using appropriate conversion factors.
5. Analysis of results.

The assessment procedure and a summary of results are presented in the main text of the report. A detailed description of emissions calculations and associated assumptions are presented in Appendix II.

A glossary of climate change terms is found in Appendix I.

2.2 Greenhouse Gases - Overview

A Climate Change Impact Assessment can include all six greenhouse gases covered by the Kyoto Protocol. The six Kyoto gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs).

The global warming potential (GWP) of each greenhouse gas may be expressed in CO_2 equivalents (see Table 1). For those gases with a high global warming potential, a relatively small emission can have a considerable impact.

Table 1. The global warming potential of the Kyoto gases

Kyoto gas	GWP*
carbon dioxide (CO_2)	1
methane (CH_4)	23
nitrous oxide (N_2O)	296
sulphur hexafluoride (SF_6)	22,200
perfluorocarbons (PFCs)	4,800 – 9,200
hydrofluorocarbons (HFCs)	12 - 12,000

*Note: the 'global warming potential' of a gas is its relative potential contribution to climate change over a 100 year period, where CO_2 =1 (see Glossary for a full definition). Source: IPCC (2001).

2.3 Greenhouse Gases – Cenin

This Climate Change Impact Assessment covers CO_2 emissions arising from fuel combustion.

2.4 Assessment Boundaries - Overview

When accounting for GHG emissions, the WBCSD/WRI Protocol places emphasis on defining clear ‘organisational’ and ‘operational’ boundaries. This approach is useful when the focus of the assessment is a company or other organisation. However for a product assessment these terms are not applicable as the scope is defined by the product definition and the production pathway of the product.

2.5 Assessment Boundaries – Cenin

Figure 3 and Table 2 shows the assessment boundary. Emissions sources within the boundary include: material lifecycle emissions; incoming delivery of materials and feedstock for the biogas plant to the production facility; electricity and gas consumption produced by the onsite biogas plant and; outgoing deliveries. The assessment does not cover final disposal of the products as the responsibility for any associated emissions is considered to be with the final owner, rather than with Cenin.

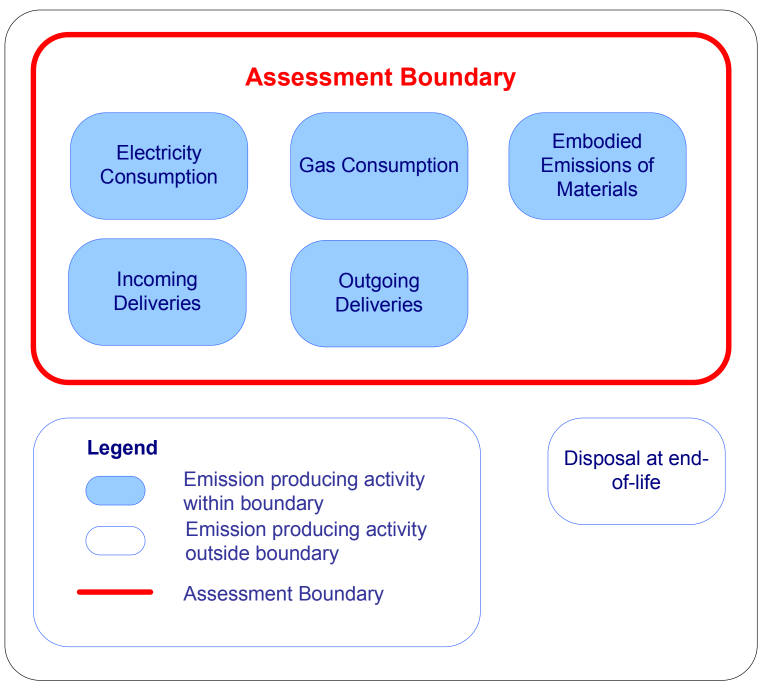


Figure 3. Assessment boundary

Table 2. Information on activities within the assessment boundary

Category	Activities: Energy Inputs	Data
Premises	Electricity consumption	✓
	Gas consumption	✓
Transport	Incoming and Outgoing Deliveries	✓
Materials	Embodied energy	✓

Key: ✓ = complete e = estimated ✓/e = combination of complete and estimated data

2.6 Reporting Approach

ESD does not base its Climate Change Impact Assessments on direct measurement of emissions, but on estimates of material and energy consumption (principally weight or volume of fuel, but also weight or volume of waste) from which estimates of emissions can be derived by the application of relevant conversion factors (i.e. amount of CO_2 produced per unit of fuel consumed). This approach is considered the most pragmatic, since the quantity of key greenhouse gases produced in most combustion and manufacturing processes is well understood. The certainty of waste and material emission estimates is lower, but direct measurement is rarely a realistic option.

The validity of all estimates depends on the accuracy, relevance and completeness of the data provided by the client and on the conversion factors used. ESD's approach is to set out as clearly as possible all the assumptions and conversion factors used, so that the report is as transparent as possible and the estimate of emissions is founded on 'best evidence'.

ESD is guided by the precautionary principle. Where there is any doubt over activities undertaken, or where there is a choice of published figures available for calculating greenhouse gas emissions, a conservative scenario is assumed unless otherwise specified.

In line with the Carbon Trust's draft methodology for the assessment of products and services, the emissions associated with co-products have been assigned according to the ratio of the relative retail value of the co-products.

2.7 Emission factors

To establish the tonnes of CO_2 equivalent emitted from the energy consuming activities emissions factors were employed from 'Environmental Reporting: Guidelines for Company Reporting on Greenhouse Gas Emissions' published by the UK government (DEFRA 2007 and 2005).

For the full set of emissions factors used and their sources, see Appendix II.

3. Data

3.1 Data Sources and Quality

The collection of the data, upon which the emissions calculations were based, was co-ordinated by Martyn Popham and Gary Hunt of Cenin.

Where preferred data were missing, estimates were made by the client, and by ESD based upon information provided by the client, and these are outlined below and detailed in Appendix II.

3.2 Data Assumptions

The fundamental assumption underlying the assessment is that all data provided by Cenin personnel were accurate.

The following specific assumptions were made:

Deliveries

- It is assumed that the maximum usable payload of a delivery vehicle used for incoming raw waste material deliveries is 29 tonnes and that all vehicles use 100% of their usable payload.
- It is assumed that the feedstock used for the biogas plant is delivered from a distance of no more than 5 kilometres.

Embodied emissions of raw materials and co-products

- It is assumed that it is appropriate and representative to allocate a portion of emissions from a products manufacture to its co-products according to the ratio of the relative retail value of the co-products (in line with the Carbon Trust's methodology).
- It has been assumed as a conservative estimate and in the absence of actual data, that equivalent quantities of primary product and its co-products are produced during manufacture.

Energy consumption

- It is assumed that all gas and electricity consumed during the manufacturing process is produced from the bio-gas plant.
- It is assumed that the biogas is produced from a homogenous feedstock and that the biogas plant produces a constant volume of gas therefore not requiring Cenin to use additional natural gas.
- It is assumed that the feedstock would otherwise be used for an activity or disposed of in a fashion that does not result in the emission of methane.
- It is assumed that the biogas plant does not leak methane.
- All electricity used to power the biogas plant is assumed to be generated by the plant itself.

All assumptions underlying the emission calculations are detailed in Appendix II.

4. Results

A breakdown of the emissions associated with each of the cement replacement products from cradle to gate *plus* product distribution is shown in Tables 3 to 8 and Figures 4 to 8 below.

For the results displayed below, it is assumed that the waste product (RM 1) is delivered by sea and the co-products (RM 3, RM 11 and RM 12) are delivered a distance of 10 miles by heavy goods vehicle. It is assumed that the finished products are distributed a distance of 25 miles by heavy goods vehicle to the customer.

The electricity and gas used during production of the products is assumed to be totally derived from renewable sources (biogas).

Table 3 displays a summary of the total emissions associated with the production and distribution of each of the Cenin products considered.

Table 3. Summary of the emissions associated with the Cenin products.

Source of emissions	CO_2 emitted (kg/tonne cement)
Cenin 1	72
Cenin 2	26
Cenin 3: 70/30	608
Cenin 3: 60/40	525
Cenin 3: 50/50	442

Cenin 1.

The cradle to gate *plus* production distribution emissions associated with Cenin 1 are 72.2 kilograms of CO_2 per tonne. A breakdown of these emissions is shown in Table 4 and Figure 4.

Table 4. Breakdown on the emissions associated with Cenin 1.

Source of emissions	CO_2 emitted (kg/tonne cement)
Incoming material delivery - HGV	0.5
Embodied energy of co-products	69.6
Fuel deliveries for biogas plant	0.3
Energy during biogas production	0.0
Product Distribution	1.8
Total emissions per tonne of Cenin 1	**72.2**

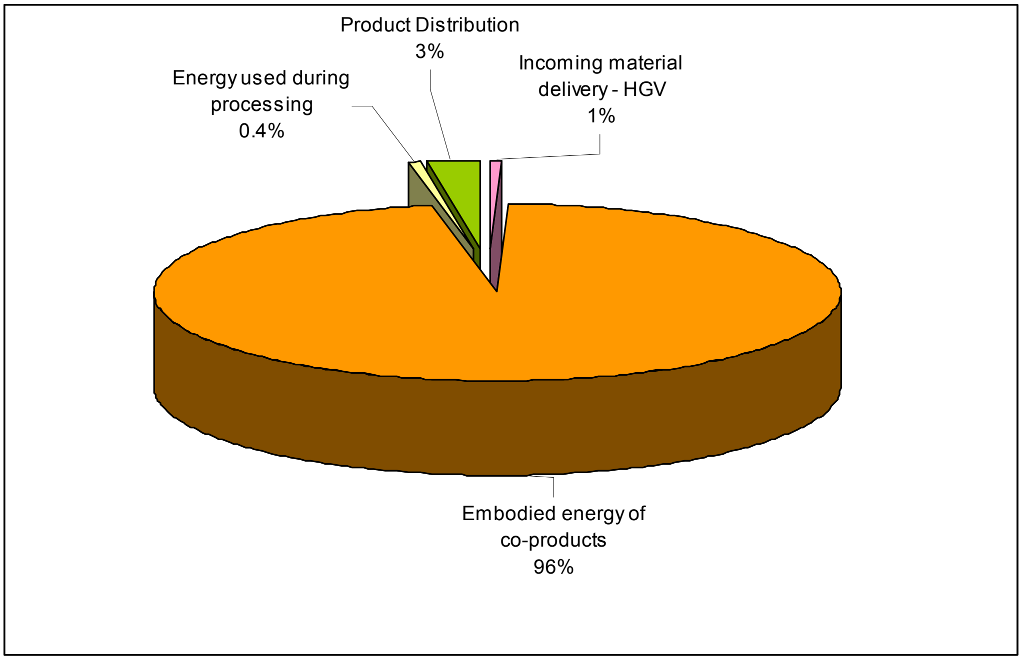


Figure 4. Breakdown of the emissions associated with Cenin 1.

Cenin 2.

The cradle to gate *plus* production distribution emissions associated with Cenin 2 are 26.5 kilograms of CO_2 per tonne. A breakdown of these emissions is shown in Table 5 and Figure 5.

Table 5. Breakdown on the emissions associated with Cenin 2.

Source of emissions	CO_2 emitted (kg/tonne cement)
Incoming material delivery - HGV	0.5
Embodied energy of co-products	23.9
Fuel deliveries for biogas plant	0.3
Energy during biogas production	0.0
Product Distribution	1.8
Total emissions per tonne of Cenin 2	**26.5**

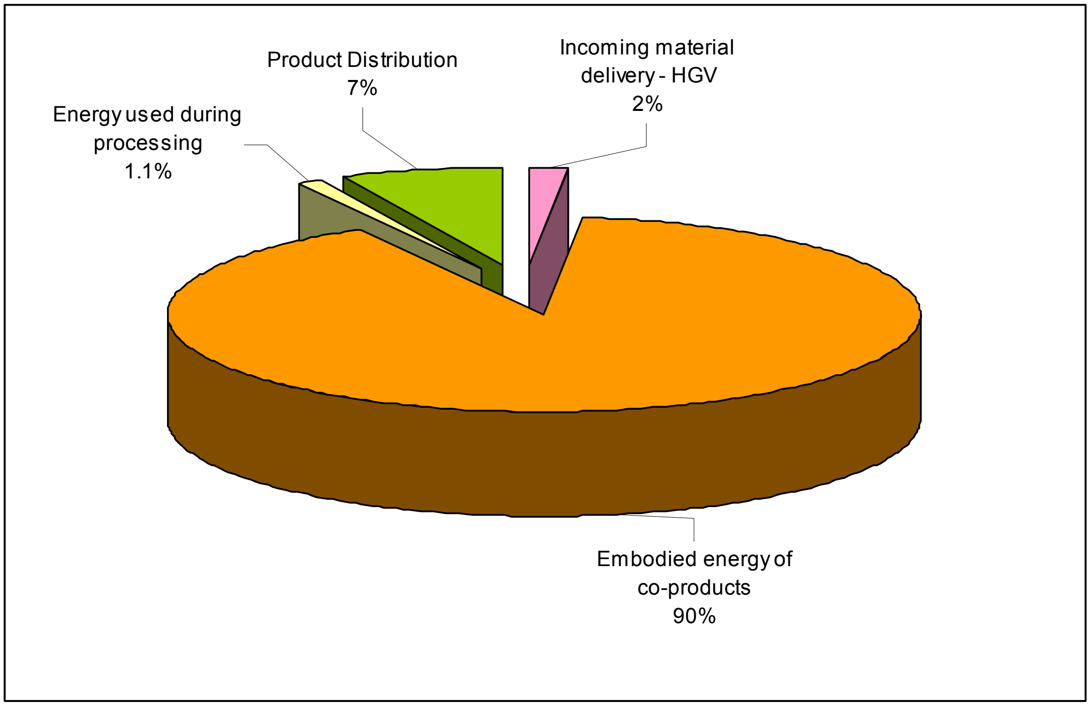


Figure 5. Breakdown of the emissions associated with Cenin 2.

Cenin 3 - 70/30

The cradle to gate *plus* distribution emissions associated with Cenin 3, composed of 70% Portland cement and 30% Cenin 3 cement replacement are 607.8 kilograms of CO_2 per tonne. A breakdown of these emissions is shown in Table 6 and Figure 6.

Table 6. Breakdown on the emissions associated with Cenin 3 70/30.

Source of emissions	**CO_2 emitted (kg/tonne cement)**
Incoming material delivery - HGV	0.7
Embodied energy of co-products	8.2
Fuel deliveries for biogas plant	0.05
Energy during biogas production	0.0
Product Distribution	1.8
Emissions of portland cement	597.1
Total emissions per tonne of Cenin 3 70/30	**607.8**

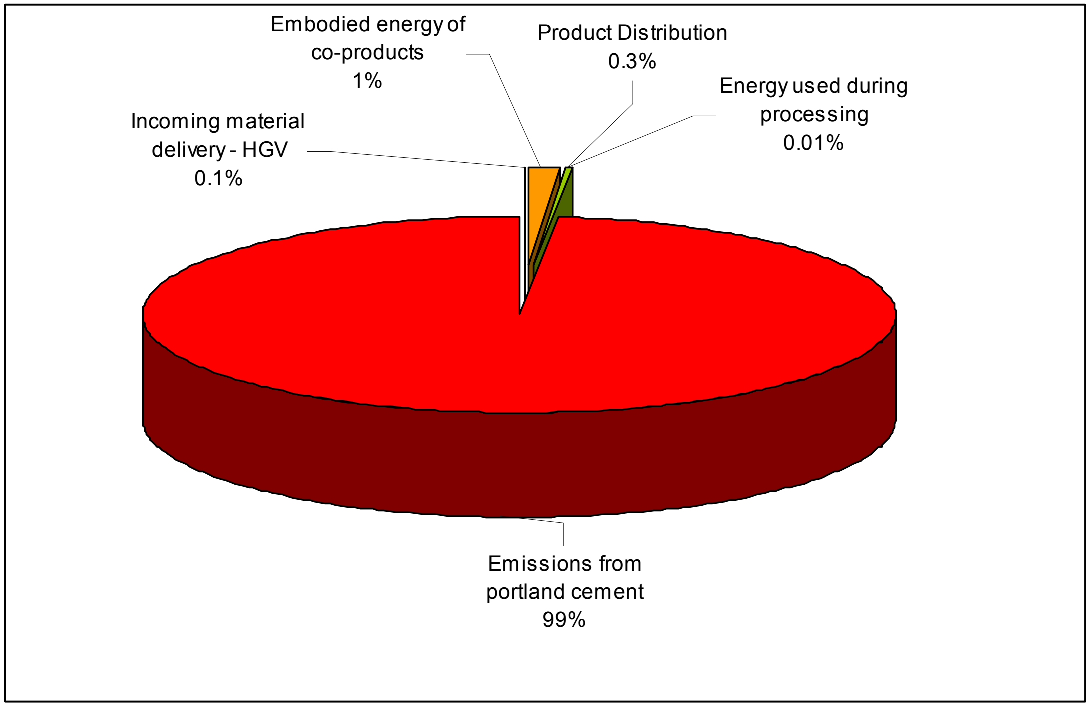


Figure 6. Breakdown of the emissions associated with Cenin 3 70/30.

Cenin 3 – 60/40

The cradle to gate *plus* production distribution emissions associated with Cenin 3, composed of 60% Portland cement and 40% Cenin 3 cement replacement are 525.2 kilograms of CO_2 per tonne. A breakdown of these emissions is shown in Table 7 and Figure 7.

Table 7. Breakdown on the emissions associated with Cenin 3 60/40.

Source of emissions	CO_2 emitted (kg/tonne cement)
Incoming material delivery - HGV	0.7
Embodied energy of co-products	10.9
Fuel deliveries for biogas plant	0.06
Energy during biogas production	0.0
Product Distribution	1.8
Emissions of portland cement	511.8
Total emissions per tonne of Cenin 3 60/40	**525.2**

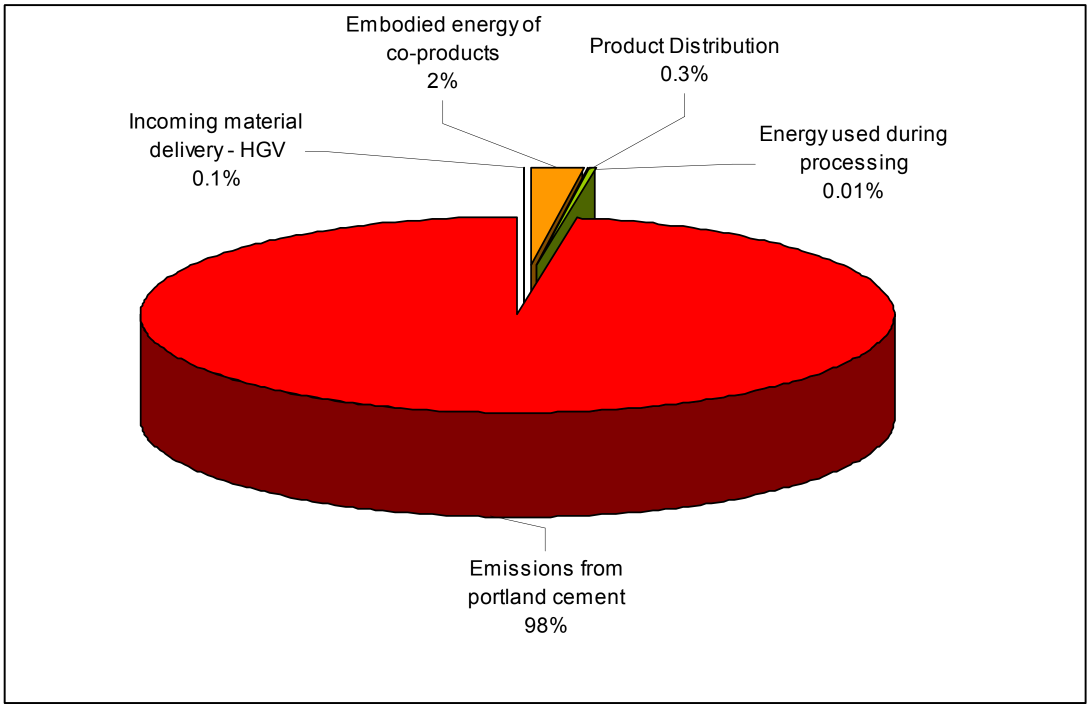


Figure 7. Breakdown of the emissions associated with Cenin 3 60/40.

Cenin 3 – 50/50

The cradle to gate *plus* production distribution emissions associated with Cenin 3, composed of 50% Portland cement and 50% Cenin 3 cement replacement are 442.7 kilograms of CO_2 per tonne. A breakdown of these emissions is shown in Table 8 and Figure 8.

Table 8. Breakdown on the emissions associated with Cenin 3 50/50.

Source of emissions	CO_2 emitted (kg/tonne cement)
Incoming material delivery - HGV	0.7
Embodied energy of co-products	13.6
Fuel deliveries for biogas plant	0.08
Energy during biogas production	0.0
Product Distribution	1.8
Emissions of portland cement	426.5
Total emissions per tonne of Cenin 3 50/50	**442.7**

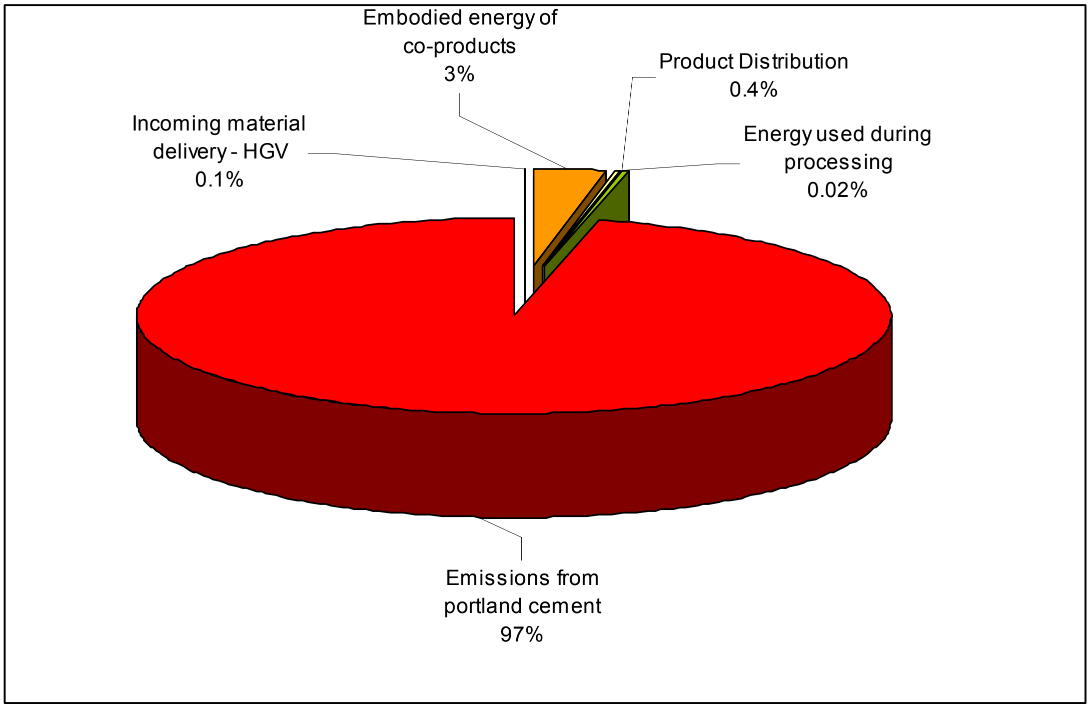


Figure 8. Breakdown of the emissions associated with Cenin 3 50/50.

5. Analysis of Results

The emissions associated with conventional Portland cement are 853 kilograms of CO_2 per tonne of cement (British Cement Association). This study demonstrates that Cenin have achieved substantial emissions reductions on this figure with their cement replacement products (an average across all products of 60% when compared to Portland cement) through a variety of measures.

Materials

Cenin use a mixture of waste products and co-products in the manufacture of their cement. The waste that Cenin uses has no associated embodied emissions as any emissions are assumed to belong to the primary product from which the waste was generated.

When a process produces other usable products in addition to the primary product, the other usable products are classified as ‘co-products’ that have an associated market value. In this case, a proportion of emissions should be allocated to the co-product. A portion of lifecycle emissions in this study has been assigned to the co-products in the ratio of the relative economic value of the co-products (in accordance with the draft Carbon Trust methodology for assessing the emissions of products and services).

By further increasing the use of waste products as opposed to co-products in the manufacture of their cement replacement products, Cenin can further reduce the emissions associated with their products.

Energy

Cenin uses renewable energy in the production of its cement replacement products – specifically biogas and wind power. Table 9 and Figure 9 demonstrates what the total emissions for each product would be if Cenin used imported electricity, drawn from the UK grid, and natural gas. The Table also compares those emissions to the total emissions using only renewable energy. The UK electricity and natural gas emissions factors used in this analysis are provided by DEFRA.

Table 9. Emissions reductions using renewable energy during processing.

Source of emissions	CO_2 emitted (kg/tonne cement)		Difference (kg)
	With renewable energy	Without renewable energy	
Cenin 1	72	240	168
Cenin 2	26	195	168
Cenin 3: 70/30	608	635	27
Cenin 3: 60/40	525	561	36
Cenin 3: 50/50	442	488	45

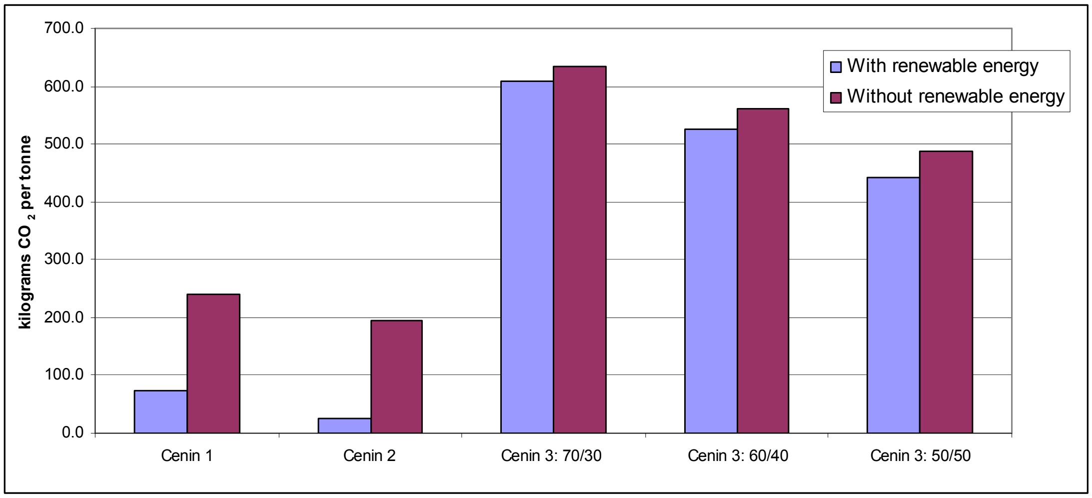


Figure 8. Breakdown of the emissions associated with Cenin 3 50/50.

The total reported emissions associated with each Cenin product using only renewable energy in Table 9 above are lower than the total emissions associated with each Cenin product reported in Table 4 in the results section of this report. This is due to the omission of biogas feedstock deliveries in Table 9. The DEFRA UK emission factors for grid electricity and natural gas that have been used are on a combustion basis only, and do not include the emissions associated with the extraction, processing and transportation of fuels for the product of electricity and gas. In this study, we have considered the transport of feedstock to the biogas plant. Electricity consumption by the biogas plant has also been considered but is derived from the biogas itself and so has no associated emissions. Therefore, for a meaningful comparison, in Table 9 the emissions associated with the transport of fuel to the biogas plant has been excluded. As there are no emissions associated with combustion of energy produced from renewable sources, there are no associated combustion emissions with the energy produced from the biogas plant and wind turbine.

Methane is a very potent greenhouse gas, with a global warming potential (see glossary for definition) of 23 times that of carbon dioxide. It has been assumed here that there is no leakage from the biogas plant. If this were to occur, the emissions associated with the cement replacement products would be significantly increased.

Deliveries

A significant proportion of emissions come from the incoming delivery of raw materials from which the cement replacement is manufactured. Cenin can minimise the emissions arising from this by sourcing their materials from as close as possible to the manufacturing facility.

Table 10 demonstrates the emissions associated with the transport of 1 tonne of raw material for distances of 10, 50 and 100 miles by heavy goods vehicle and shows the importance of sourcing materials as close to the manufacturing facility as possible.

Table 10. Emissions associated with different incoming delivery distances.

Weight transported (tonnes)	Distance transported (miles)	Estimated fuel consumption (litres)	CO_2 emitted (kg/tonne)
1	10	0.2	0.7
1	50	1.2	3.3
1	100	2.5	6.5

Further savings can be made by choosing forms of transport with the lowest associated emissions. Cenin have achieved savings of 15 kilograms of CO_2 per tonne of product by shipping the waste product they use by sea as opposed to by heavy goods vehicle. Rail and canal shipping are other examples of transport with low associated emissions.

The distribution of the finished product has also been considered in this assessment. Like incoming material delivery, the distance over which the product is delivered will have an impact on the overall emissions associated with the products. For illustrative purposes, we have assumed that the distance over which the product is distributed is 25 miles. If this distance were to increase to 150 miles, the emissions associated with product distribution would increase from 1.8 to 10.9 kilograms of CO_2 per tonne of product delivered, as shown in Table 11.

Table 11. Emissions associated with different distribution distances.

Weight transported (tonnes)	Distance transported (miles)	Estimated fuel consumption (litres)	CO_2 emitted (kg/tonne)
1	25	0.7	1.8
1	50	1.4	3.6
1	100	2.8	7.3
1	150	4.2	10.9

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Appendix I - Glossary

Glossary

Carbon Dioxide Equivalent (CO_2e). The universal unit of measurement used to indicate the global warming potential (GWP) of each of the 6 Kyoto greenhouse gases. It is used to evaluate the impacts of releasing (or avoiding the release of) different greenhouse gases.

Climate change. A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability over comparable time periods (Source: United Nations Framework Convention on Climate Change).

Control. The ability of a company to direct the operating policies of a facility or organisation. Usually, if the company owns more than 50% of the voting interests, this implies control. The holder of the operating licence often exerts control, however, holding the operating licence is not a sufficient criteria for being able to direct the operating policies of a facility or organisation. In practice, the actual exercise of dominant influence itself is enough to satisfy the definition of control without requiring any formal power or ability through which it arises.

Direct emissions. Emissions that are produced by organisation-owned equipment or emissions from organisation-owned premises, such as carbon dioxide from electricity generators, gas boilers and vehicles, or methane from landfill sites.

Equity share. The percentage of economic interest in/benefit derived from an organisation.

Global warming The continuous gradual rise of the earth's surface temperature thought to be caused by the greenhouse effect and responsible for changes in global climate patterns (see also Climate Change).

Global Warming Potential (GWP) The GWP is an index that compares the relative potential (to CO_2) of the 6 greenhouse gases to contribute to global warming i.e. the additional heat/energy which is retained in the Earth's ecosystem through the release of this gas into the atmosphere. The additional heat/energy impact of all other greenhouse gases are compared with the impacts of carbon dioxide (CO_2) and referred to in terms of a CO_2 equivalent (CO_2e) e.g. Carbon dioxide has been designated a GWP of 1, Methane has a GWP of 21.

Greenhouse gases. The current IPCC inventory includes six major greenhouse gases. These are Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF_6).

IPCC. The Intergovernmental Panel on Climate Change. A special intergovernmental body established by the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO) to provide assessments of the results of climate change research to policy makers. The Greenhouse Gas Inventory Guidelines are being developed under the auspices of the IPCC and will be recommended for use by parties to the Framework Convention on Climate Change.

Indirect emissions. Emissions that are a consequence of the activities of the reporting company but occur from sources owned or controlled by another organisation or individual. They include all outsourced power generation (e.g. electricity, hot water), outsourced services (e.g. waste disposal, business travel, transport of company-owned goods) and outsourced manufacturing processes. Indirect emissions also cover the activities of franchised companies and the emissions associated with downstream and/or upstream manufacture, transport and disposal of products used by the organisation, referred to as product life-cycle emissions.

Kyoto Protocol. The Kyoto Protocol originated at the 3rd Conference of the Parties (COP) to the United Nations Convention on Climate Change held in Kyoto, Japan in December 1997. It specifies the level of emission reductions, deadlines and methodologies that signatory countries (i.e. countries who have signed the Kyoto Protocol) are to achieve.

Appendix II - Emissions Calculations and Assumptions

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