Life Cycle Assessment of Concrete Canvas (CCT2)

Report for Concrete Canvas
ED13616

Customer:

Concrete Canvas

Customer reference:

ED13616

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10 June 2022

Ricardo Energy & Environment reference:

Ref: ED13616 - Issue Number 2

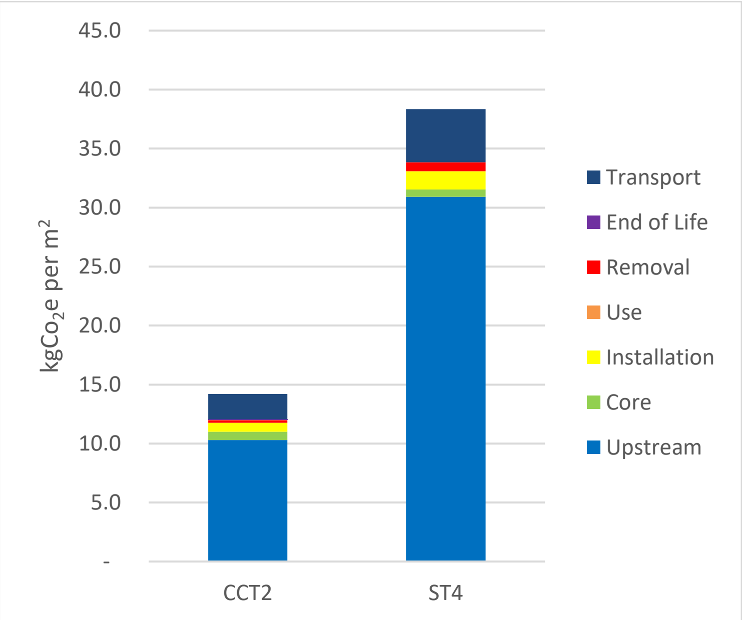
Executive summary

Concrete Canvas appointed Ricardo Energy & Environment (Ricardo) to undertake a life cycle assessment (LCA) of the global warming potential (GWP) of its concrete-filled geosynthetic product, CCT2. CCT2 is an 7.5mm thick Geosynthetic Cementitious Composite Mat (GCCM), which is a geosynthetic filled with a dry concrete mix. It is supplied on a roll and can be installed with minimal equipment, setting once water is applied to it.

CCT2 can be used to line channels that might otherwise be constructed from traditional concrete. To understand which of these systems is preferable, Ricardo assessed the GWP of using Concrete Canvas's CCT2 material or 150mm thick ST4 20MPa concrete to produce a 1,800m^2 channel, 500m in length located 200km from Concrete Canvas' facility and 20km from a local ST4 supplier.

The study considered the 'upstream' impacts associated with raw material extraction, the 'core' impacts associated with manufacturing each product and the 'downstream' impacts associated with installation, removal and end of life. The impacts arising from transportation between these stages were also considered. Primary data concerning Concrete Canvas' raw materials and utility consumption was used in combination with secondary data from life cycle assessment databases.

It is found constructing the channel with **CCT2 results in a GWP value that is 63% lower than that of the ST4 alternative over the products life cycle**. ST4 reports higher impacts in all life cycle stages apart from the core stage and end of life.



Both systems report impacts in similar life cycle stages, with the upstream stage being the key hotspot. This impact is associated with the supply of raw materials before they reach GCCM or concrete manufacturing facilities. It is found that the procurement of cement has the greatest impact of these raw materials. Concrete Canvas has selected a cement supplier that was able to

LCA Terminology

Global warming potential
This is the potential of CO_2, CH_4 and other greenhouse gas emissions to contribute to warming the planet, causing climate change.

Upstream
This is the first stage of a life cycle and refers to activities that occur before the 'core' activity, in this instance before GCCM and concrete manufacturing.

Core
This life cycle stage considers activities that are within the company's core control – in this instance GCCM and concrete manufacture.

Downstream
This life cycle stage considers all activities after the company's core function, in this instance everything after the factory gate i.e. distribution, installation, removal and disposal.

provide an emission factor specific to its cement, which has helped to lower its upstream burdens. However, the key driver is found to be the difference in scale between the two systems. To deliver the same project, ST4 requires 19 times as much raw material. This difference in weight also leads to greater transport burdens. The study has found that CCT2 results in higher impacts during its manufacture, however, this difference is not sufficient to outweigh the higher impacts that ST4 has during its upstream, installation, removal and transport stages.

Sensitivity analysis has been performed in three areas to test the assumptions in this report:

Cement type

ST4 was modelled using the same cement provider as CCT2 to understand whether simply changing suppliers could make ST4 preferable to CCT2. While this analysis found that switching to CCT2's cement supplier resulted in ST4's raw material impacts reducing by 11%, the net reduction of potential carbon impacts was only 3% once the same transport assumptions used for CCT2's suppliers was applied.

Removal

By volume, less CCT2 is required per m^2 of channel compared to ST4 and it is assumed that it can be removed faster. The initial analysis assumed it would be removed roughly as fast as it could be installed. Sensitivity analysis was undertaken to speed up ST4's removal rate to understand what impact these assumptions had. Again, ST4's impact was found to reduce but doubling its removal rate was insufficient to make it preferable to the default CCT2 system.

Weight

A key differentiator appears to be the weight of ST4 required per m^2 compared to the weight of CCT2, so a final sensitivity was undertaken to reduce the thickness of ST4 required to create the channel. This variable drives reductions in all life cycle stages, since they are predicated on the weight of ST4 being produced, transported, installed or removed. The sensitivity identified that the depth of ST4 must be reduced by 63% before it can be found to be preferable to CCT2, although without the addition of steel reinforcement, this would not likely be practical in reality.

The sensitivity analyses found that the results are sensitive to model assumptions, however, CCT2 was found to be preferable under all of the scenarios assessed, unless the thickness of ST4 required can be reduced by more than half. It is understood that when the thickness of poured concrete is below 100mm, steel reinforcement is typically required, which would increase the GWP.

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1 Introduction

Concrete Canvas appointed Ricardo Energy & Environment (Ricardo) to undertake a life cycle assessment (LCA) of the global warming potential (GWP) of its concrete filled geosynthetic product; CCT2, compared with traditional concrete. CCT2 is an 7.5mm thick Geosynthetic Cementitious Composite Mat, which is a geosynthetic filled with a dry concrete mix. It is supplied on a roll and can be installed with minimal equipment, setting once water is applied to it.

To understand the global warming potential of Concrete Canvas's product in comparison to traditional concrete, Ricardo undertook a LCA of constructing a concrete channel with either CCT2 or 150mm of ST4 concrete. The LCA is based on a constructing a concrete channel for HS2 and therefore the channel dimensions and transport distances reflect the HS2 requirements. In this study, the channel measures 500m in length and has a cross channel width of 3.6m. To calculate the GWP in transport from production to installation, the channel is considered to be located in Birmingham, 200km away from Concrete Canvas Ltd's factory in Pontyclun and 20km away from a theoretical ST4 concrete batching plant. The ST4 concrete batching plant is closer as ST4 is restricted in distance from the project site before the concrete sets.

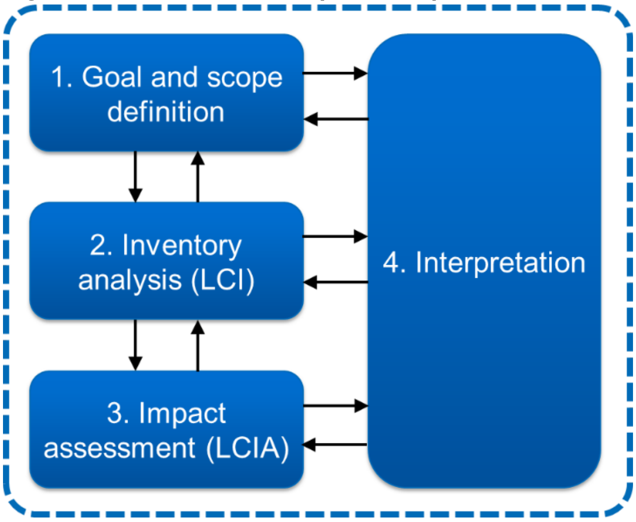
This report outlines the goal and scope of the LCA study, the methodology and assumptions made in compiling the life cycle inventories and assesses the global warming potential of constructing one square metre of the aforementioned channel.

2 Life Cycle Assessment

Life cycle assessment (LCA) is a method for analysing the environmental impacts of a product or service over the course of its lifetime. This study measures the impacts that occur within Concrete Canvas's control as well as those that occur upstream (connected to producing the raw materials needed for CCT2) and downstream (linked with product installation, use and end of life).

By assessing all 'flows' within a study's system boundary, we can identify the real impact hotspots and better target decision making. Life Cycle Assessment is the compilation of the inputs and outputs of a product system over its lifetime and the calculation of the potential environmental impacts. Undertaking a life cycle assessment is an iterative process, which starts with defining the study's goal and scope before compiling the lifecycle inventory and then conducting and interpreting the impact assessment results. This study follows the principles of ISO 14040.

Figure 1: The LCA Process (ISO14040)



3 Goal & Scope

The goal of this LCA is to undertake a comparative life cycle assessment between CCT2 and 150mm ST4 poured concrete (20 MPa), with the aim of determining whether CCT2 provides a GWP saving for channel lining projects when assessed from cradle to grave.

3.1 Platform

At the outset of this project, Concrete Canvas expressed a wish to possess the LCA tool after the study, in order to use the results going forward and support exploring different project scenarios. With this in mind, Microsoft Excel® was selected as the platform to undertake the LCA.

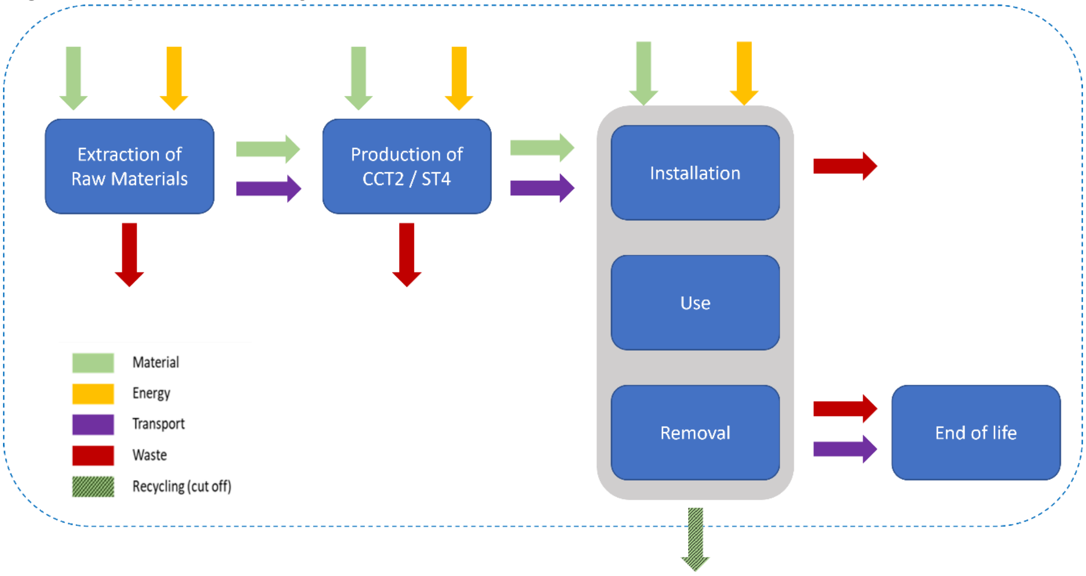
3.2 Environmental Impact Criteria

This study has been limited to assessing the global warming potential of the two systems. This study uses a 100-year period following the formation of the product as a temporal boundary, using the IPCC 2013 100a assessment method.

3.3 System boundary

This study considers a cradle-to-grave system boundary. This means it includes all the upstream processes associated with raw material extraction, core processes such as energy use during manufacture, and downstream processes such as installation, use, removal and disposal.

Figure 2: System boundary

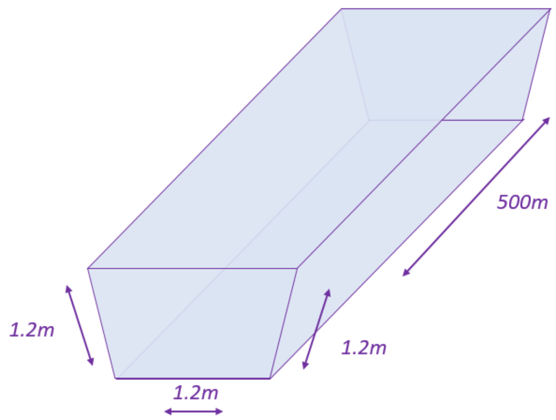


For geographic boundaries, the facility and project site are assumed to be in the United Kingdom (UK). Ecoinvent[1] processes that best match this geography were selected when building the life cycle inventory.

3.4 Functional Unit

The functional unit for this assessment is one square metre of a project channel measuring 500m by 3.6m, as depicted in Figure 3.

Figure 3: Project channel diagram



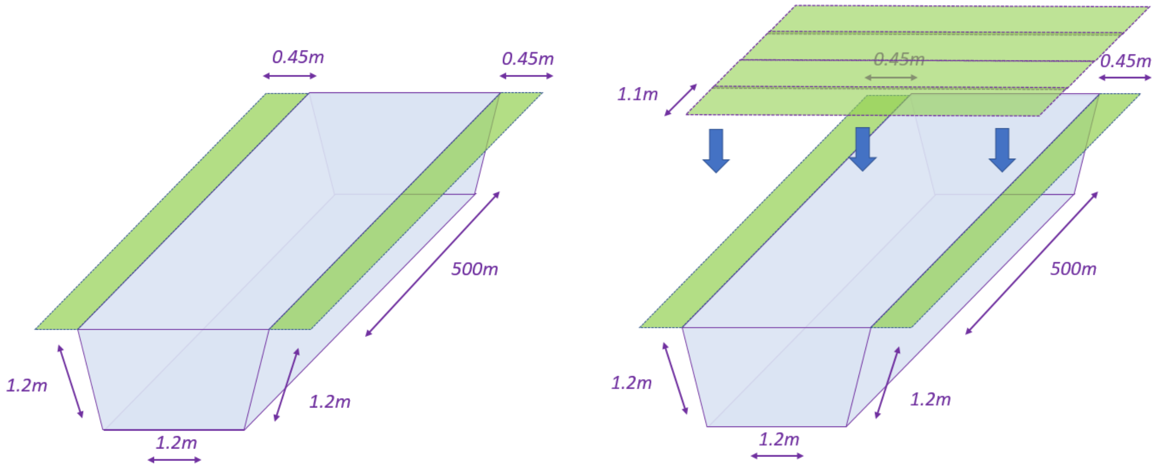
3.4.1 Reference Flow

Concrete Canvas and traditional concrete are quite different. CCT2 is supplied as 1.1m wide rolls and is laid in sections across the channel, requiring a 100mm overlap between sections. Edges are captured in anchor trenches at the crest of the channel, as shown in Figure 4 below. The anchor

[1] ecoinvent v3.71 https://ecoinvent.org/the-ecoinvent-database/data-releases/ecoinvent-3-7-1/

trenches and 100mm overlaps mean that the total area of CCT2 required is greater than the project area.

Figure 4: CCT2 anchor trenches and overlapping sections



Poured concrete does not require overlapping or anchor trenches and is simply the project area multiplied by the desired depth, in this case 0.15m. Table 1 below shows the reference flow for each system per functional unit and per the total project. Please note that CCT2 is given in units of area (m^2) whereas ST4 is provided in units of volume (m^3).

Table 1: Reference flows for CCT2 and ST4 for one square metre of channel

Channel	CCT2	ST4
(1.2x3) x 500 = 1,800m^2	(0.45x2 + 1.2x3) x 500 x 1.1 = 2,475m^2 => 1.375m^2 / m^2 channel	(1.2x3) x 500 x 0.15 = 270m^3 => 0.15m^3 / m^2 channel

3.5 Data quality

Obtaining reasonable data for an LCA is critical and is usually the determining factor for a project's quality and also for the effort required to complete the work. LCA practitioners prefer to use primary data where possible, direct from the systems being studied, and only revert to secondary data (from literature) when required. The balance of primary and secondary data is often dictated by the budget and timescale of the study.

Concrete Canvas provided Ricardo with primary data covering the materials consumed in its production process between 1st of September 2020 and 31st August 2021. This was provided alongside the amount of each product line produced and the waste flows. Primary data on the facility's utility consumption was also provided. Ricardo extrapolated this data to cover the same period as the material flow data. Secondary data was taken from the ecoinvent database to model ST4's production. Updated product thickness and weight information was provided in May 2022.

Concrete Canvas also provided Ricardo with an independent comparison report including a cost estimation for labour and plant, as well as typical installation rates for Concrete Canvas and ST4. Ricardo used these estimates to build inventories for downstream installation and removal. The inventories were built using processes from ecoinvent v3.7[2] and the UK Government's GHG Conversion Factors[3].

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[2] ecoinvent v3.71 https://ecoinvent.org/the-ecoinvent-database/data-releases/ecoinvent-3-7-1/

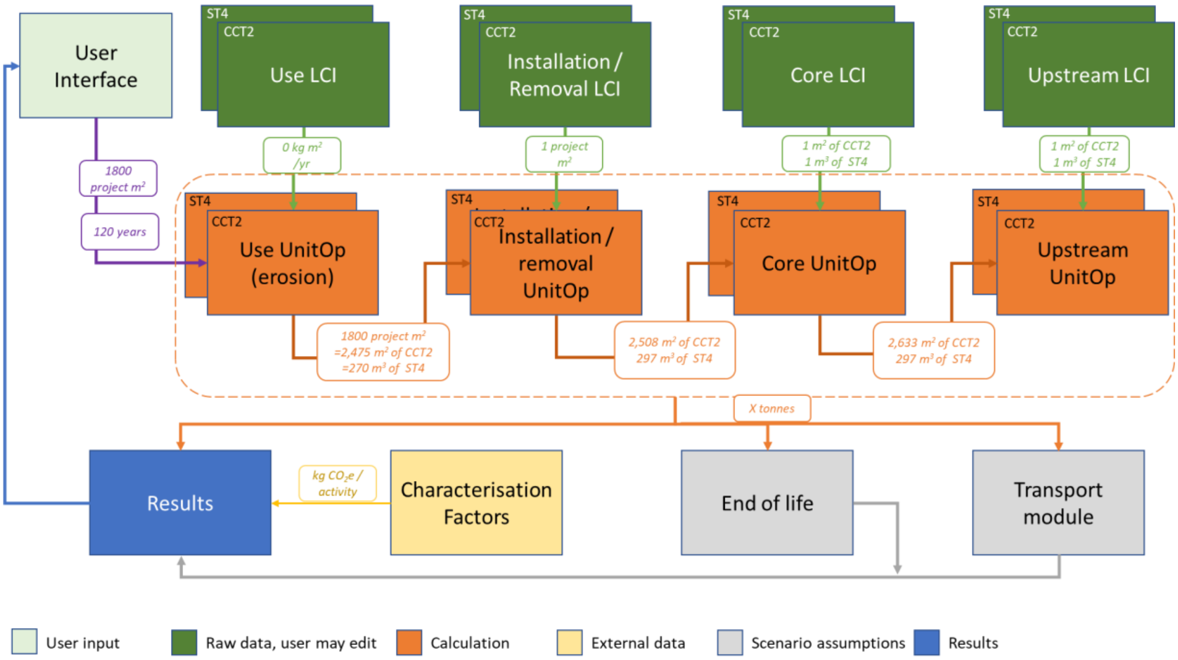
[3] Greenhouse gas reporting: conversion factors 2021 https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021

4 Inventory analysis

Lifecycle inventories were developed to model the life cycle stage for each system, as well as inventories for the transport between stages and each product's end of life.

Raw data described activities at different scales, for example a year's worth of production, or the effort involved in a m^3 of concrete. These raw datasets were read and scaled up or down by Unit Operations (UnitOp) to create an inventory representative of the 1,800m^2 channel. The UnitOp inventories described the flow of materials and energy for their given stage. The requirement for each stage is cascaded backward so that the amount required at installation (including losses) informs the Core stage (manufacturing), which in turn informs the upstream phase. In this way, the amount of upstream raw materials required includes those turned to waste within the manufacturing and installation life cycle stages. Figure 5 below illustrates how the Life Cycle Inventory (LCI) model worked, with LCIs communicating to one another to ensure sufficient provision.

Figure 5: Schematic diagram of model



4.1 Upstream

The upstream stage covers the extraction of raw materials. For CCT2 this was based on primary data provided by Concrete Canvas. Table 2 below shows the materials used within CCT2. While laminate does not form part of CCT2, it is used in other product lines and was added to the model so that Concrete Canvas could amend the tool to assess other products in the future.

Table 2: CCT2 composition

Material	%wt
Sand	53%
Cementitious material	35%
PVC	6%
Geosynthetic	5%
Laminate	0%

Within the model, CCT2 cement is modelled with the specific emission factor provided by Concrete Canvas' supplier as stated in its EPD[4]. PVC is modelled using two ecoinvent processes:70% polyvinylchloride[5] and 30% chalk[6]. The laminate process, while not used within this assessment of CCT2, is modelled using an ecoinvent process for polyvinylchloride.

The ST4 upstream materials are taken from the ecoinvent process for 1m^3 concrete production 20MPa[7]. The materials are listed in Table 3. The model includes functionality to swap the cement flow from the ecoinvent default to the same cement used in CCT2.

Table 3: ST4 composition

Material	%wt
Gravel	47%
Sand	43%
Cement	10%
Fatty alcohol	<1%
Ethylene oxide	<1%
Steel	<1%
Acetic Acid	<1%
Other, Chemical, organic	<1%
Rubber	<1%

4.2 Core

The Core stage is the part of the lifecycle within the producer's control i.e. manufacturing. Concrete Canvas provided primary data on its 2020/2021 production volumes of its GCCMs covering CC5, CC8, CC13, CCH5 and CCH8 (which have now been replaced by CCT1, CCT2, CCT3, CCHT1 and CCHT2 respectively). Data covered the total area and weight produced for each range. Additionally, Concrete Canvas provided data on its natural gas and grid electricity consumption. This data covered a period of 365 days. Both types of energy use were modelled using the UK GHG Conversion Factors for grid electricity and natural gas. This is inclusive of the Scope 1 and 2 emissions, as well as the upstream emissions associated with transmission & distribution and the effort involved in producing fuels, prior to their combustion (Well-To-Tank emissions).

Within the model, this utility burden can be allocated to CCT2 using either an equal area allocation or an area allocation that factors in production time. It was assumed that the effort to produce a Concrete Canvas GCCM product would be dependent on the time it moved across machinery and therefore, this analysis is limited to area factoring in machine time allocation.

[4] Environmental Product Declaration, Calcium Aluminate Binders – Low alumina content. CIMENT FONDU® – TERNAL® RG – TERNAL® RG-S – TERNAL® SE 2019. Kerneos Aluminate Technologies.

[5] Polyvinylchloride, bulk polymerised {RER}| polyvinylchloride production, bulk polymerisation | Cut-off, U

[6] Limestone, crushed, washed {CH}| market for limestone, crushed, washed | Cut-off, U

[7] Concrete, 20MPa {RoW}| concrete production 20MPa, RNA only | Cut-off, U

In addition to the energy flows, Concrete Canvas provided data on its skip usage which includes all GCCM waste. For 2020, by weight this equalled 3.8% of purchased cement, for the purposes of modelling this figure was rounded up to 5%, this is also included as a variable within the user interface. While it is assumed that 5% of CCT2 produced at Concrete Canvas' facility is 'wasted', it should be noted that some of this material will have been used as part of Quality Control testing and serves a purpose. This is modelled with an ecoinvent landfill process[8].

Table 4: CCT2 Energy consumption per m^2 channel

Material	MJ/m^2
Natural gas	4.34
Electricity	6.00

The ST4 Core stage is based on the ecoinvent process for concrete production 20MPa, albeit that the electricity and gas processes were modelled using the UK GHG Conversion Factors mentioned above, rather than the default grid assumptions contained in ecoinvent. In addition to natural gas and grid electricity, the ecoinvent process consumes a modest amount of diesel, as well as consumables such as water and lubricating oil.

Table 5: ST4 Energy consumption per m^2 channel

Material	MJ/m^2
Diesel	2.58
Electricity	2.15
Natural gas	-

4.3 Downstream

4.3.1 Installation

Plant

Concrete Canvas stated that CCT2 can be conservatively laid at a rate of 500m^2 per day and would require the use of a 13-tonne excavator and a 6-tonne dumper. It is assumed that the excavator and dumper would be in use throughout the installation period. To model this, Ricardo undertook desktop research into the engine power of both vehicles, assuming an average operation of 50% of max power, this was used to determine diesel consumption of 2.76 litres per hour for both vehicles.

The independent comparison report provided by Concrete Canvas also provided information on typical installation of ST4 concrete, stating a typical installation rate of 28m^3 per day. Like CCT2, a 6-tonne dumper would be used but a smaller 2.5-tonne excavator would also be required for ST4. Using the same assumptions as CCT2 above, fuel consumption of 2.76 litres per hour was modelled for the dumper and 0.9 litres per hour for the excavator.

Materials

In addition to the vehicles, during installation CCT2 is secured in place with galvanised mild steel pins and the overlaps are joined together with stainless steel screws. Sealant may be used in combination with the screws to join the CCT2 sheets. The model includes functionality to model this, however this analysis is focussed on a scenario where only screws and pins are used, sealant was not required. In addition to fixings, water is required to set the CCT2.

[8] Inert waste, for final disposal {CH}| treatment of inert waste, inert material landfill | Cut-off, U

To lay the ST4 concrete, construction joints and consumables are required. These were modelled using an ecoinvent process for wood[9]. This was estimated at 0.05m^3 of wood per m^3 of ST4 based on the comparison report provided by Concrete Canvas.

Table 6: Installation flows per m^2 of channel

	ST4	CCT2
Excavator	1.42 MJ	2.18 MJ
Dumper	4.24 MJ	2.18 MJ
Wooden joints	0.00697 m^3	-
Water	-	8.25l
Screws	-	13.6g
Pins	-	156g
Sealant*	-	-*

*62.5ml if sealant is used

Some flows were excluded from the inventories. CCT2 installation would also require the use of a water bowser and small tools. ST4 would require additional formwork, a single tool compressor and poker as well as small tools. These were considered unlikely to be materially significant and difficult to model accurately so have been excluded.

4.3.2 Use

Both products are inert during the use phase. However, Concrete Canvas indicated that at a future date it may wish to model the potential impacts of any product erosion. The model was built with functionality to model this step, however, there is currently no data to quantify such erosion. Erosion is unlikely to contribute to climate change, but it may be a consideration for other environmental indicators.

4.3.3 Removal

It is assumed that a 13 tonne excavator will be used for removal. It is assumed that both products' removal time is similar to their installation time. Once removed, the products are transported back to the site entrance. This transport is modelled using CCT2's set weight, which is heavier than the dry weight[10].

4.3.4 End of Life

At end of life, CCT2 is assumed to be sent to landfill. This is modelled using an ecoinvent process for inert landfill. ST4 concrete is assumed to be recycled for aggregate at end of life. Following the polluter pays principle, it is cut-off from this system boundary at the point it is removed from the site.

4.4 Transport

Transport occurs throughout the life cycle. Mini inventories were created to model the upstream transport from suppliers to the manufacturing facility, from the facility to the channel site, and from the site to end of life.

[9] Sawnwood, beam, softwood, raw, dried (u=20%) {GLO}| market for | Cut-off, U

[10] CCT2's dry weight is 12.34kg/m2, once water is added this increases to 15kg/m^2

4.4.1 Transport Upstream

As detailed in Table 2 in Section 4.1, CCT2 comprises four materials: cement, sand, geosynthetic, and PVC. Concrete Canvas provided the location of its suppliers for these materials. Desktop research was undertaken to determine the distance via road between the Concrete Canvas factory and its suppliers. This information was combined with the mass of materials required to deliver the project channel (including reject products and losses at the installation site) to determine a tonne kilometre freight value.

While laminate is not used within the CCT2 product, the model includes transport assumptions for it that are mostly undertaken by sea freight.

ST4's upstream burdens are contained within the raw materials modelled in the upstream phase. These are market processes that include typical transport burdens for bringing those materials to market.

4.4.2 Transport production-to-installation

ST4 is assumed to be procured locally, travelling 20km from its factory location to the project site, whereas CCT2 travels 200km. While CCT2 is transported further, the volume of ST4 concrete required is significantly heavier than the equivalent area of CCT2, largely because water is added to the CCT2 product in situ. Consequently, significantly more road movements are required for the ST4 system. Table 7 below shows the tonne-km (tkm) requirement for both system's Core transport.

Table 7: Core transport tkm per m^2 of channel

ST4 road freight	CCT2 road freight
7.13tkm	3.44tkm

4.4.3 Transport end of life

It is assumed that the distance from the site to end of life for both CCT2 and ST4 would be 40km, undertaken by road. However, unlike the Core transport step, the set weight of CCT2 is greater than the dry weight. CCT2's freight requirement increases to account for this, whereas ST4's burdens reduce as some installation waste has already been disposed of before the main end of life stage.

Table 8: EoL transport tkm per m^2 of channel

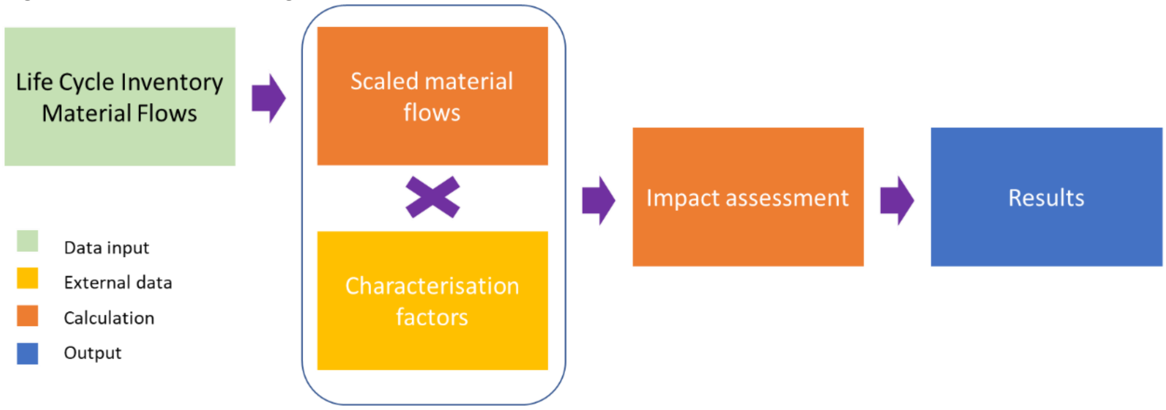
ST4 road freight	CCT2 road freight
14.01tkm	0.825tkm

5 Impact Assessment

As described above, the model 'reads' input data from "raw" sheets, this data is then scaled within Unit Operation (UnitOp) sheets to provide the amount of material required for the defined project. These UnitOperations form the model's inventory, which is described in Section 4.

Alongside these inventories, the impact assessment is performed. An emission factor is loaded from the 'Characterisation Factors' sheet for the given flow, then multiplied by the amount to determine emissions. This flow of data is illustrated in Figure 6 below.

Figure 6: Model Flow Diagram



5.1 End of life

This study has used a cut-off approach to end of life. This allocates the primary production of materials to the primary user of a material. If a material is recycled, the primary producer does not receive any credit for the provision of any recyclable materials. Recyclable materials are then available burden-free to recycling processes and secondary materials bear only the impacts of the recycling processes. For example, systems that use secondary materials will likely receive smaller capital burdens compared to those that use virgin materials, but processes that send materials to recycling do not receive a credit. Instead, processes that send material to recycling avoid a waste management burden. The assumptions for end of life fates for materials contained in the model is shown in Table 9 below.

Table 9: Key end of life assumptions

Material	Fate
Waste CCT2 (at core)	Landfill
Waste CCT2 (at installation)	Landfill
Waste CCT2 (at removal)	Landfill
Waste ST4 (at core)	ecoinvent assumption – market for waste concrete[11]
ST4 losses (at installation)	Sent for aggregate
Waste ST4 (at removal)	Sent for aggregate

It should be noted that Concrete Canvas is researching processes for reducing material sent to landfill at all stages of use.

[11] Waste concrete {Europe without Switzerland}| market for waste concrete | Cut-off, U

5.2 Quality Assurance

Ricardo takes the quality assurance of its spreadsheet model very seriously and has developed a bespoke QA Workbench tool to automatically crawl over workbooks, build logs of their characteristics and assist the auditor in reviewing the results and recording actions.

In the development of the model in 2020, the QA auditor reviewed 946 unique formula and 35 named ranges, identifying 14 points for review. These included extending named ranges, clarifying formatting, and providing additional commentary. These points were shared with the model owner, addressed and logged in a separate QA file. One notable bug was identified regarding the Concrete Canvas' overlap; this was addressed, and data validation put in place to prevent future errors.

All changes to the model made in this update, including any formula changes, new data entries and transcription and emission factor updates have all been reviewed and approved following the update.

6 Results

This section outlines the initial results of this study. As noted above, the tool developed for this study is capable of assessing different project dimensions and different concrete canvas products, so it is important to revisit the key parameters and assumptions. Table 10 below states the key project parameters and the amounts of CCT2 and ST4 required, based on their individual assumptions. The assumptions for each system are also stated in tabular form in Appendix 1.

Table 10: Key parameters

Parameter	Value
Channel Length	500m
Cross Channel width	1.2m + 1.2m + 1.2m
Project area	1,800m^2
CCT2 requirement	2,475m^2
ST4 requirement	270m^3
Project lifetime	120 years
Entrance to channel distance	2km
Factory to entrance distance	20km (ST4) 200km (CCT2)

Table 11 below presents each system's impact per 1m^2 installed, broken down by life cycle stage. It is important to note this isn't the impact of producing 1m^2, it is inclusive of the effort involved in producing products that are rejected or wasted on site.

Table 11: Initial results, kg CO_2e per 1m^2

Life cycle stage	CCT2	ST4
Upstream	10.3	30.9
Core	0.71	0.64
Installation	0.76	1.55
Use	-	-
Removal	0.22	0.75
End of Life	0.09	-
Transport	2.14	4.49
Total	**14.21**	**38.3**

The results show that the ST4 concrete has the greatest global warming potential, with higher impacts at almost every life cycle stage. The core stage and end of life are the only life cycle steps where CCT2 has a higher impact.

6.1 Upstream

As illustrated in Figure 7 and Figure 8 below, we can see that both systems' highest impact is found during the upstream stage, which is associated with producing CCT2 and concrete's raw materials.

Figure 7: kgCO₂e per m²

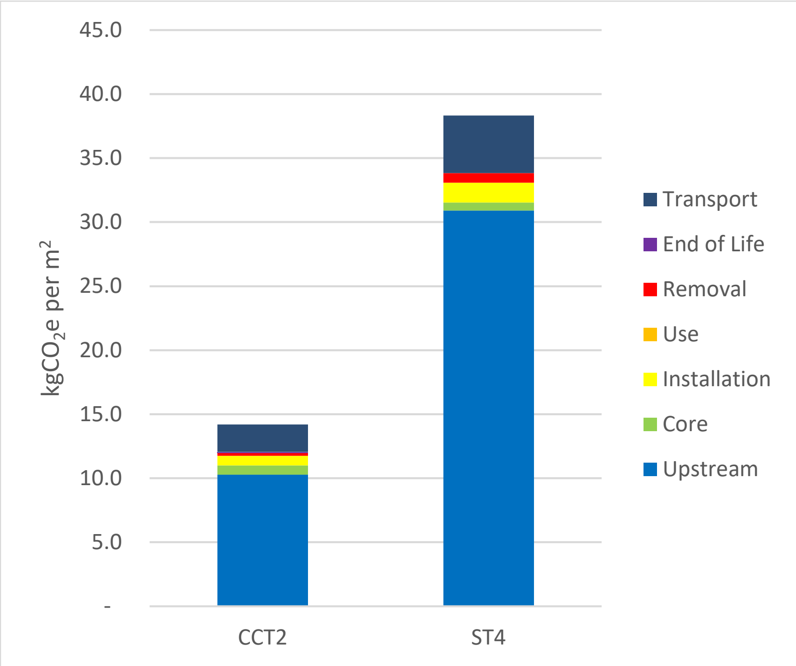
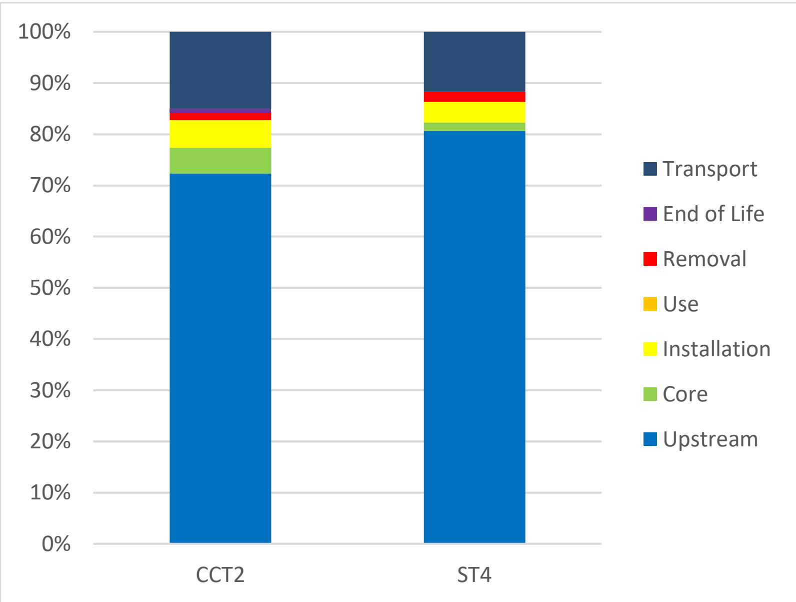


Figure 8: Relative impact by life cycle stage



While the upstream stage is the key stage for both systems, ST4's impact is 201% higher than CCT2's. This is primarily due to two factors; the amount of upstream materials and the type of cement.

Upstream materials

For every 1m^2 of project, ST4 requires 324.26kg of raw materials, whereas CCT2 requires 16.97kg. This is shown in Table 12.

Table 12: Weight (in kg) of raw material required per m² of channel

	ST4	CCT2
Cement	30.92	6.02
Gravel	152.94	-
Sand	140.21	9.03
Geosynthetic	-	0.89
PVC	-	1.04
Miscellaneous	0.19	-
Total	**324.26**	**16.97**

It should be noted that CCT2 is just 7.5mm thick, whereas the ST4 is 150mm. While CCT2 requires overlapped joints and anchor trenches, more ST4 is simply required to construct the same channel. Of these raw materials, cement accounts for 90% of ST4's upstream impact and 45% of CCT2's upstream impact.

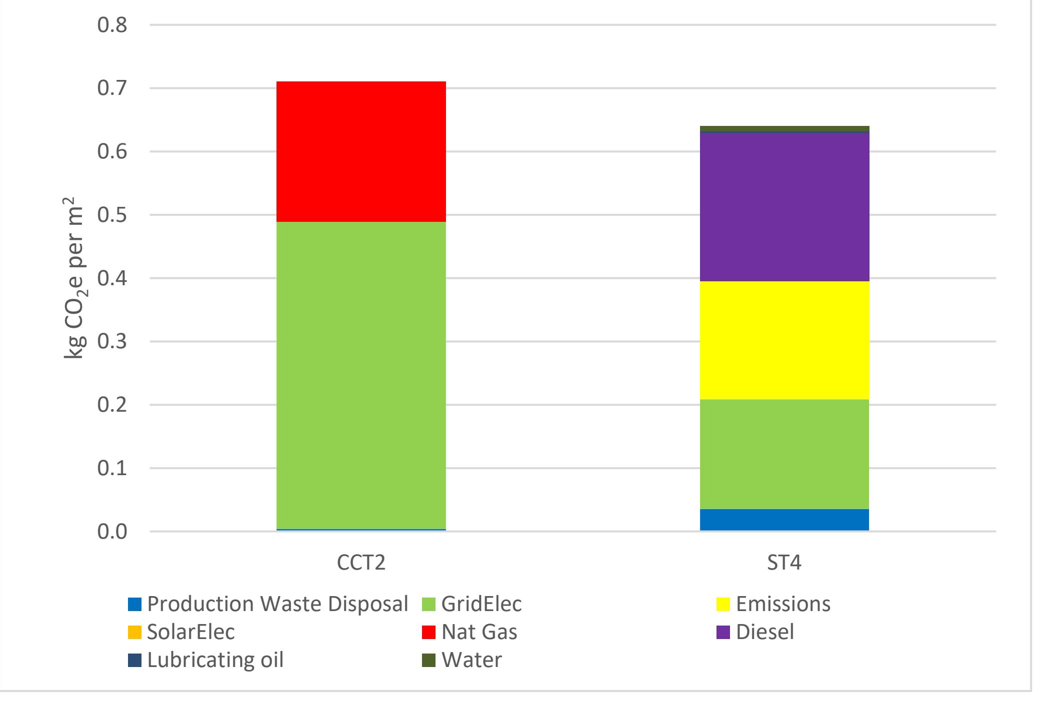
Cement type

The second driver for CCT2's lower upstream burden is the type of cement that has been modelled. As noted in Section 4.1, Concrete Canvas provided an emission factor specific to its cement supplier, and this is lower than the emission factor contained in the ecoinvent data set used to model ST4. The impact of switching ST4's cement for the same supplier is considered further in sensitivity.

6.2 Core

As seen in Figure 8, both system's impacts appear in similar life cycle stages. However, CCT2 has a marginally higher core impact (11% higher than that of ST4). This is to be expected as Concrete Canvas is a more complex product than ST4 that involves combining the cementitious material into a geosynthetic with a PVC backing. ST4 in comparison simply mixes the raw materials together. Figure 9 below compares the Core impacts for both systems. It is interesting to note the impact of diesel consumption and emissions released to atmosphere that are is present within ST4.

Figure 9: Core impacts, kg CO_2e per m² of channel



While undertaking the data collection, Concrete Canvas stated that its new production facility did not contain solar PV but this is something that may be considered in the future. Grid electricity consumption alone accounts for 2.8 times ST4's total core impact, so introducing solar PV would significantly reduce CCT2's core impacts. "Production waste" in the core stage only includes the emissions associated with disposal rather than manufacture of that material.

6.3 Installation

The systems' installation impacts occur from different activities. Per m^2 of channel, ST4 emits twice as much CO_2e laying the concrete compared to CCT2. For ST4, this is closely linked with assumptions regarding the installation rate. Based on the installation rates in the cost comparison report provided by Concrete Canvas, ST4 takes approximately 2 weeks to construct the 1,800m^2 channel. It is assumed that the plant is used throughout this time, and diesel combustion accounts for 33% of the installation impact. CCT2's installation rate is faster, and the 1,800m^2 channel can be built in approximately 1 week. Diesel combustion is lower because of this faster install rate but this is counterbalanced by other impacts.

For CCT2, diesel combustion accounts for 52% of the installation stage's impact. For the entire channel, 11,250Nr 4x30mm stainless steel screws and 1,002 galvanised mild steel 250mm long pins are required to fix the canvas, amounting to 306kg of steel. This is modelled using an ecoinvent process for stainless steel and low alloy steel. It accounts for 0.35 kg CO_2e / m^2 of channel, representing 46% of the installation impact.

Waste is also generated during installation. It is assumed that this waste is not laid and does not require breaking up. Waste CCT2 is sent to landfill, contributing <0.1% to the GWP[12] of the installation stage. It is assumed waste ST4 can be used for aggregate. While this is cut off from the system boundary at this point, the effort involved in moving this extra material around the site contributes to 2% of the total installation burdens.

6.4 Removal

CCT2 is relatively easy to remove; it can be broken up with disc cutters or deliberate removal using an excavator and toothed bucket. For this reason, it was assumed that the removal time would be similar to installation time – with CCT2 having a much smaller removal time. It was also assumed that a 13 tonne excavator would be used for removal. For both systems, the result is a relatively small removal burden compared to the total burden (1% for CCT2 and 2% for ST4). This is however, an acknowledged area of uncertainty.

Table 13 below compares these removal flows on the basis of MJ per tonne of concrete removed. While CCT2's total installation burdens are already smaller than those of ST4, the assumption of a 'worst-case' scenario, where energy of removal equals that of installation, is likely a large overestimation and in reality, CCT2 should have even lower impacts. As seen in Table 13 below, the worst-case scenario of removal, as modelled for CCT2, results in the modelling of a comparably much higher diesel per tonne value for CCT2 than for ST4, which realistically would be lower.

Table 13: Diesel per tonne of concrete removed

ST4	CCT2
13.1 MJ/t	105.6 MJ/t

[12] This waste is calculated in model based on the channel, roll size and overlap parameters set by the user. Based on the parameters set for this analysis, 1.3% of CCT2 arriving at site is assumed to be lost through offcuts.

It should also be noted that the effort involved in breaking up the concrete is not the only flow considered under 'removal'. The vehicle movements from the channel to the site entrance are also modelled. For ST4, these on-site vehicle movements are the important process (49% of removal GWP). The greater weight of ST4 requires more vehicle movements. For CCT2, 10% of removal burdens are linked to moving the concrete to the site entrance.

6.5 End of life

After removal, each product reaches the end of its life. It is assumed that ST4 is used for aggregate in another life cycle and is cut-off from this assessment. CCT2 is assumed to be sent to landfill, an ecoinvent process for inert landfill is used to model this, this represents 1% of the total GWP for CCT2.

6.6 Transport

There are three transport stages, from upstream suppliers to the production facility, from the facility to the installation site and then to end of life.

It should be noted that the upstream transport for ST4 is contained in the ecoinvent processes used to model upstream. CCT2's upstream burdens are modelled with transport distances based on Concrete Canvas' specific suppliers.

It is also worth noting that even though CCT2's production facility is assumed to be located 200 km away from the installation site (a distance 10 times greater than ST4), the GWP for this travel is still ~50% lower for CCT2. This is due to the difference in the weight that needs to be transported. If Concrete Canvas' production facility was closer to the installation site this difference would be even greater. If the same distance used in the ST4 system (20 km) were applicable to the CCT2 system, the transport burden would be 20.8 times lower than ST4. Ricardo calculated that Concrete Canvas' production facility would need to be located 416 km away from the installation site before CCT2's core transport impact equals ST4's.

Table 14 below compares the impacts of the three transport stages.

Table 14: kgCO_2e per m^2 of channel, by transport stage

Transport stage	ST4	CCT2
Upstream transport	-	1.24
Core transport	1.52	0.73
EOL transport	2.98	0.18

7 Sensitivity

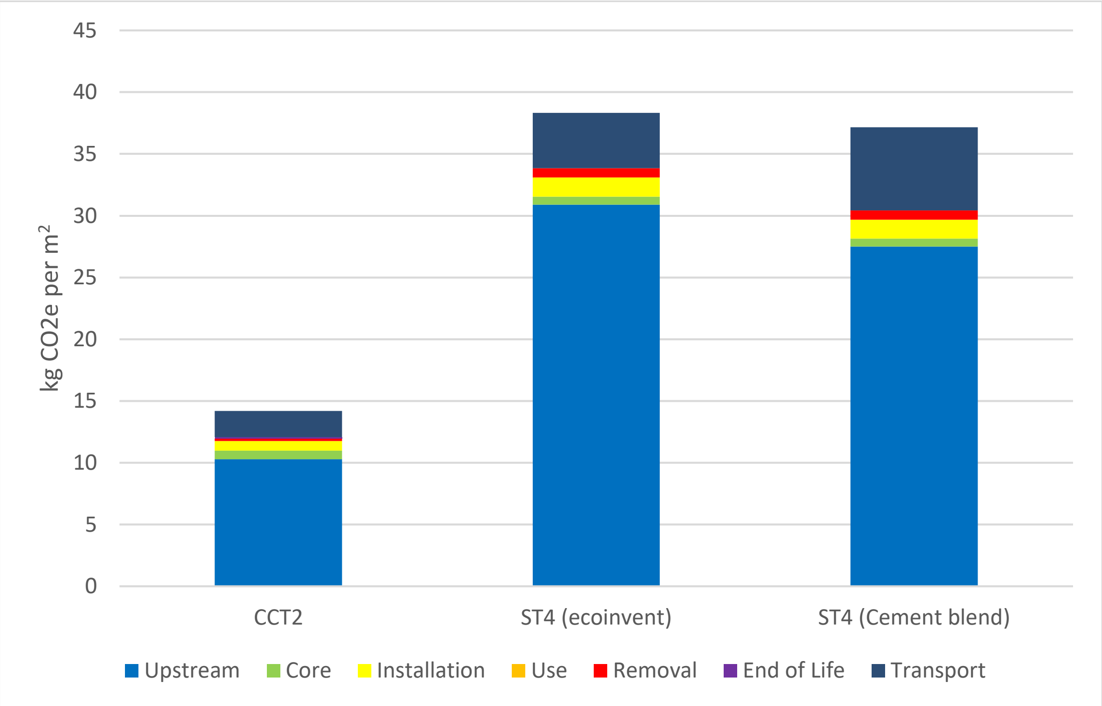
7.1 Cement type

As noted in Section 6.1, the upstream step is the key life cycle stage and within this, cement is responsible for the greatest share of CO_2e emissions. Within the initial analysis above, ST4 and CCT2 use different cement types. ST4's is taken from ecoinvent, whereas CCT2's is taken from supplier data.

This section assesses the impact if ST4 is made using the same supplier emission factor as CCT2. In addition to swapping the cement emission factor, it is also necessary to add on a transport burden for ST4, since its upstream cement process is inclusive of transport burdens. It has been assumed that the ST4 facility is the same distance away as CCT2's site.

Figure 10 below compares CCT2, ST4 using ecoinvent assumptions and ST4 using the same cement blend as CCT2. The results show that using the same cement blend as CCT2, ST4's impact reduces by just 3%. This is perhaps surprising, since ecoinvent's assumptions are attempting to model averages, and factors specific to suppliers can be significantly lower, particularly if they procure green energy. Under the supplier cement scenario, ST4's upstream impact reduces by 11%, however its transport burdens increase by 49.7%, resulting in the small net reduction.

Figure 10: Global warming potential per m^2 of channel, by life cycle stage, comparing ST4 under ecoinvent and other cement assumptions



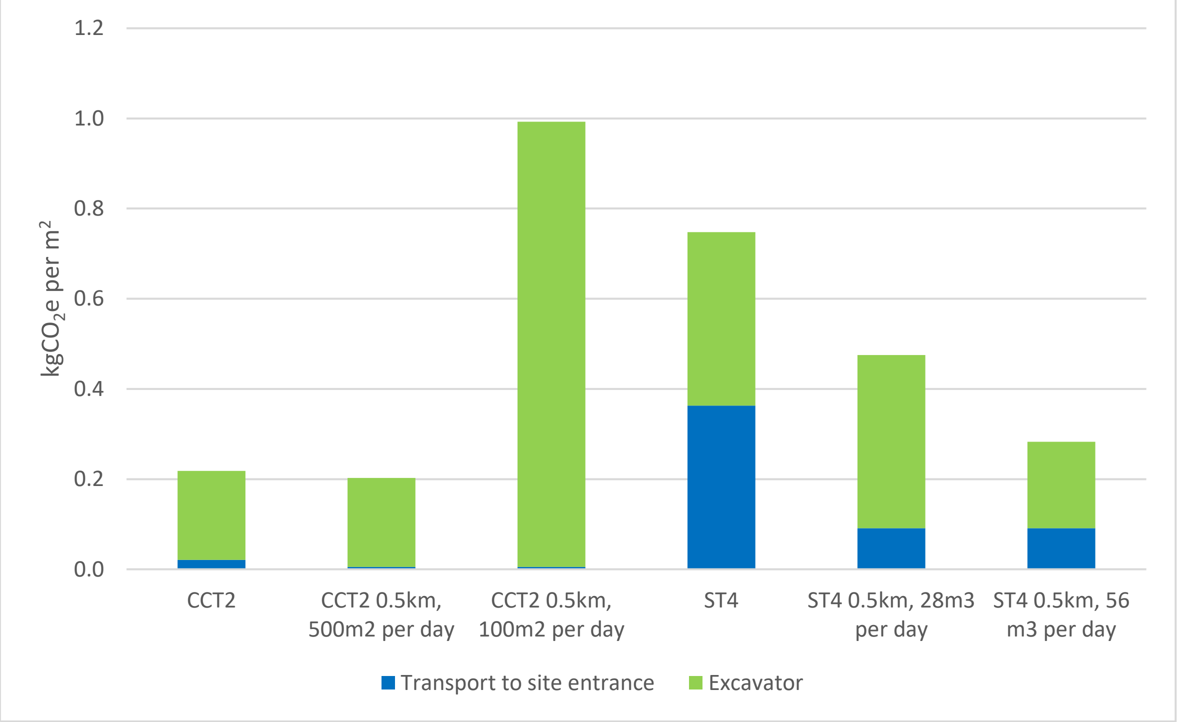
7.2 Removal

As noted in Section 6.4, removal is an area of relative uncertainty within the model. While Table 13 suggests that this uncertainty is likely to err unfavourably for CCT2 (the energy requirement per tonne of CCT2 removed is far higher than per tonne of ST4 removed), this section assesses how sensitive the results are to assumptions regarding ST4's removal. The initial results assume that all removed material is moved 2km to the site entrance, prior to transport to final disposal/recycling. For the sensitivity, this has been reduced to 500m and it has been assumed that ST4 can be removed twice as quickly. Additionally, it is assumed that CCT2 has a far slower removal rate (100m^2 per day).

Figure 11 below compares the two systems across the scenarios modelled. It shows that for CCT2, whilst reducing the distance from site entrance to installation site from 2km to 0.5km (500m) results in a small reduction in the transport impact during removal, reducing the rate of removal from 500m^2 per day to 100m^2 per day, results in additional impacts which far outweigh this small benefit in the removal stage. The figure also shows that for the ST4 system, reducing the distance from site entrance to installation site from 2km to 0.5km results in a 36% reduction in overall potential carbon impacts for the removal stage due to reduced tkm value. Doubling the rate of removal (from 28m^3 per day to 56m^3 per day), results in a 62% reduction of the impacts for this stage, due to reduction in impacts related to the consumption of diesel by the excavator.

Overall, this sensitivity analysis indicates that reducing the distance from site entrance to installation site, and increasing the rate of removal, can reduce potential carbon impacts for ST4, highlighting the variability and uncertainty that these two factors can have on the results of a comparison. It also suggests, unless there is a significant reduction in the rate of removal of the CCT2 and significant increase in the rate of removal of ST4, that CCT2 will outperform ST4 in terms of potential carbon impacts. It is worth noting, that even in the scenario where ST4's removal impacts are a third of CCT2's, CCT2 is still preferable over the whole life cycle.

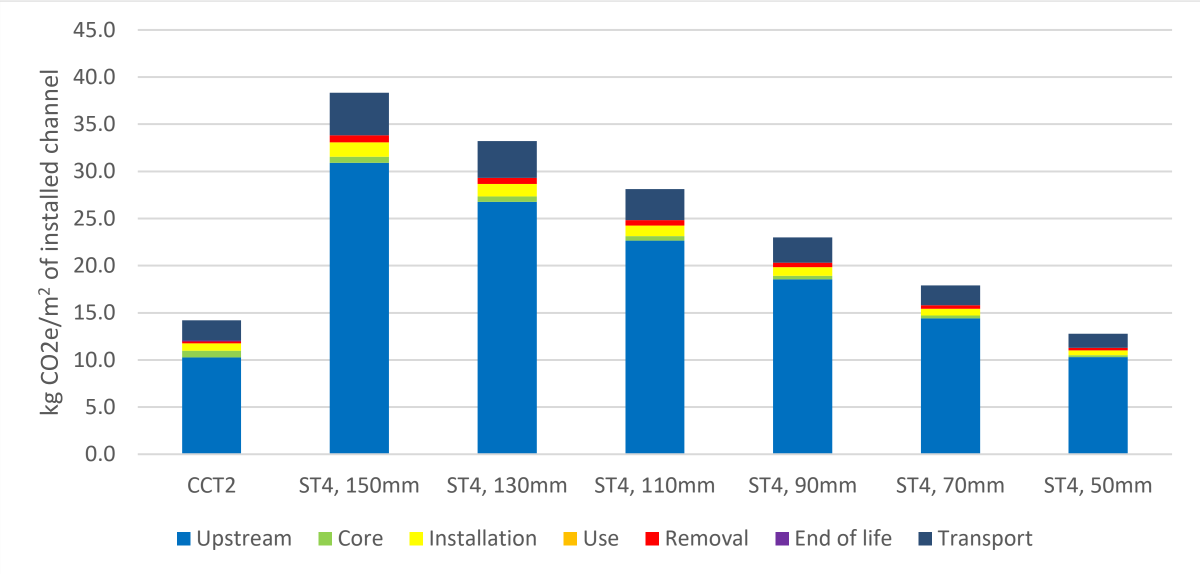
Figure 11: kgCO_2e per m^2 of channel during removal of CCT2 and ST4



7.3 Weight

While the type of cement and removal rates are important variables, the previous two sensitivities both suggest that the key variable is the amount of ST4 required to construct the same channel. The initial, default results assume that ST4 must be laid at a thickness of 150mm. This sensitivity assesses the impact of reducing ST4's thickness requirement in 20mm increments to identify the tipping point at which ST4 becomes preferable. Figure 12 below compares these scenarios. It shows that reductions are evenly distributed across each life cycle stage as these inventories are predicated on the weight of ST4 being produced, transported, installed or removed. The thickness of ST4 must be reduced by 63% to 55.6mm, before ST4 becomes preferable to CCT2 in terms of potential carbon impacts. However, it is understood that below 100mm, ST4 would require steel reinforcement for structural integrity, which would increase the GWP for a given thickness. Therefore, it appears reasonable to conclude that CCT2 will provide a GWP saving over any practical thickness of ST4.

Figure 12: kgCO_2e per m^2 of channel, under different ST4 thickness scenarios



8 Summary

This study has assessed the GWP of using CCT2 or ST4 to produce a 1,800m^2 channel. The study has considered the upstream impacts associated with raw material extraction, the core impacts associated with producing each product and the downstream impacts associated with installation, removal and end of life. The impacts arising from transportation between these stages have also been considered, with CCT2 being transported 10 times further from factory to site.

The results indicate that using CCT2 to construct the channel has a 63% lower GWP than ST4. Per m^2 of channel, 20.6kg[13] of CCT2 are required, compared to 320kg[14] of ST4. Both products' key life cycle stage is the upstream stage, in particular cement production. Using a product that requires less cement results in lower CO_2e emissions.

Both systems' impacts are distributed similarly across the life cycle stages, albeit that ST4 has significantly higher upstream burdens due to its higher amount of material inputs and type of cement. CCT2 has greater end-of-life burdens, due to it being landfilled, rather than re-used as aggregate.

Sensitivity analysis has identified that this study is sensitive to assumptions regarding the type of cement used in the upstream stage, the rate at which each system can be installed and removed and the total weight of ST4 required. However, unless significantly less (63%) ST4 can be used, CCT2 appears to be preferable.

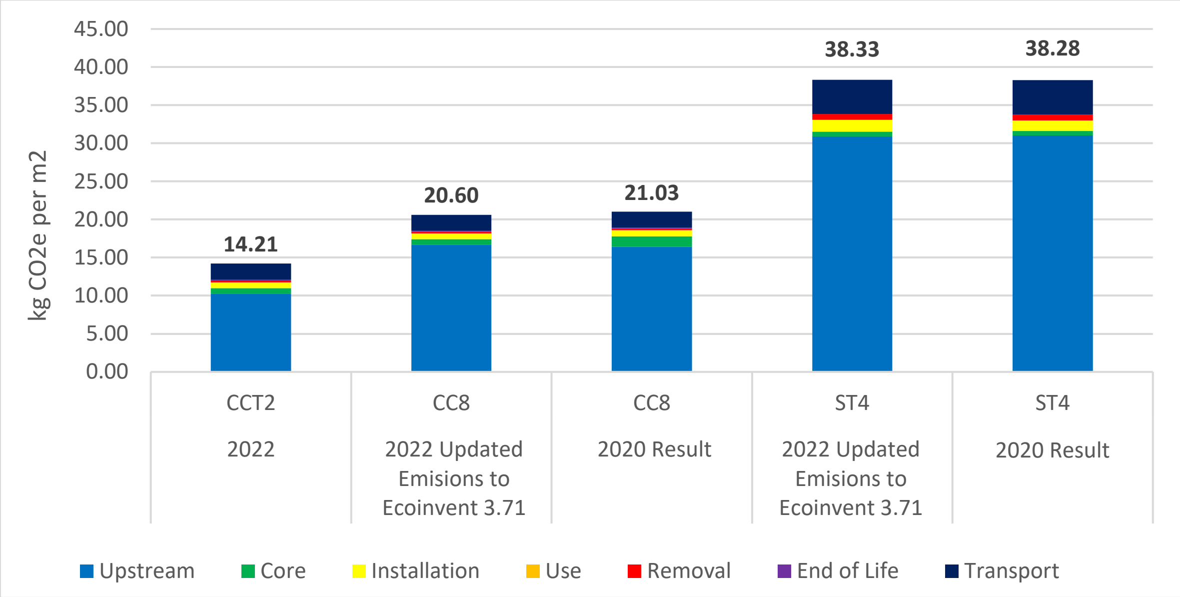
9 Changes since 2020

Our 2019/2020 study investigated the GWP of Concrete Canvas's original CC8 GCCM. Since the 2019/2020 study was published, Concrete Canvas have been working to lower the GWP of their GCCMs, replacing their CC5, CC8 and CC13 GCCM products with CCT1, CCT2 and CCT3 GCCMs respectively.

[13] Installed set weight
[14] Installed set weight

Under the parameters set out in this 2022 report, CCT2's GWP is 63% lower than that of ST4. This is a further overall GWP reduction of 18% compared to the LCA on CC8 conducted in 2019/2020 which used the same parameters. CCT2's GWP has decreased compared to CC8, as a result of efforts undertaken by Concrete Canvas to reduce the upstream impact of CCT2 by altering the material composition and product thickness. CCT2 GWP impact in 2022 is 32% lower than the CC8 results in 2020. Figure 13 shows the CCT2, CC8 and ST4 results from the different studies below.

Figure 13: Global Warming Potential over time



Please note that while CC8's overall impact using the updated emission factors decreased compared the original 2020 result for CC8, the products upstream impact (shown in light blue in Figure 13 above) increased by 2% compared to the same study in 2019/2020. This is because the updated emission factors for PVC and laminate using are 20% higher using Ecoinvent 3.71 compared to Ecoinvent 3.6 in 2019/2020.

10 Next Steps

While the new CCT2 product is a lower thickness/weight product and results in a reduced upstream, installation and transport impact for CCT2, although upstream remains the largest contributor, accounting for 72% of CCT2's GWP impact. It is advised that Concrete Canvas continue to look for ways to reduce this impact further. As a future improvement, Ricardo recommends engaging suppliers with a view to obtaining primary data to update the Ecoinvent assumptions used in this study. The cement emission factor used is already supplier specific and is 12% lower than the Ecoinvent value. If Concrete Canvas can obtain this data from its other suppliers, particularly the fabric supplier, then this could reduce the upstream impact further.

If Concrete Canvas were to utilise renewable energy sources or install on site renewables at its facility, the core impacts could also be reduced.

This study has focused on supporting Concrete Canvas in understanding the global warming potential of CCT2 compared to traditional ST4, rather than on communicating results. If Concrete Canvas wishes to use LCA data for customer engagement, Ricardo recommends preparing a formal Environmental Product Declaration or undertaking a peer reviewed study in order to share results in the public domain. Please note that an Environmental Product Declaration would require a wider range of environmental impacts to be studied than the current global warming potential. As a future study, Ricardo recommends that Concrete Canvas should consider adding additional environmental indictors to allow for a more holistic understanding of the product's environmental impact and avoid any potential burden shift.

Appendices

Appendix 1: CCT2 and ST4 variables

Table 15: CCT2 parameters

Parameter	Value
Roll size (width)	1.1m
Roll size (length)	114m
CC Product	CCT2
CC overlap	0.1m
Anchor trench (length)	0.45m
Product lifetime	120 years
Product waste (at factory)	5%
Distance from factory to site	200km
Installation rate	$500m^2$ / working day
Sealant	Not required
Water use	6l / m^2

Table 16: ST4 parameters

Parameter	Value
Product lifetime	120 years
Depth of ST4	150mm
Concrete Emission Factor	ecoinvent Process
Comparator - electricity	UK Average Grid
Distance from factory to site	20km
ST4 Installation Rate	28 m^3 / working day
Installation losses (%)	10%
Comparator - End of life	Recycling

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