Implementation of GHG Tracking Software for Sustainable Transportation Infrastructure Projects

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ABSTRACT

The benefits of sustainable business practices are well documented. The Canadian Precast/Prestressed Concrete Institute has provided the tools for its member plants that will have a measurable impact on their environmental and economic performance, using a customised industry software, the *Sustainable Precast Concrete Benchmark Calculator* (v1.0). The ultimate benefit is to the facility owner who can use the information to identify environmental "hotspots" and make informed decisions about the environmental impact to their transportation infrastructure project.

The software, developed for CPCI by the Athena Sustainable Materials Institute (ASMI), enables manufacturers to measure their "cradle-to-gate" life cycle environmental footprint. Once a manufacturing facility enters their raw material usage, electricity, natural gas, gas, diesel, heavy fuel oil and liquefied propane gas usage the software uses ASMI's life cycle inventory database to calculate a set of sustainability indicators – global warming potential (GWP), total primary energy (PE) and water usage for the plant. The facility, as part of the overall *CPCI Sustainable Plant Program*, also self-evaluates and reports their environmental performance indicators – dust, noise and waste materials.

Participating plants report their tracked results to CPCI on a quarterly basis, the results of which are presented in an annual industry report. Individual plants are also provided a customised report on a quarterly basis for their own internal benchmarking. Specifiers and owners can request the sustainability impacts on a project basis and are also encouraged to include this informational requirement in their contract specifications.

INTRODUCTION

In 2012 the Canadian Precast/Prestressed Concrete Institute (CPCI) published a multi-year life cycle assessment (LCA) "*Life Cycle Assessment Study for Commercial Buildings*" for a typical commercial building with various structural assemblies in two distinctly different Canadian climates, Toronto and Vancouver (1). The LCA was instrumental in understanding concrete's relative environmental performance in the context of building construction, use, and end-of-life. Among the key findings of the ISO compliant study was that operating energy was responsible for the majority of the environmental impacts for a typical commercial building; for example, over a 73 year building lifecycle, greater than 90% of the total primary energy (PE) and global warming potential (GWP) impacts for a building in Toronto were associated with the operation of the building. These findings were consistent with other recent studies (G. Verbeeck and H. Hens 2010 (2), UNEP 2009 (3)). In addition, these studies support the sustainable movement towards net-zero construction, for example Architecture Canada 2030 Challenge.

In the same study (1), concrete manufacturing was responsible for approximately 9% of the aforementioned impacts. Nevertheless, in 2012, CPCI launched the *Sustainable Plant Program* to benchmark the Canadian precast industry's impact on the environment in the areas of global warming, energy and water use, waste, dust and noise generation. At the center of the Sustainable Plant Program is the *Sustainable Precast Concrete Benchmark Calculator (v1.0)*, a tool that measures and quantifies the impacts of all input materials through their life cycle stages of extraction, transportation, processing, and finally through their optimization in the precast manufacturing process (See Figure 1). Ultimately, the precast industry is striving to reduce the environmental impact at the manufacturing level while creating a culture of sustainability. The *CPCI Life Cycle Assessment study for Commercial Buildings* has helped to identify where the industry can improve its manufacturing stage life cycle impacts, with a goal to positively influence the environmental impact over the entire life of the precast product in use.

This is of particular interest to transportation infrastructure projects, where long term performance and total cost of ownership are well understood in the decision making process, but the cradle-to-construction environmental impacts have not yet been readily or clearly defined or available. The innovative tracking software enables individual manufacturers to measure their "cradle-to-gate" environmental footprint on a facility, product or client project basis (with cradle being raw material resource extraction and gate being the finished product leaving the precast plant for the construction site).

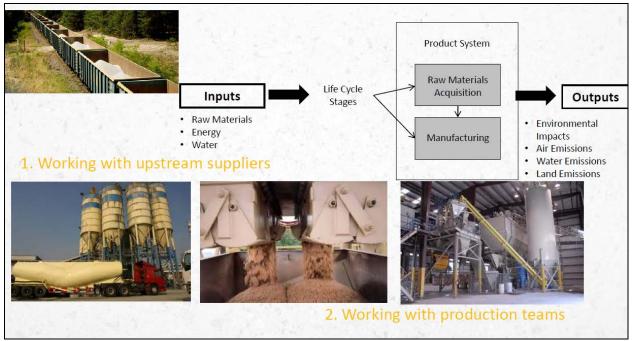


Figure 1: Visual schematic of the *Sustainable Plant Tracking Program* showing the input materials through their life cycle stages of extraction, processing, and finally through their optimization in the precast manufacturing process.

SUSTAINABLE PLANT SOFTWARE

The Athena Sustainable Materials Institute (ASMI) developed *the Sustainable Precast Concrete Benchmark Calculator (v1.0)* to quickly determine two environmental impact measures, Global Warming Potential (GWP) and Primary Energy (PE) consumption, along with water use, to benchmark individual plants' precast concrete production as well as individual custom precast concrete products for specific client projects. The scope of the tool is "cradle-to-gate" with the cradle being the "earth" and the gate being the finished product ready for shipping at the precast plant.

Global warming potential (GWP) is a midpoint metric proposed by the International Panel on Climate Change (IPCC), for the calculation of the potency of greenhouse gases relative to CO_2 . GWP can be considered one of the most accepted sustainability metric categories due to the methodology and science behind the GWP calculation. GW_{P100} is expressed on equivalency basis relative to CO_2 – that is, equivalent CO_2 mass basis; e.g. kg of CO_2 . (See equation 1).

 CO_2 Equivalent kg = $CO_2 + (CH_4 \text{ kg x } 25) + (N2O \text{ kg x } 298)$Eq. 1

PE is reported in mega-joules (MJ) and includes all primary energy consumed (primary and indirect) to transform or transport raw materials into products. This is also often referred to as the embodied energy, and includes inherent energy contained in the raw or feedstock materials that are also used as common energy sources. In addition, the measure captures the pre-combustion

(indirect) energy associated with processing, transporting, converting and delivering fuel and energy to its point of use.

It is important to note that, for precast concrete products, the PE and GWP impacts include more than just the components making up the concrete material. Since the product coming out of the precast facility (or gate) is a finished component it includes the impacts associated with reinforcement (material and placing), formwork (labour and materials), and curing (energy). Specifiers and owners are therefore cautioned against comparing precast's impacts to unfinished materials such as ready mixed concrete which only include the impacts associated with the concrete material at the gate. The full impact of those materials needs to include the reinforcing, forming and curing at the construction site if they are to be compared. Because of this difference, the impacts from the *Sustainable Precast Concrete Benchmark Calculator (v1.0)* software can be considered as "cradle-to-construction".

USING THE SOFTWARE

In the first step, Section A of the input sheet, the plant identifies it's provincial location from the dropdown list (See Figure 2). This will identify manufacturing and energy grid data for their plant location. They then complete the product names and masses for up to four finished precast product categories, for the reporting period. The "Total Production for Specified Reporting Period" mass at the bottom of section A is then used to calculate the "per tonne" of material values in the results tables at the top of the worksheet.

In Section B, the precaster completes the amounts and one-way transportation distances for each mode of transport, for each material (See Figure 2). They can input the amounts in one of several units in the drop down boxes. The total mass of all component materials in the product, excluding wash water and consumables, is calculated at the bottom of section B. For each input material a modal transportation distance must be entered or an "incomplete input" warning will occur to the left of the row. Materials can be transported by more than one transportation mode, and these are identified in the drop down boxes.

In Section B, the amount and transportation distances for Portland Cement cannot be entered directly in this worksheet. These are entered in a separate "Cement Sources" worksheet. It is possible that a plant may be sourcing Portland Cement from outside of their province. On this worksheet, they will enter the source locations and cement amounts for up to four source locations, and the one-way transportation of each mode of transport. A US average cement profile is also available if the plant is sourcing cement from the US. A weighted average LCA profile for cement and transportation is then calculated and the weighted average values are automatically entered in the Portland Cement row in the "Plant Inputs" worksheet.

In Section C, the plant enters the operating energy consumption by fuel type for the specified reporting period (See Figure 3). The "Per tonne of Precast" operating energy values are then used in the custom project calculator page to estimate energy use on a unit product basis.

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Figure 2: The precast manufacturer inputs all production quantities for the precast produced for a given period of time or per project basis.

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Brand T0000 minn 700 000 minn 64% 1.000 M M FAP 0.000 minn 0% 0.00 0.000 <	Portianad Connect Fine Aggregate - natural cand Fine Aggregate - natural cand Coarse Aggregate - natural cannel Coarse Aggregate - nuclear atoms BOMe - Files Funch EOMe - Files Funch EOMe - Files Funch EOMe - Files Funch EOMe - Alles Funch EOMe - Alles Funch	5,500.00 0.00 6,100.00 2,200.00 0.00 0.00 4,800.00	mton mton mton mton kg mton mton iter	2,806.000 5,500.000 0.000 6,100.000 2.200 0.000 0.000 5.280	mton mton mton mton mton mton mton mton	14% 28% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0%	79.24 50.00 0.00 45.00 80.00 0.00 0.00 0.00 500.00				km km km km km km km km km km
FAP D.00 mton 0.000 mton 0% 0.00 mton 0% Dispander Polyshme 0.000 box freet 0.000 mton 0% 0.00 mton 0% Exbraider Polyshme 0.000 box freet 0.000 mton 0% 0.00 mton 1.00 Exbraider Polyshyme 0.000 mton 1.500.000 mton 0% 0.00 Mton Mton Strika 1.500.000 mton 1.500.000 mton 6% 0.000 Mton	Portianto Connett Prin Aggregatia - natural cand Prin Aggregatia - natural cand Prin Aggregatia - natural greest Coarse Aggregatia Coarse Aggr	5,500.00 0.00 5,100.00 2,200.00 0.00 4,800.00 2,100.00 2,100.00	mton mton mton mton kg mton iter iter	2,806.000 5,500.000 0.000 6,100.000 2,200 0.000 5,280 2,520	mion mion mion mion mion mion mion mion	14% 28% 0% 0% 31% 0% 0% 0% 0%	79.24 50.00 0.00 45.00 80.00 0.00 0.00 0.00 500.00				km km km km km km km km km km km
Expanded Polydynea 0.00 boxe feet 0.00 mtm 0% 0.00 mtm %	Portisance Connect Print Aggregate - natural sand Fine Aggregate - natural sectors Coarse Aggregate - natural greest Coarse Aggregate - natural greest Coarse Aggregate - natural greest Coarse Aggregate - suruhed clone SCML - Fly Add SCML - Fly Add SCML - Fly Add SCML - Status SCML - Status Commissi Administre - Alle Entraining Agent Ohemissi Administre - Plastister Form Relases Agent Reber	5,500.00 0.00 6,100.00 2,200.00 0.00 0.00 4,800.00 2,100.00 1,600.00 7,50.00	mion mion mion mion kg mion mion liter liter liter mion	2,806,000 5,800,000 0,000 0,000 6,100,000 2,200 0,000 0,000 5,280 2,520 2,340 750,000	mion mion mion mion mion mion mion mion	14% 28% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0%	79.24 50.00 0.00 45.00 80.00 0.00 500.00 500.00 700.00 1,500.00	22.57			km km km km km km km km km km km
Edrusde Polychyrene 0.00 boor fred 0.00 mton 0% 0.00 in in Strikt 1.50.00 mton 1.50.000 mton 8% 6600.00 in in Granife 1.00.00 mton 1.100.000 mton 6% 335.00 in in Pigmenfa 3.00.00 mton 1.100.000 mton 2% 600.00 in in Pigmenfa 3.00.00 mton 2% 600.00 in in Act Concumbries 250.00 inton 2% 600.00 inton inton Wafer 750.00 m3 750.000 mton 4% inton	Portiand Connett Portand Connett Fine Aggregate - natural cand Fine Aggregate - natural resort Coarse Aggregate - arushed Coarse - Status Coarse - Sta	5,500.00 0.00 5,100.00 0.00 0.00 4,000.00 2,100.00 1,800.00 750.00 750.00	mtion mtion mtion mtion kg mtion tter iter iter iter iter iter mtion	2.405.000 5.500.000 0.000 0.000 5.100.000 2.200 0.000 5.280 2.320 2.340 750.000 700.000	mbon milon milon milon milon milon milon milon milon milon milon milon	14% 28% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 4% 0%	79.24 50.00 0.00 45.00 80.00 50.00 500.00 600.00 770.00 1,500.00 1,500.00	22.57			km km km km km km km km km km km km
Brids 1,500.00 mton 1,500.00 mton 8% 600.00 mton 8m Oranda 1,100.00 mton 1,100.000 mton 6% 338.00 mton 8m Pigmentin 300.00 mton 320.000 mton 2% 600.00 mton 8m Act Concumable 25000 Iter 0.225 mton 0% 440.00 mton 8m Balin Wafer 750.00 m3 750.200 mton 4% 5m 5m 5m	Portianto Connett Port Aggregate - natural sand Fine Aggregate - natural sand Fine Aggregate - natural grows Coarse Aggregate Coarse Aggregate - natural grows Coarse Aggregate Coarse Aggre	5,500.00 0.10 0.00 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.00 0.10 0.10 0.00 0.10 0.10 0.00 0.10 0.10 0.00 0.10 0.00 0.10 0.00 0.10 0.00 0.	milon milon milon milon milon milon liter liter liter milon milon milon	2.3405.000 5.560.000 0.000 0.000 5.100.000 2.200 0.000 5.380 2.340 2.340 750.000 700.000 0.000	mion mion mion mion mion mion mion mion	14% 28% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0%	7 9 24 50.00 0.00 45.00 0.00 0.00 0.00 500.00 500.00 700.00 1,500.00 1,500.00	22.57			km km km km km km km km km km km km
Oracle 1,000.00 mbm 1,100.000 mbm 6% 335.00 mom km Pigments 300.000 mbm 300.000 mbm 2% 600.00 mm Mm Value 230.000 mbm 2% 600.00 mm Mm <td>Portiand Connett Portand Connett Fine Aggregate - natural sand Fine Aggregate - natural resord Coarse Aggregate - natural grave1 Coarse Aggregate - natural grave1 Coarse Aggregate - natural grave1 Coarse Aggregate - arrunded stone Stoles - Title Arm Stoles - Titles Arm Stoles - Art Enfortating Agent Chaminas Admittares - Ar Enfortating Agent Chaminas Admittares - Ar Enfortation Fabba Fab</td> <td>5,00 00 0,00 5,00 0 2,00 00 2,00 00 0,00 4,00 00 2,00 00 1,00 00 750 00 750 00 0,00</td> <td>miton miton miton miton miton miton iter iter iter iter iter miton miton miton board feet</td> <td>2.406.000 5.500.000 0.000 0.000 2.000 0.000 0.000 5.200 2.520 2.340 750.000 700.000 0.000 0.000</td> <td>mion mion mion mion mion mion mion mion</td> <td>14% 28% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0%</td> <td>79.24 50.00 0.00 45.00 80.00 0.00 500.00 500.00 770.00 1.500.00 1.500.00 0.00 0.00</td> <td>22.57</td> <td></td> <td></td> <td>km km km km km km km km km km km</td>	Portiand Connett Portand Connett Fine Aggregate - natural sand Fine Aggregate - natural resord Coarse Aggregate - natural grave1 Coarse Aggregate - natural grave1 Coarse Aggregate - natural grave1 Coarse Aggregate - arrunded stone Stoles - Title Arm Stoles - Titles Arm Stoles - Art Enfortating Agent Chaminas Admittares - Ar Enfortating Agent Chaminas Admittares - Ar Enfortation Fabba Fab	5,00 00 0,00 5,00 0 2,00 00 2,00 00 0,00 4,00 00 2,00 00 1,00 00 750 00 750 00 0,00	miton miton miton miton miton miton iter iter iter iter iter miton miton miton board feet	2.406.000 5.500.000 0.000 0.000 2.000 0.000 0.000 5.200 2.520 2.340 750.000 700.000 0.000 0.000	mion mion mion mion mion mion mion mion	14% 28% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0%	79.24 50.00 0.00 45.00 80.00 0.00 500.00 500.00 770.00 1.500.00 1.500.00 0.00 0.00	22.57			km km km km km km km km km km km
Pigmentin 10000 mton 200,000 mton 2% 400,00 Mton hm Het Concurnable 25800 Iter 0.225 mton 0% 440.00 Iter hm Balin Wafer 750.00 m3 750.00 mton 4% Vent Ve	Portianto Connett Port Aggregate - natural sand Pine Aggregate - natural escone Coarse Aggregate - natural greest Coarse Aggregate Coarse Aggregate Para Relaxe - All Entrating Agent Para Fara Espanded Polytymene Espanded Polytymene Espanded Polytymene	5,00,00 0,00 0,00 0,00 0,00 0,00 0,00 0	milon milon milon milon milon milon iller iller iller iller milon milon milon milon milon board feet	2.3405.000 5.560.000 0.000 6.100.000 2.300 0.000 5.380 2.320 2.320 2.320 7.520 7.520 7.50.000 7.50.000 0.000 0.000 0.000	mion mion mion mion mion mion mion mion	14% 28% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0%	7924 50.00 0.00 45.00 500.00 500.00 500.00 700.00 1,500.00 1,500.00 0.00 0.00 0.00	22.57			km km km km km km km km km km km km
Batin Water 750.00 m3 770.000 mton 4% Wath Water 58.45.00 Brd 52.45.0 Brd 54.15	Portiand Connett Portagregate - natural sand Prine Aggregate - natural sand Prine Aggregate - natural gravet Coarse Aggregate - argument Solar - 197 Jan Down Delta - 1	5.00 00 0.00 5.00 00 2.200 00 0.00 4.00 00 7.00 00 7.00 00 7.00 00 0.00 0.00	milan milan milan milan milan milan milan milan milan milan milan milan baara feet baara feet milan	2.466.000 5.500.000 0.000 0.000 2.100.000 2.200 0.000 5.280 2.520 2.440 750.000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.00000 0.0000 0.0000 0.00000 0.0000 0.0000 0	mion mion mion mion mion mion mion mion	14% 28% 0% 0% 31% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0%	7934 50,00 0,00 45,00 50,00 500,00 500,00 1,500,00 1,500,00 1,500,00 0,00	22.57			km km km km km km km km km km km km km
Wash Water 26,425.00 Iter 26,425 mton	Portiand Connett Print Aggregate - natural sand Print Aggregate - natural sand Print Aggregate - natural gravet Coarse Aggregate - arrunde dione Scher. Print Aggregate - arrunde dione Print Print Aggregate - Printlement Frint Aggregate - Brinter Scher Beiter Scher Beiter Scher Beiter Print	5,500,60 0,500 5,100,500 2,200,500 2,200,500 2,200,500 4,400,500 4,400,500 1,400,500 1,400,500 1,750,500 0,500,500 1,100,500 1,100,500 3,000,500 1,100,500 3,000,500 1,000,500 3,000 3,000 3,000,500 3,000	mion mion mion mion mion by mion titer iter iter mion mion mion board feet board feet board feet mion mion mion	2 836 000 5 500 000 0 000 0 000 1 200 0 000 1 200 0 000 5 380 2 200 1 300 0 000 5 380 0 000 0 0000 0 0000 0 0000 0 0000 0 0000 0 0000 0 0000 0 00000 0 0000	Adam Adam Adam Adam Adam Adam Adam Adam	14% 28% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0%	7 93.3 50.0 0.00 45.00 0.00 0.00 0.00 0.00 0.00 1.900.00 1.900.00 0	22.57			km km km km km km km km km km km km km k
	Portisant Cennett Print Aggregatis - natural sand Prine Aggregatis - natural resolution Prine Aggregatis - natural resolution Coarse Aggregatis - natural resolution From Release Agent Rebor Estruited Polystymen Estruited Polystymen Briok Prigments Net Concurrenties	5,500,60 0,00 5,000,00 5,000,00 2,200,00 0,000 4,400,00 4,400,00 1,100,00 1,100,00 1,5	mion mion mion mion kg mion kg iter iter iter mion mion mion board feel mion mion mion iter iter	2.880.000 5.500.000 0.000 0.000 0.000 1.200 0.000 0.000 1.210 0.000 0.000 1.210 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.00000 0.00000 0.00000000	ntion miton	14% 28% 28% 2% 2% 2% 2% 2% 2% 2% 2% 2% 2% 2% 2% 2%	7 93.3 50.0 0.00 45.00 0.00 0.00 0.00 0.00 0.00 1.900.00 1.900.00 0	22.57			km km km km km km km km km km km km km k
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ECAST CONCRETE PLANT OPERATING ENERGY CONSUMPTION ELLOW GELLS BELOW, ENTER THE PLANT OPERATIVG ENERGY CONSUMPTION DATA FOR THIS REPORTING PERIOD.	Portand Connett Portand Connett Pine Aggregate - natural cand Pine Aggregate - natural reset Coarse Aggregate Coar	5,500.00 0,000 5,000,000,00 5,000,000,00 5,000,000,00 5,000,000,000,000 5,000,000,000,000 5,000,000,000,000,000,000,000,000,000,0	mion mion mion mion Non Non Non Non Non Non Non Non Non N	2.886.800 5.500.000 0.0000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.0000 0.0000 0.0000 0.000000	mbn mbn mbn mbn mbn mbn mbn mbn mbn mbn	14% 28% 28% 2% 2% 2% 2% 2% 2% 2% 2% 2% 2% 2% 2% 2%	7 93.3 50.0 0.00 45.00 0.00 0.00 0.00 0.00 0.00 1.900.00 1.900.00 0	22.57			km km km km km km km km km km km km km k
	Portand Connett Portand Connett Print Aggregate - natural cand Print Aggregate - natural cand Coarse Aggregate - natural gravet Coarse Aggregate Coarse Aggrega	\$500.00 \$500.00 \$00.	mion mion mion mion Non Non Non Non Non Non Non Non Non N	2.886.800 5.500.000 0.0000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.0000 0.0000 0.0000 0.000000	mbn mbn mbn mbn mbn mbn mbn mbn mbn mbn	14% 23% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0%	7 95.24 50.00 0.00 445.00 500.00 500.00 500.00 1,500.00 1,500.00 0.00	2247			km km km km km km km km km km km km km k
ELLOW CELLS BELOW, ENTER THE PLANT OPERATING ENERGY CONSUMPTION DATA FOR THIS REPORTING PERIOD.	Portant Connett Print Aggregate - natural sand Print Aggregate - natural sand Print Aggregate - natural growt Coarse Aggregate - Naturate Coarse Aggregate Extruded Polystyrene Extruded		mion mion mion mion kg mion kg mion iter mion mion boar feet board feet board feet mion mion iter mion mion mion ter mion mion mion mion mion mion mion mion	2.880.000 5.500.000 0.0000 0.0000 0.0000 0.0000 0.000000	Adim misia misia Adim Adim Adim Adim Adim Adim Adim Adim	14% 28% 28% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 6% 6% 6% 6% 2% 0% 4% 2% 0% 4% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 0%	79:24 50:00 0:00 45:00 0:0	2247 2,500.00 2,500.00	0.00		km km km km km km km km km km km km km k
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Figure 3: Example of completed plant input sheet. Note that each material is also assigned a oneway distance from the source to the plant.

OUTPUT SUMMARY

The GWP, PE and Water Use (batch and wash water) results are summarized in tables and graphs as outputs within the software program. These can be easily excerpted for customized product or project reports. The overall results are presented by Life Cycle Stages (raw materials, raw material transportation, and plant operations) for either GWP or PE (See Figures 4 and 6). The material effects can also be isolated and a cut-off criterion can be selected. For example a precaster may choose to highlight those materials representing greater than 1% of the effects (See Figures 5 and 7).

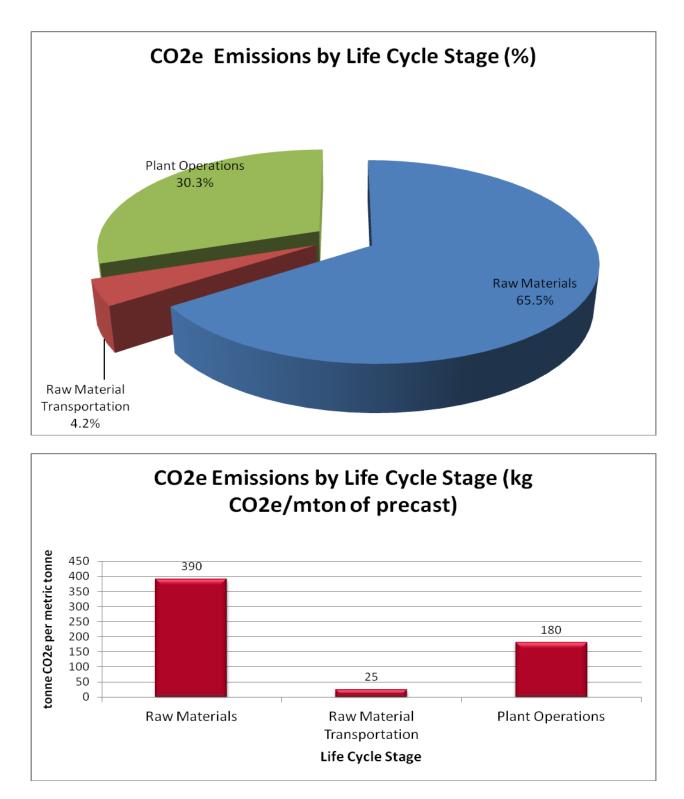
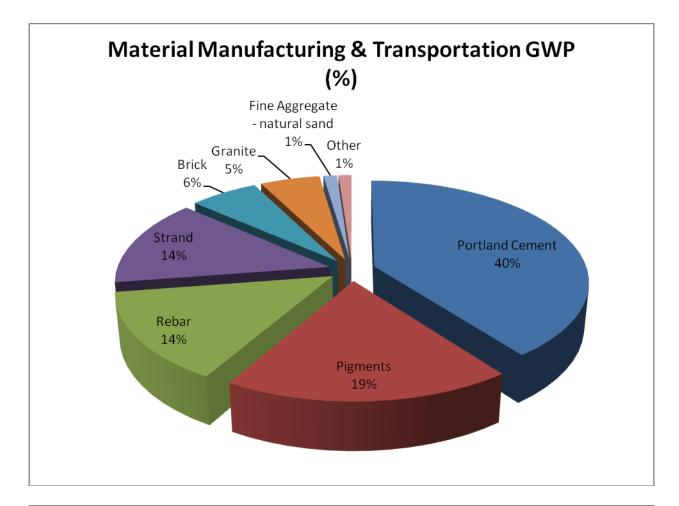


Figure 4: The plant output summarizes the CO_2 equivalent emissions by life cycle stage: from the raw materials, raw material transportation, and according to the plant operations.



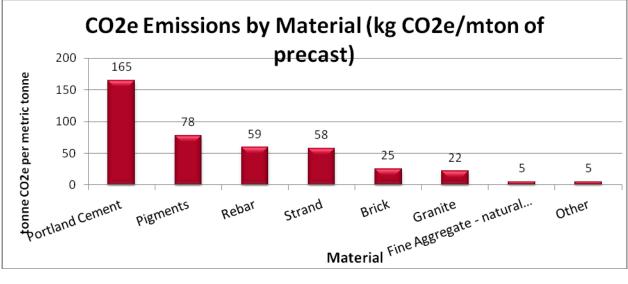
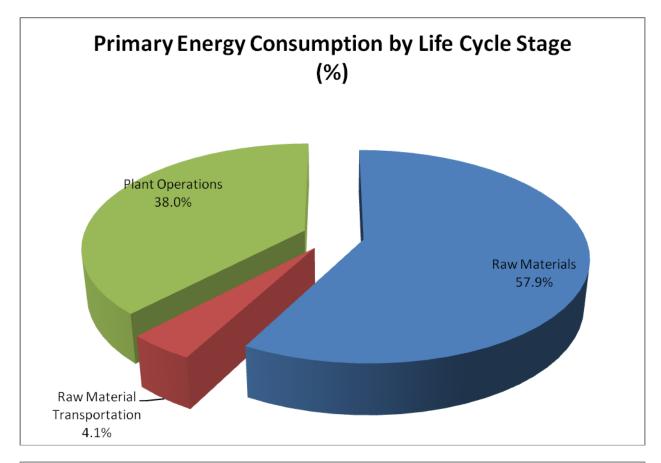


Figure 5: CO_2 equivalent emissions for the individual materials can also be isolated. In this example all materials with a contribution of 1% or higher are graphically represented.



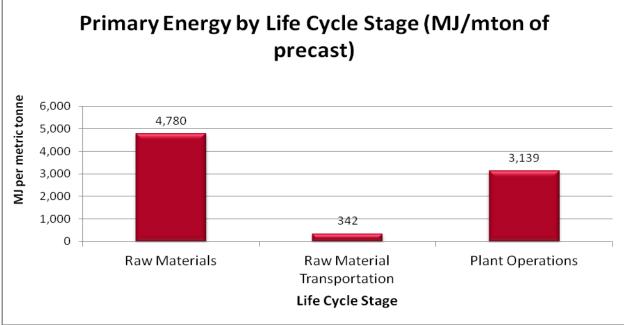
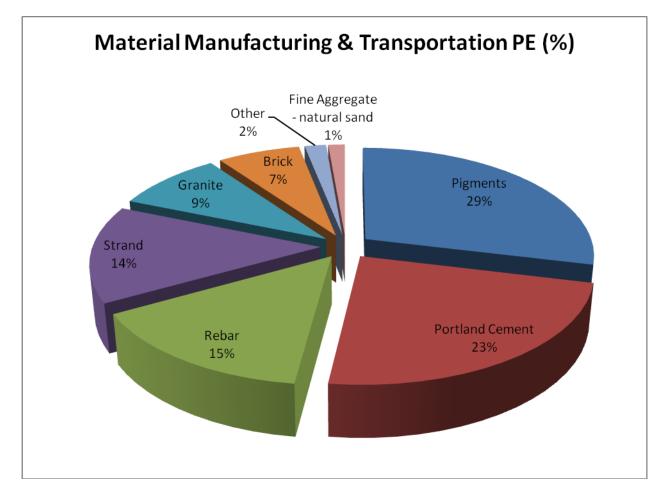


Figure 6: The plant output summarizes the Primary Energy consumption by life cycle stage: from the raw materials, raw material transportation, and according to the plant operations.



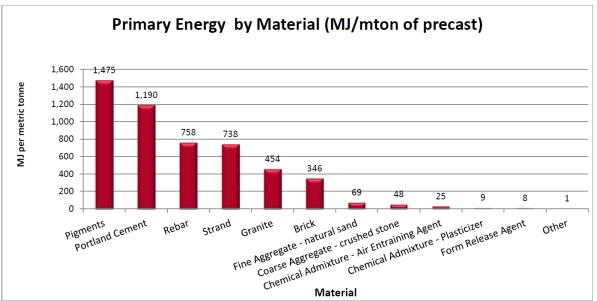


Figure 7: Primary Energy consumption for the individual materials can also be isolated. In this example all materials with a contribution of 1% or higher are graphically represented.

OTHER ENVIRONMENTAL PERFORMANCE INDICATORS

In addition to the sustainable plant indicators, the plants also record their environmental performance. Facilities self-evaluate their plant performance against standard environmental indicators. A grading system is used for each measure and an overall grading is achieved. These additional environmental indicators include:

1. Dust Control – The facility takes measures to control dust including any dust produced by traffic, storage activities or the handling of materials (See Figure 8).

2. Process Water, Storm Water and Chemical Management - The facility ensures that it does not discharge untreated process / waste water to the natural environment, and meets the requirements of local ordinances (See Figure 9).

3. Noise Control Requirements - The facility makes efforts to control noise to surrounding sensitive receptors (examples; residences, hotel/motels, nursing homes, hospitals, etc.), and meets the requirements of local ordinances (See Figure 9).

	Requirements for Environmental Performance Standards
а	Dust Control – The facility takes the following measures to control dust including any dust produced by traffic, storage activities or the handling of materials, and meets the requirements of local ordinances.
1	The facility maintains a best management practice plan for the control of fugitive dust emissions.
2	All bulk cementitious materials are stored in silos equipped with bag houses/dust collectors.
3	Facility ensures that silo emissions are in compliance with their best management practices.
4	All silo emissions meet relevant government requirements.
5	All cementitious material bag houses are inspected a minimum of once per month.
6	All outside aggregate storage is in three-walled enclosures.
7	Aggregate is washed prior to receiving at plant.
8	All exterior aggregate conveyor systems are equipped with protective wind enclosures.
9	All weigh hoppers are located inside an enclosed building.
10	All unpaved traffic areas on plant facility (including storage area traffic locations) use approved dust suppression techniques or environmentally friendly chemicals.
11	Paved traffic areas (including storage area traffic locations) have a regular sweeping program in place.
12	All sand blasting (or similar post-manufacture applied finish that creates dust) is done in an environment (indoors or outdoors) that controls and collects fugitive dust.
13	Crushing of waste concrete is conducted in such a manner not to affect the environment as defined in their facility best management practices.

Figure 8: The facility self-evaluates and benchmarks measures their environmental performance in relation to dust control.

h	Durance Weter Steve Weter and Chamical Management Dequivements. The site
b	Process Water, Storm Water and Chemical Management Requirements - The site
	does not discharge untreated process / waste water to the natural environment, and
	meets the requirements of local ordinances.
1	The facility maintains a best management practice plan for the control of process
_	water, waste water and chemical management.
2	Process / waste water is; directed to the storm sewer OR recycled in the process OR
	collected for transfer to an approved off-site facility OR if discharged to the ground
	the plant ensures that the runoff has acceptable levels of pH, acceptable levels of
	suspended solids, and acceptable hydrocarbon concentration.
2	
3	Process water discharged to the ground is sampled and analysed a minimum of
4	once/month.
4	Storm water run-off from the yard and traffic areas is; captured and recycled on site
	OR captured and discharged to the municipal storm sewer OR captured and transported off-site for disposal OR if discharged to a creek, has been reviewed and
	is in compliance with local authority approved drainage plans.
5	All effluent from acid etching or retarding chemical washing procedures are
5	captured on site and disposed of according to applicable requirements.
6	All sealants, acids, chemical retarding agents or form release agents meet
Ŭ	acceptable VOC requirements.
7	All chemicals stored in clearly marked containers with safety markings, and
	enclosed in spill containment areas where required by WHMIS.
8	All fuel is stored on-site in approved containers and enclosures as required by
	applicable regulations.
С	Noise Control Requirements - The facility makes efforts to control noise to
	surrounding sensitive receptors (examples; residences, hotel/motels, nursing homes,
	hospitals, etc.), and meets the requirements of local ordinances.
1	The facility maintains a best management practice plan for the control of noise.
2	The facility has a noise reduction plan such as; performing lower dBA activities, OR
	using acoustic enclosures OR enclosing noise sensitive operations when; 1.
	Manufacturing during non standard hours according to local ordinances and/or 2.
	When operating within "reasonably close" distance to sensitive receptors.
3	The facility controls nuisance vibrations to surrounding sensitive receptors.
	General - The facility documents in writing all environmental incidents that
	contravene applicable environmental regulations or CPCI Canadian Precast Concrete
	Green Plant Program requirements. Such documentation includes resolution of
	complaints. The plant notifies regulatory authorities as required by legislation.

Figure 9: The facility self-evaluates and benchmarks their environmental performance in relation to process and storm water management, chemical management, and noise requirements.

CONCLUSION

The goal of the CPCI Sustainable Plant Program is to benchmark the precast industry's impact on the environment in the areas of global warming, energy, water use, waste, dust and noise generation. Ultimately, the precast industry is striving to reduce the environmental impact at the manufacturing level while creating a culture of sustainability. The CPCI Life Cycle Assessment study for Commercial Buildings (2012) has helped to identify where the industry can improve its impacts, at the manufacturing stage of the life cycle, with a goal to positively influence the impacts at the end of life. The Canadian Precast/Prestressed Concrete Institute has provided the tools for its member plants to measure and implement improvements that will have a measurable impact on their environmental and economic performance, using the customised industry software, the *Sustainable Precast Concrete Benchmark Calculator (v1.0)*. The ultimate benefit is to the owner who can use this information to make informed decisions on the environmental impact to their transportation infrastructure project.

REFERENCES

- 1. CPCI 2012. CPCI Life Cycle Assessment study for Commercial Buildings Canadian Precast/Prestressed Concrete Institute, Ottawa, ON
- 2. G. Verbeeck and H. Hens, "Life cycle inventory of buildings: A contribution analysis," Building and Environment, vol. 45, pp. 964-967, 2010.
- 3. United Nations Environmental Programme, "Buildings and Climate Change," Sustainable Buildings & Climate Initiative, Ed., ed. Paris: UNEP, 2009.