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) .

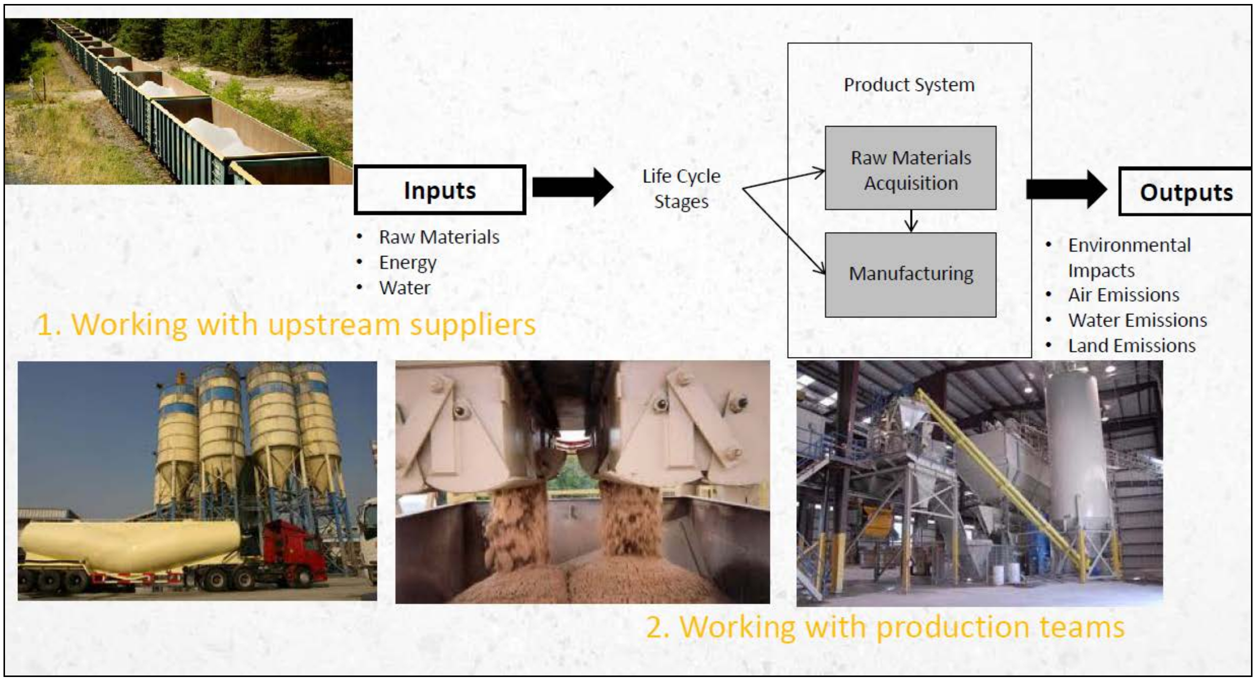


Figure 1: Visual schematic of the *Sustainable Plant Tracking Program* showing the input materials through their life cycle stages of extraction, processing, and finally through their optimization in the precast manufacturing process.

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 kg x 25) + (N2O 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.

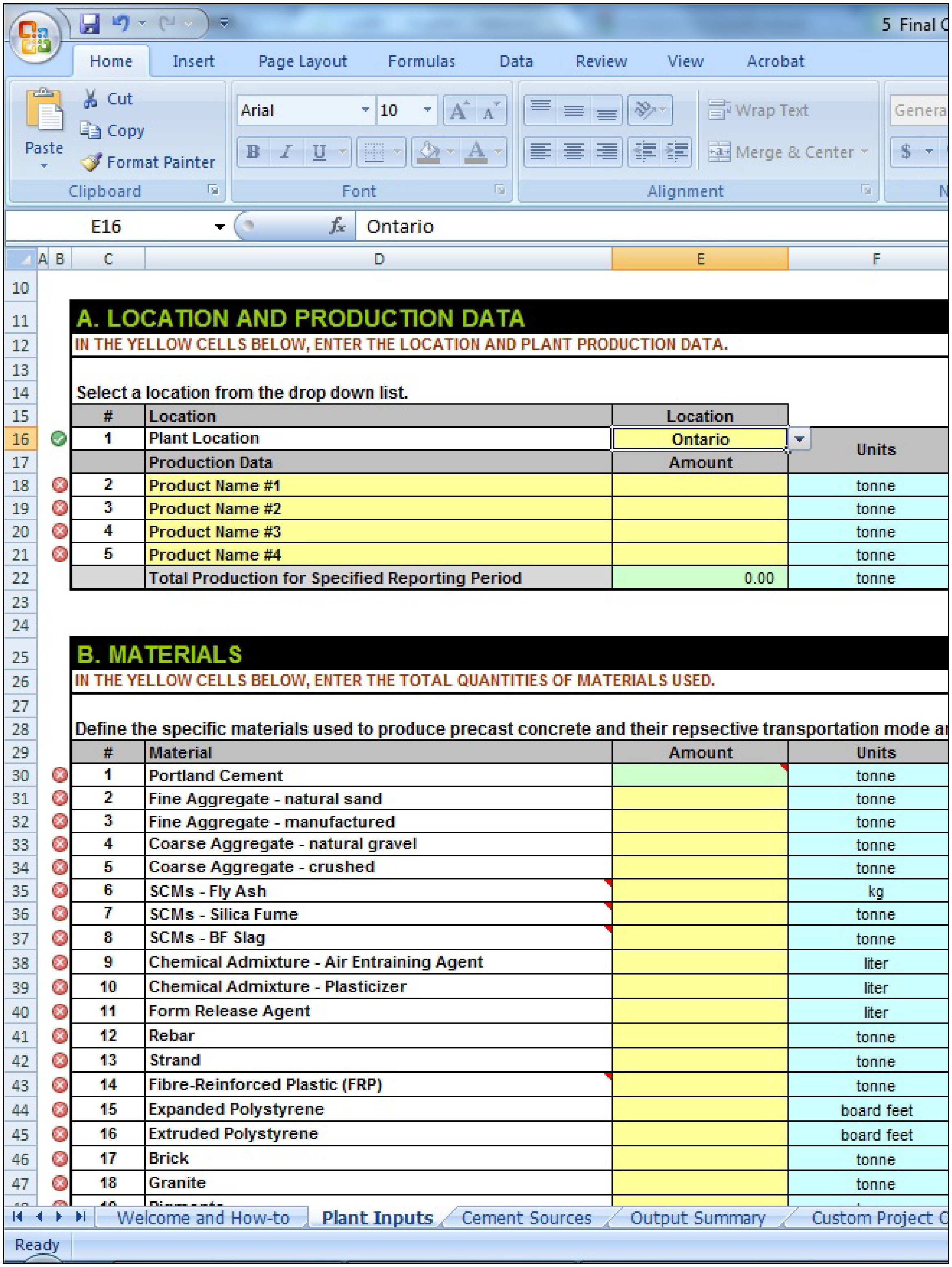


Figure 2: The precast manufacturer inputs all production quantities for the precast produced for a given period of time or per project basis.

CPCI Sustainable Plant Tool

Data Input is 100% Complete

RESULTS SUMMARY Reporting Period: My plant Q1 2012	Total	Per Tonne of Precast
Global Warming Potential (CO_2e)	10,827.7 mton	595.7 kg/mton
Primary Energy Consumption	150,156.9 GJ	8,260.8 MJ/mton
Water Use	776,425.0 liter	42.7 liter/mton
Plant Rating		

A. LOCATION AND PRODUCTION DATA

IN THE YELLOW CELLS BELOW, ENTER THE LOCATION AND PLANT PRODUCTION DATA.

Select a location from the drop down list.

#	Location	Location			
1	Plant Location	Alberta	Units	Global Warming Potential (CO_2e)	Primary Energy Consumption
	Production Data	Amount			
2	Product Name #1	18,177.00	mton	10,827.7 mton	150,156.9 GJ
3	Product Name #2	0.00	mton	0.0 mton	0.0 GJ
4	Product Name #3	0.00	mton	0.0 mton	0.0 GJ
5	Product Name #4	0.00	mton	0.0 mton	0.0 GJ
	Total Production for Specified Reporting Period	18,177.00	mton		

B. MATERIALS

IN THE YELLOW CELLS BELOW, ENTER THE TOTAL QUANTITIES OF MATERIALS USED.

Define the specific materials used to produce precast concrete and their repsective transportation mode and distance (scroll right).

							One-Way Distance From Material Source to Plant by Tranportation Mode				
#	Material	Amount	Units	Mass	Units	% of Total Mass	Truck	Rail	Ocean	Barge	Units
1	Portland Cement	2,806.00	mton	2,806.000	mton	14%	79.24	22.67	0.00	0.00	km
2	Fine Aggregate - natural sand	5,500.00	mton	5,500.000	mton	28%	50.00				km
3	Fine Aggregate - crushed stone	0.00	mton	0.000	mton	0%	0.00				km
4	Coarse Aggregate - natural gravel	0.00	mton	0.000	mton	0%	0.00				km
5	Coarse Aggregate - crushed stone	6,100.00	mton	6,100.000	mton	31%	45.00				km
6	SCMs - Fly Ash	2,200.00	kg	2.200	mton	0%	80.00				km
7	SCMs - Silica Fume	0.00	mton	0.000	mton	0%	0.00				km
8	SCMs - BF Slag	0.00	mton	0.000	mton	0%	0.00				km
9	Chemical Admixture - Air Entraining Agent	4,800.00	liter	5.280	mton	0%	500.00				km
10	Chemical Admixture - Plasticizer	2,100.00	liter	2.520	mton	0%	600.00				km
11	Form Release Agent	1,800.00	liter	2.340	mton	0%	700.00				km
12	Rebar	750.00	mton	750.000	mton	4%	1,500.00	2,500.00			km
13	Strand	700.00	mton	700.000	mton	4%	1,500.00				km
14	FRP	0.00	mton	0.000	mton	0%	0.00				km
15	Expanded Polystyrene	0.00	board feet	0.000	mton	0%	0.00				km
16	Extruded Polystyrene	0.00	board feet	0.000	mton	0%	0.00				km
17	Brick	1,500.00	mton	1,500.000	mton	8%	600.00				km
18	Granite	1,100.00	mton	1,100.000	mton	6%	335.00				km
19	Pigments	300.00	mton	300.000	mton	2%	600.00				km
20	Net Consumables	250.00	liter	0.225	mton	0%	450.00				km
21	Batch Water	750.00	m3	750.000	mton	4%					
22	Wash Water	26,425.00	liter	26.425	mton						
			Total Mass	19,618.585	mton						

C. PRECAST CONCRETE PLANT OPERATING ENERGY CONSUMPTION

IN THE YELLOW CELLS BELOW, ENTER THE PLANT OPERATING ENERGY CONSUMPTION DATA FOR THIS REPORTING PERIOD.

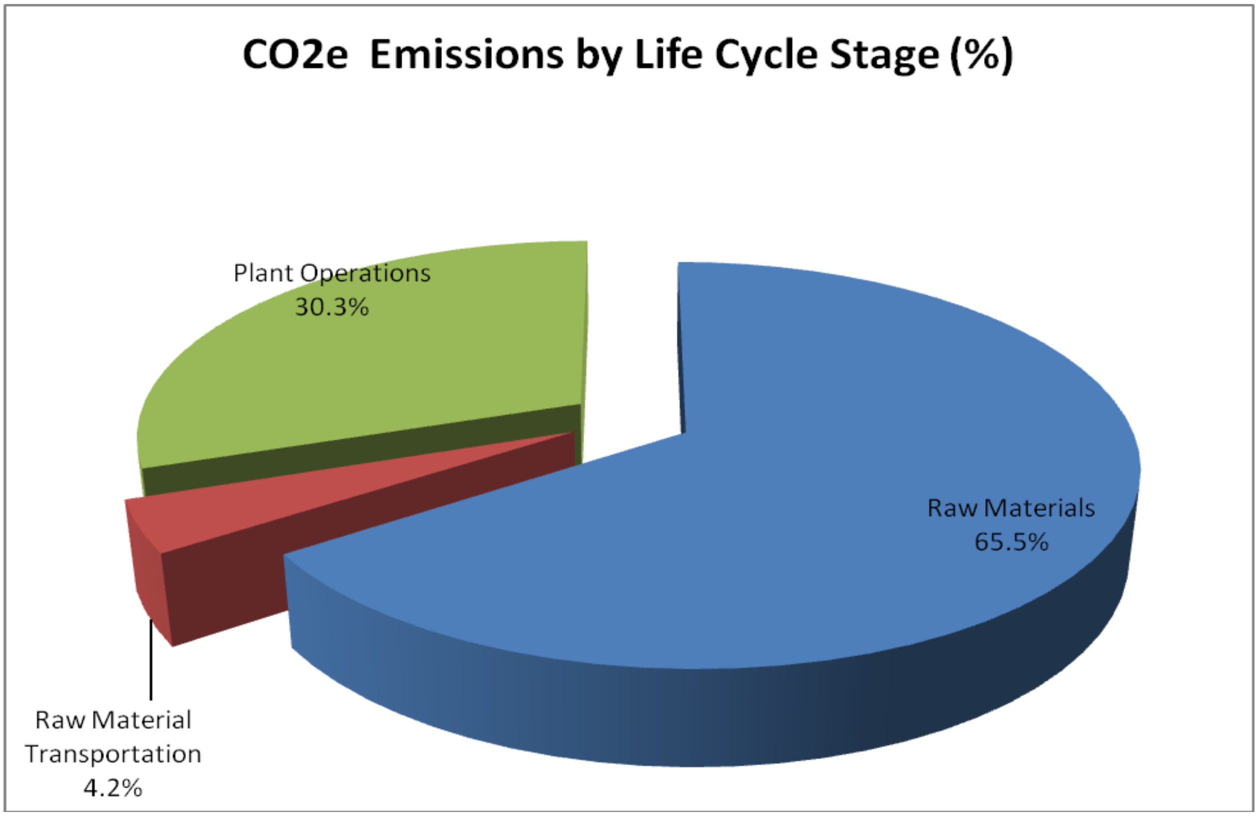
Define the operation and maintenance data for the precast concrete plant.

						Global Warming Potential (CO2e)	Primary Energy Consumption	Per mton of Precast	
#	Energy Type	Amount	Units	Per mton of Precast		mton CO2 eq.	GJ	kg CO2 eq./mton	MJ/mton
1	Purchased Electricity (from Regional Electricity Grid)	350,000	kWh	19.3	kWh/mton	365.34	5,160.03	20.10	283.88
2	Gasoline	650	liter	0.0	liter/mton	1.79	27.29	0.10	1.50
3	Natural Gas	1,200,000	m3	66.0	m3/mton	2,908.61	51,851.10	160.02	2,852.57
4	Diesel	0	liter	0.0	liter/mton	0.00	0.00	0.00	0.00
5	Heavy Fuel Oil	360	liter	0.0	liter/mton	1.36	18.41	0.07	1.01

Figure 3: Example of completed plant input sheet. Note that each material is also assigned a one-way 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).



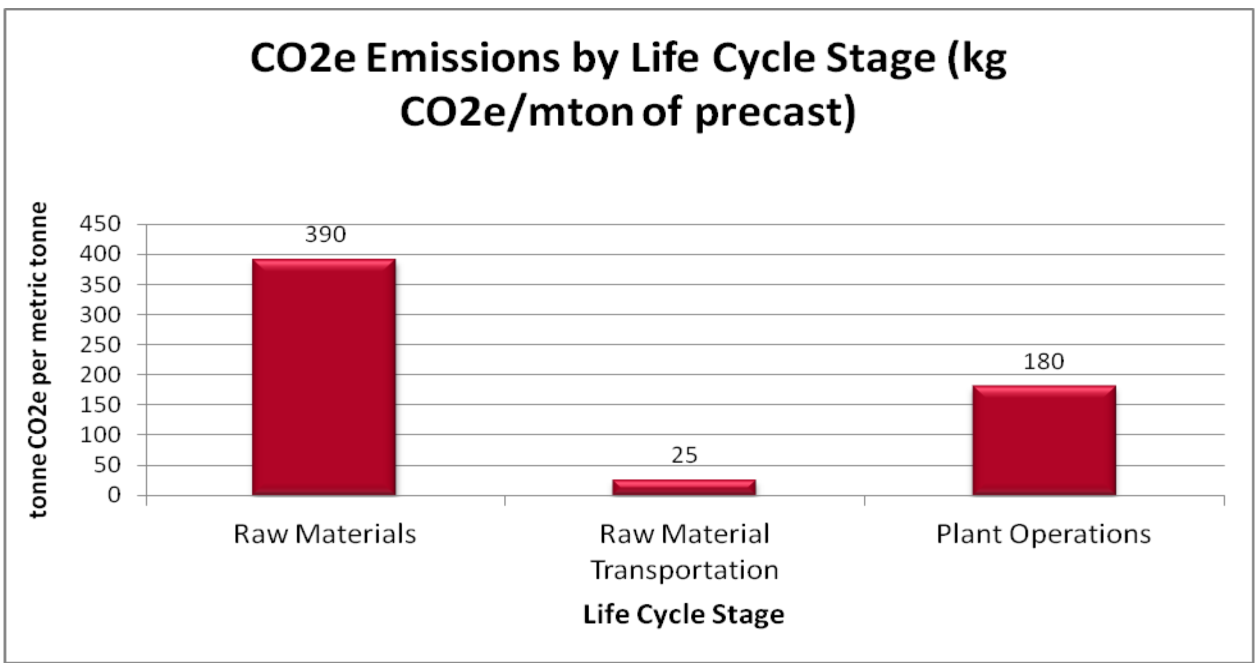
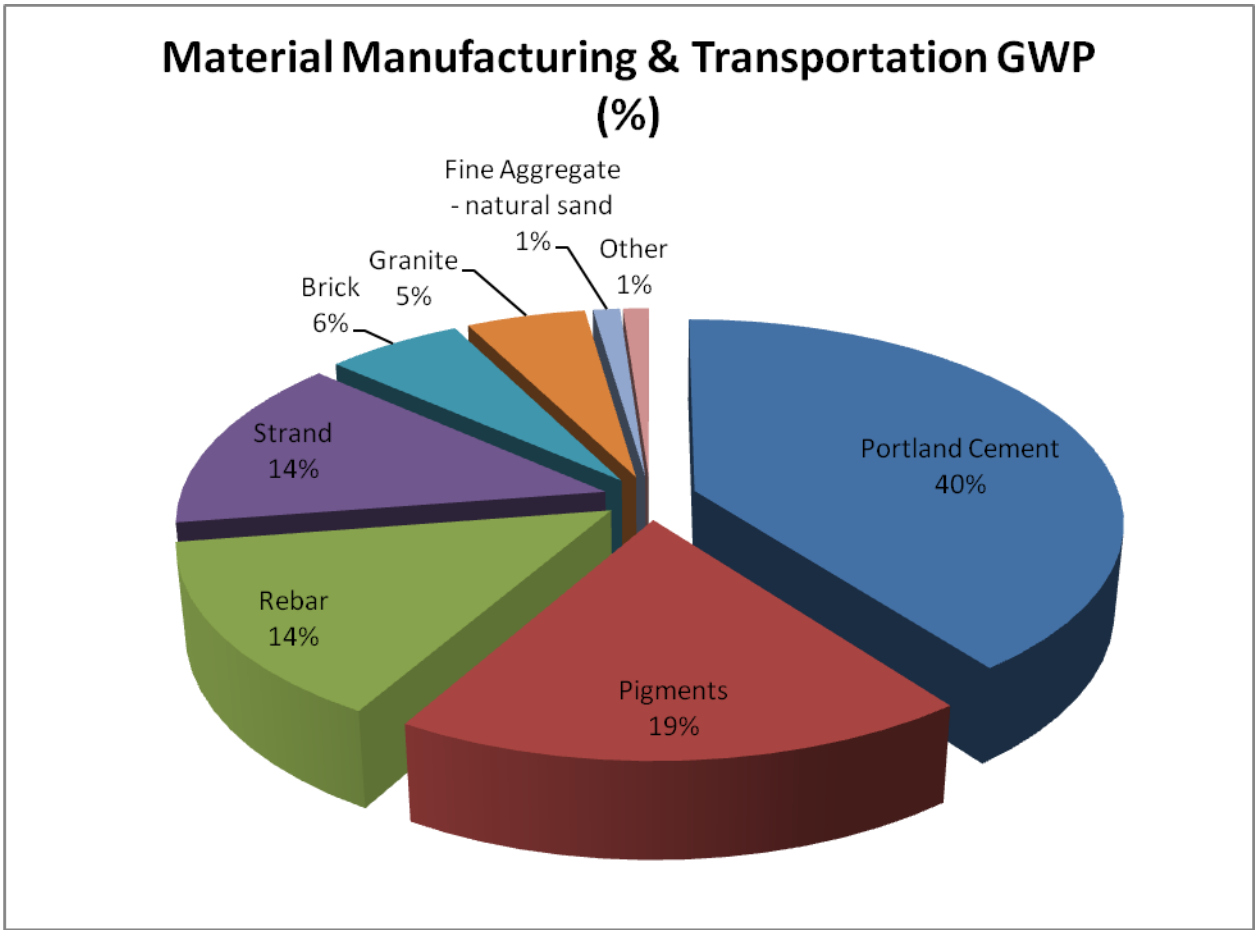


Figure 4: The plant output summarizes the CO_2 equivalent emissions by life cycle stage: from the raw materials, raw material transportation, and according to the plant operations.



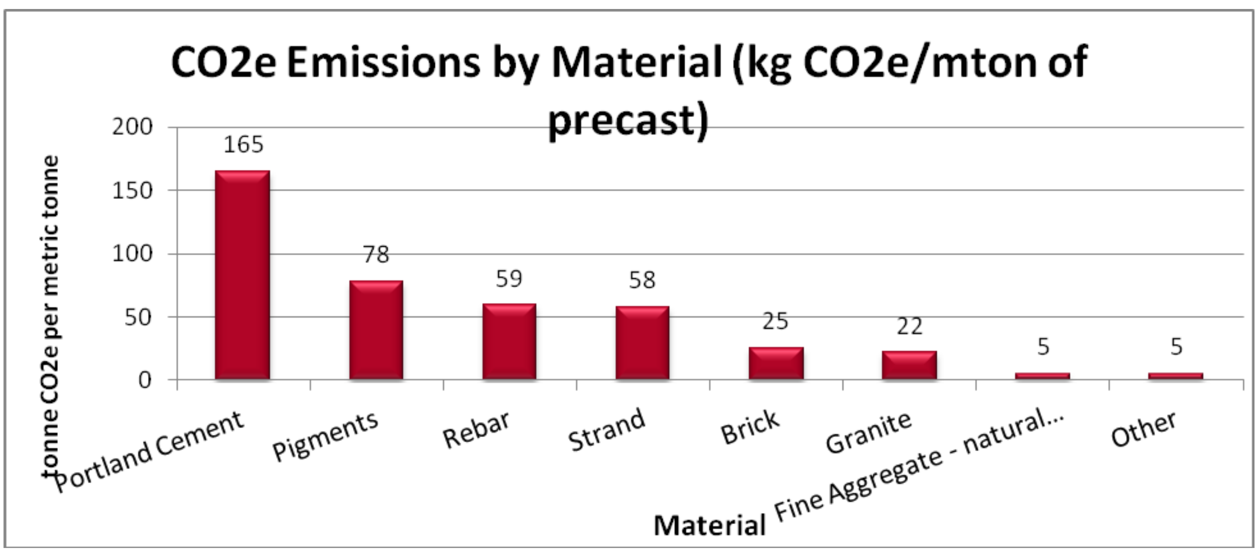
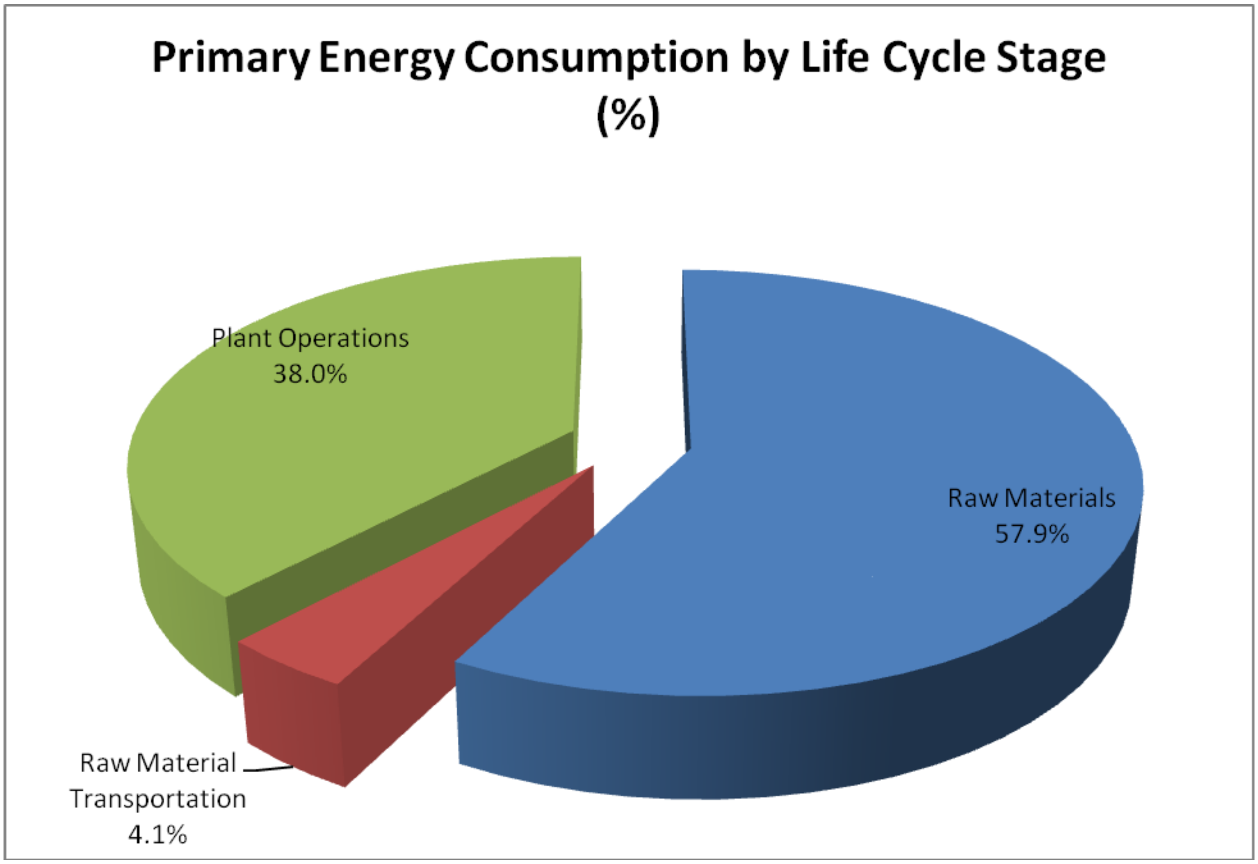


Figure 5: CO_2 equivalent emissions for the individual materials can also be isolated. In this example all materials with a contribution of 1% or higher are graphically represented.



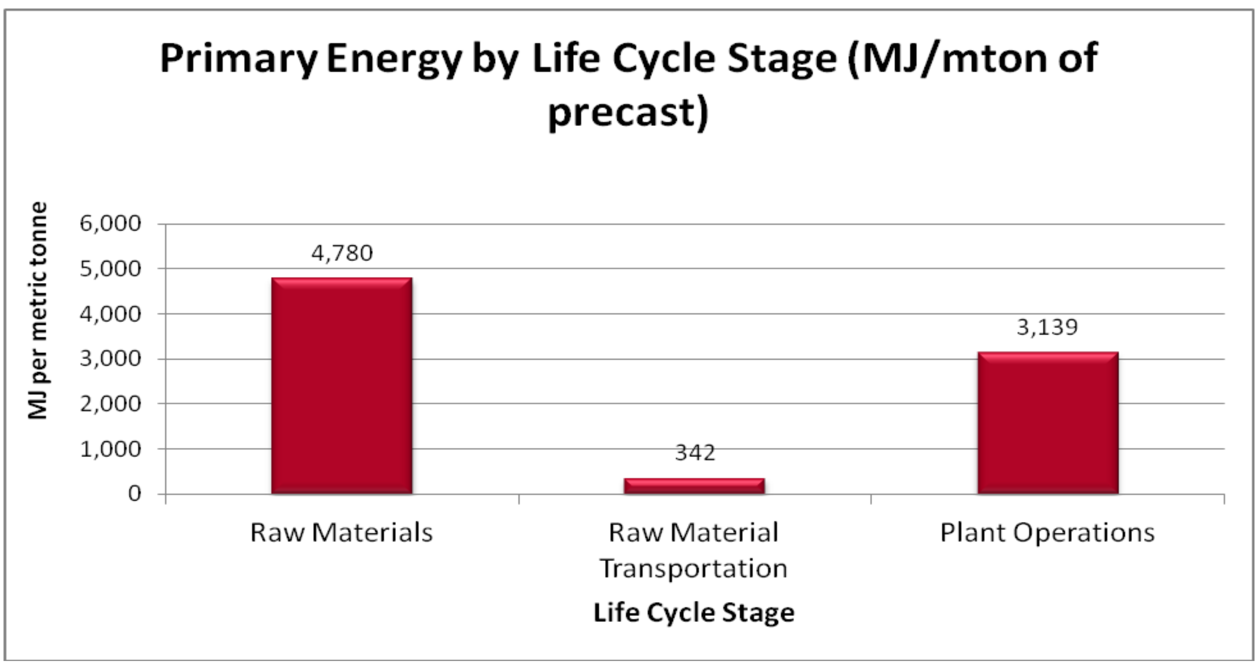
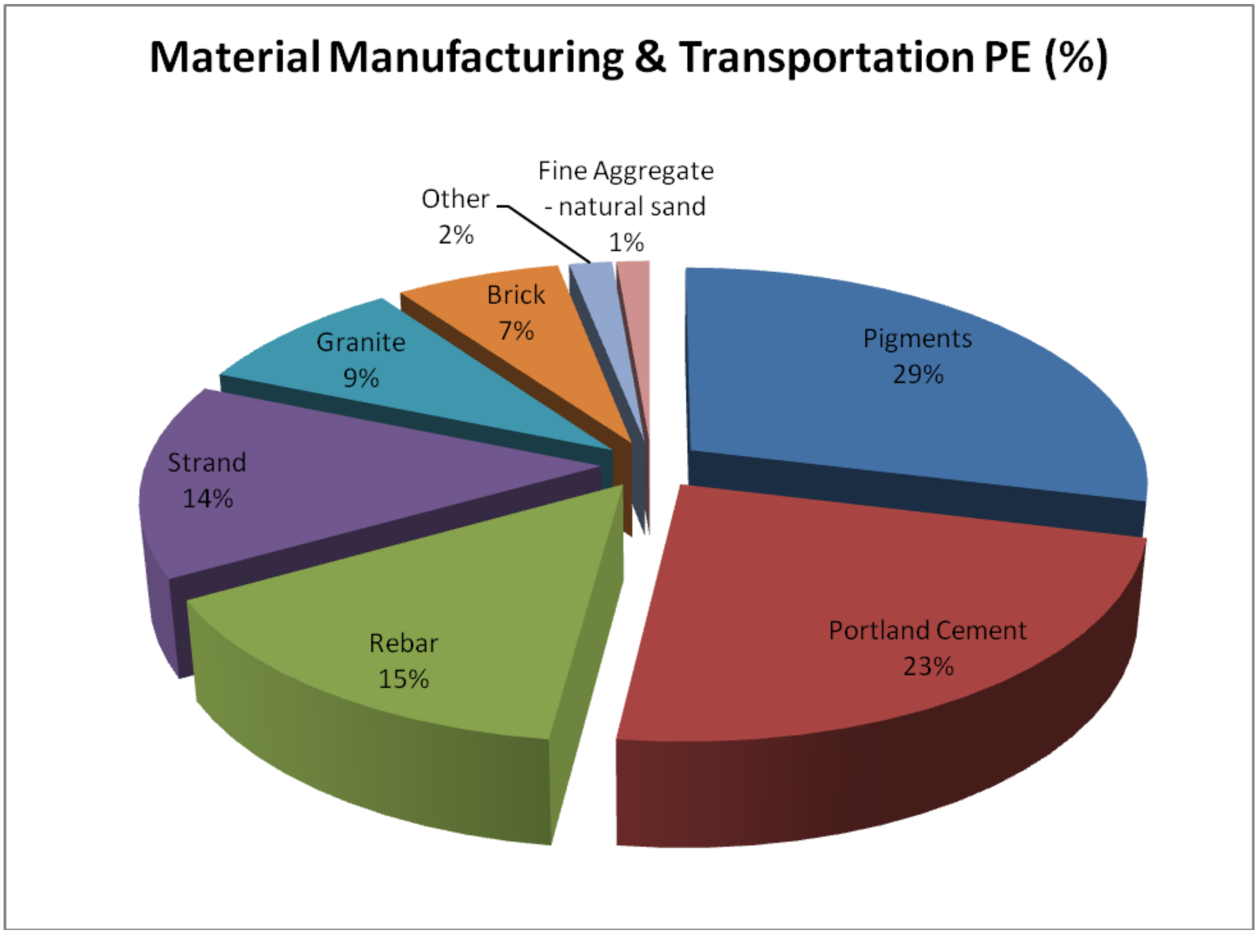


Figure 6: The plant output summarizes the Primary Energy consumption by life cycle stage: from the raw materials, raw material transportation, and according to the plant operations.



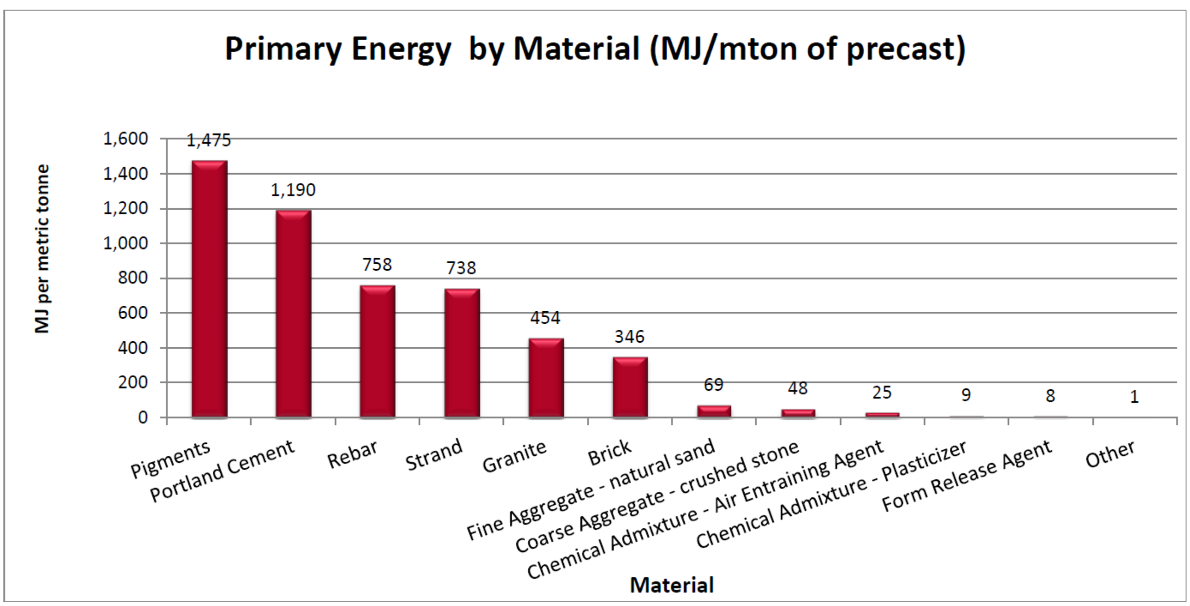


Figure 7: Primary Energy consumption for the individual materials can also be isolated. In this example all materials with a contribution of 1% or higher are graphically represented.

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
a	**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.

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.
3	Process water discharged to the ground is sampled and analysed a minimum of 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 captured on site and disposed of according to applicable requirements.
6	All sealants, acids, chemical retarding agents or form release agents meet 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.
c	**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.