FINAL ESSAY

Development project of methodology for calculated comparison of emissions of greenhouse gases (GHGs) between construction processes of fiberglass swimming pools (FRP) and concrete pools.

Pontifical Catholic University of Rio Grande do Sul

Instituto do Meio Ambiente (Environmental Institute)

Centro de Excelência em Pesquisa sobre Armazenamento de Carbono (Excellence Center for Research on Carbon Storage)

Coordinator: Prof Dr. Jorge Alberto Villwock (IMA)

Prof. João Marcelo Ketzer (CEPAC)

Eduardo Bandeira Maia (CEPAC)

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1. INTRODUCTION

It is now known that the greenhouse gas (GHG) emissions, mainly carbon dioxide (**CO2**), are primarily responsible for the heat retention and the temperature oscillation on the earth's surface.

Through reports, the IPCC (which in English means; Intergovernmental Panel on Climate Change U.N.) is warning the world about the causes and consequences of human activities upon the planet climate.

There is currently a correct understanding of cause-effect relationship involved in global warming, and thus mitigating actions are being increasingly disseminated and implemented, whether from public areas (governments, states and even cities), business and civil in order to reduce its impact on the increasing concentration of GHG in the atmosphere.

The companies are looking for ways to reduce their emissions from changes in their activities, either directly, by knowing the sources, through an inventory of emissions, and thus create a portfolio of mitigating actions (which include the adoption of more efficient processes and materials and less emission), or indirectly, to promote the reduction of emissions by other ways or through the offset emissions from common practices of carbon absorption like planting trees.

The public worried about climate changes is increasing, and nowadays, many companies have adopted control measures of reducing GHG emissions. They have achieved competitive advantages in demanding markets for green products with low **CO2** emissions.

2. OBJECTIVE

This project's main objective is the application of the methodology by calculating the amount of GHG emitted in manufacturing and construction of a pool of 4 feet by 8 feet of plastic reinforced with fiberglass (FRP), produced by iGUi enterprise and comparing it with GHG emissions of the traditional method of pool construction with concrete pools.

3. METHODOLOGY

For this study, there was an Initiative of the GHG Protocol methodology (www.ghgprotocol.org) in the organization of datas, methods of accounting and disclosure parameters.

The calculation tools used by the GHG Protocol emissions are compatible to ISO 14064 (International Organization for Standardization), and they follow the purposes established by IPCC.

The conversion factors used were surveyed in several studies, and the sources are quoted together with the factor used and the bibliographical materials consulted.

The amount of greenhouse gases is expressed in carbon dioxide, **CO_2**, other greenhouse gases (methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6)) are converted into **CO_2** equivalent to (**CO_2**e) and incorporated into the accounting factor.

The GHG emissions were calculated by dividing them into three scopes, set by the GHG Protocol:

Escope 1: Direct GHG emissions

Emissions that are directly controlled by the companies on their location, being mainly the result of the following activities: power generation, heat or steam, chemical and physical processes, transportation and fugitive emissions.

Scope 2: Indirect GHC emissions

The emissions from the purchase of electricity that is consumed by their own equipments are accounted or controlled by the company itself.

Scope 3: Indirect GHG emissions

This scope is considered by GHG Protocol as an option. It is the accounting of emissions generated by production and transportation of raw materials, product usage, hired activities, hired vehicles, employee's transportation, waste disposal and employee's business trips.

The accounting of Scope 3 can generate an almost infinite regression if the life cycle analysis is adopted for each material. It is advised by the GHG Protocol to make a pre-analysis in order to focus from two to three activities that were the main generators of greenhouse gas emissions.

4. PROJECT AIM

This project aims the production, manufacturing and installation of a FRP (Fiber Reinforced Plastic Glass) pool, manufactured by iGUi enterprise (San Antonio Pool Industry Factory Ltda.) and the construction of a concrete pool, both with similar sizes.

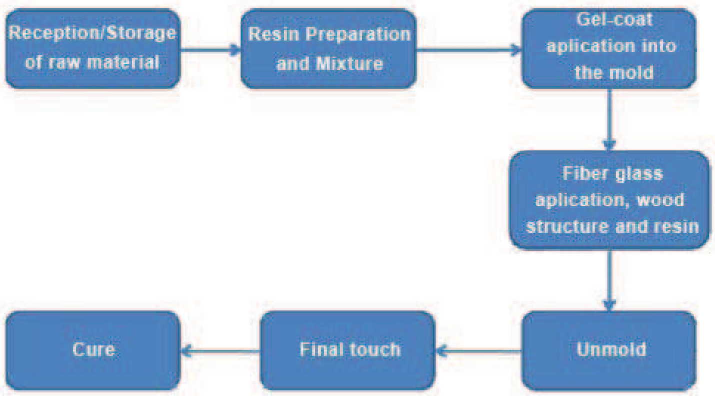
The postings of related emissions in other sections that combine iGUi company's activity (design, marketing, sales, after sales) were not accounted. This work focuses on the comparison of two building methods of a same civil apparatus, the swimming pool.

5. PROJECT RESULTS

5.1. iGUi's Swimming Pool in FRPG

5.1.1. Descriptive history of the manufacturing process

The manufacturing process of a pool in FRP (Fiber Reinforced Plastic Glass) in iGUi´s factory, Santo Antonio Pools Industry Ltda, is a simple process, as shown in the diagram below.



Receiving / Storage of Raw Materials

The first fabrication process consists in the reception of raw materials and containers like big gallons and cans, transported by the product supplier (Table 1). Then the material is packed in a shed attached to the factory, later moved to the production area, by a company tractor, in the required quantities for the daily manufacturing.

Table 1 - Raw materials used in the manufacturing process and their suppliers.

Product	Company
Resins	Cromitec
Fiber glass	Vetrotex
Meck Calalyzer	Axo Nobel
Aerosil	Diosil
Cobalt	Diosil
Titanium Dioxide	Diosil
Blue Pigment	Confibras
Orange Pigment	Trancor
Solvent	Resicor

Reference: iGUi

Preparation and Resin Mixture

In this process step, the mixtures are made for the preparation of the GELCOAT and the resin for the lamination. In preparing the GELCOAT, the mixture of the materials is elaborated (Table 2), through an electric mixer, directly in the original resin cylinder.

Table 2 - Material Quantities and Proportions for the GEL-COAT Production.

Product	Quantities for mixture (kg)	Quantities for 1 pool (kg)	Proporcion in percentage
Polyester Orthophtalic Resin	100	40	90,76
Cobalt	0,45	0,18	0,41
Aerosil	3	1,2	2,72
Titanium Dioxide	6	2,4	5,45
Blue Pigment	0,43	0,172	0,39
Tinovin	0,3	0,12	0,27

Reference: iGUi

The process for preparing the polyester resin for ortophalic lamination is similar to the process of preparing the gel-coat, only changing the composition of the mixture (Table 3).

Table 3 - Material Quantities and Proportion for the Polyester Orthophthalic Resin.

Product	Quantities for mixture (kg)	Quantities for 1 pool (kg)	Proportion in percentage
Polyester Orthophtalic Resin	200	170,0	99,5
Orange Pigment	1	0,8	0,5

Reference: iGUi

2% of Meck catalyst is added in both processes.

GEL-COAT Application

During the process of gel coat application, the swimming pool mold is placed at a specific place for a safe application. The Gel-coat composition is described in Table 2. A layer of about 6 mm is applied, and then the frame is placed for natural drying.

Fiberglass, Resin and Wooden Structure Application

After drying the GELCOAT, the swimming pool mold is placed in the fiber area application, using the joint application equipment (fiberglass chopper gun and polyester resin applicator).

During the process of applying the fiberglass and polyester resin, the wooden structure is placed on the sides and the fiberglass mixture and the polyester resin are applied, creating a layer of about 4 mm thick at the bottom of the pool and about 10mm thick on the sides and the edge.

At the end of the application, the mold is left for a quick cure before being unmold.

Unmolding

After the primary drying of the fiberglass mixture and polyester resin, the mold is suspended by pulleys within a specialized structure. Right after, compressed air is injected at pre-established places, to make possible to unstuck the swimming pool from the mold.

A release agent, called SK3 is applied to unstick the pools from the mold, in an amount ranging from 200g to 500g. For each time the release agent is applied on the molds, about 30 swimming pools are produced.

Finishing

During this process, the employees cut the trimmings and edges, giving the pool its final shape.

Curing

The final process of manufacturing the swimming pool is the natural cure that lasts about 2 days. The pool is transported by tractor to the yard outside the factory, where it stays until the time of transportation for sale.

5.1.2. Descriptive history of the installation process

Between 4 to 8 people are needed to install the pool at the customer's house, with no need of machinery use for the excavation. This is followed by preparing the soil placing a "cushion" of sand at the bottom of approximately 10 cm.

Emissions from the process of installing the pool in FRP were not accounted, because they equate to the initial process of construction of the concrete pool, which were not accounted either.

5.1.3. Identification Scopes

The process for accounting GHG emissions by manufacturing and installing the pool in FGRP, was separated by scopes, according to the following methodology.

Scope 1 - Direct emissions from the factory
- Fuel burning (diesel) by using tractor.
- Fuel burning (LPG) - for cooking employees' meals.

Scope 2 - Indirect emissions by purchasing electricity
- Power consumption of the factory in kW / h.

Scope 3 - Indirect emissions - transportation and acquisition of raw materials
- Emissions for fiberglass mining, manufacturing and transportation.
- Emissions for manufacturing and polyester resin transportation.
- Emissions for employees' transportation.
- Emissions for swimming pool transportation to the customers.

5.1.4. Calculations and tables

Scope 1

Fuel Burning(diesel).

A small diesel powered tractor for handling the molds and the swimming pools, which is also used for cutting grass and the transportation of materials and wastes.

Average fuel consumption, multiplied by diesel emission was done for calculating (table 4).

Fuel Burning (GLP).

GLP is used for cooking employees' meals. About 13 kgs of GLP is used monthly for so. (Table 4).

Table 4 Fuels, emission factors, quantities, diesel **CO2** emission and **CO2** quantity by pool.

Scope 1				
Diesel	Quant. L	Factor*	Kg CO_{2e}	Kg CO_{2e} for pool
Average	80	2,654	212,32	**1,279**
GLP	Quant. Kg	Factor*	Kg CO_{2e}	Kg CO_{2e} for pool
Average Comsuption	13	3,034	39,442	**0,237**

Reference: * GHG Protocol/ CEPAC

Scope 2

The factory average electricity consumption was obtained by the average between the highest and the lowest month's consumption. (Table 5).

Table 5 Monthly electricity consumption, emission factor for South and Southeast, **CO2** quantity and **CO2** quantity by pool.

Scopo 2					
Monthly Electricity	Kwh	Factor	ton CO_{2e}	Ton. CO_{2e} for pool	Kg CO_{2e}
High Consumption	10.421	0,000268*	2,789	0,01680	16,805
Low Consumption	8.141	0,000268*	2,179	0,01312	13,128
Average Consumption	9.281	0,000268*	2,484	0,01496	**14,967**

Reference: National Energitic Balance 2005. Based on 2004 Final Report/Mines and Energy Ministry / Energetic Enterprise Research/RJ

Scope 3

Mine Emission, manufacturing and fiber glass transportation.

An emission factor published by Wallon Institute of Economic and Social Development in the article "Greenhouse gas emissions reduction and material flows Housing system analysis- Part II- Processes description", January 2001, was used to calculate the emissions related to mining (silicon dioxide), ore transportation until it turns into fiberglass. However the fact it is defined according to European standards, the manufacturing are processes are not different from Brazilian processes, unless by emission related to electricity , which in this case, Brazil, by not owning an energetic matrix cleaner than the European, which is why it emits less GEE with the same electricity consumption.

Due to the fact that it is a positive exceeding on the amount of **CO2**, the use of European factor does not affect the work result. Once the calculation result shows a greater amount than the actual emissions output.

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Table 6 - **CO2** emissions from production and transportation of fiberglass.

Product	Quant. for 1 pool kg		Kg CO_2 / Kg fiber*		Kg CO_2
Fiber glass	85		0,9		76,5
Company	location	distance to iGUi**	kg CO_2 / ton. km***	kg CO_2 / ton	Kg CO_2 / pool
Vetrotex	Capivari	1093	0,072	78,696	6,69
TOTAL Kg CO_2 for pool					83,19

- * Wallon Institute; ** Guia Quatro rodas *** GHG Protocol

Manufacturing and Transportation of Polyester Resin Emissions

Because of the lack of specific literature on emission estimation on the production of polyester resin, we contacted CROMITEC enterprise, from BRAMPAC group, which provides the resins to iGUi enterprise, to provide us information allowing the estimation of GHG emissions on the production of polyester resin.

The data provided by Cromitec on the consumption of fuel and electricity, as well as resin production, were organized to provide the emissions related to scopes 1 and 2, thereby obtaining the emission factor of **CO2** per kg of resin (Table 7).

Completing the calculation, it was added to the emission factor for resin production the emissions of material transportation from the factory CROMITEC in Piracicaba, SP, to iGUi factory in San Antonio da Patrulha (Table 7).

Product	Quant. for 1 pool kg		Kg CO_2 / Kg resin *		Kg CO_2 for pool
Polyester Resin	210		0,17		35,7
Company	location	distance to iGUi**	kg CO_2 / ton. km***	kg CO_2 / ton	Kg CO_2 / pool
Vetrotex	Piracicaba	1114	0,072	80,208	16,84
TOTAL Kg CO_2 for pool					52,54

Table 7 - **CO2** emissions from manufacturing and transportation of polyester resin. Sources: * CEPAC, ** Guia Quatro Rodas, *** GHG Protocol. Reference: * CEPAC, ** Guia Quatro rodas, *** GHG Protocol

Emissions by transportation of employees to the factory.

It was identified that the employees' transportation from their homes to the unit Santo Antonio Pools Industry Ltda., could be an important factor of swimming pool production-related emissions, since emissions from scopes 1 and 2 are low and the two products that comprise 90% more of the composition of the products accounted above.

Table 8 shows the summary of employees' transportation:

Table 8 - miles traveled by employees and their **CO2** emissions.

Transportation	Km/ day	Km/month	Km / pool / month	Kg CO_2/ km*	Kg CO_2
Car	246,8	5429,6	32,71	0,16	5,23
Motorcycle	34,4	756,8	4,56	0,108	0,49
Bus	85	1870	11,27	0,19	2,14
Total each for pool					**7,87**

Reference: * GHG Protocol

Emissions by swimming pools transportation to the customers

It was performed an estimated average distance between the major cities served by the unit Santo Antonio Pools Industry Ltda. (Annex 2) and the city of Santo Antonio da Patrulha.

The average distance between customer and supplier was of around 300 km, and the truck that makes the transportation crosses the road twice (round trip) and it may carry from 1 to 10 swimming pools per trip.

The calculation will be based on the distance of 600 km divided by five pools, getting the equivalent of 120 Km per swimming pool (Table 9).

Table 9 - **CO2** emissions by the final transportation of each swimming pool.

	dist.(km)	consumption (km/l)	diesel (L)	Kg CO_2/ L*	Kg CO_2
Transportation by medium truck	120	5	24	2,654	63,69

Reference: *CEPAC

Table 10 - Total **CO2** emissions from Scope 3.

Scope 3 Summary	Kg CO_2
Fiber Glass	83,19
Polyester Resin	52,54
Employee's transportation	7,87
Pool transportation to the customer	63,69
Total	**207,3**

Reference: Author

5.1.5. Summary of emissions by iGUi swimming pools in FRP

According to the sum of the scopes (Table 11), we obtained a total of GHG emissions related to the production of swimming pools of about 223 kg of **CO2**.

Table 11 - Total of **CO2** emissions per swimming pool.

Production	Kg CO2/ pool
Scope 1	1,517
Scope 2	14,967
Scope 3	207,3
TOTAL	**223,78**

Reference: Author

5.2. iGUi swimming pool in FRP

5.2.1. Descriptive history of the manufacturing process.

Conducting the comparative calculation, we adopted a swimming pool standard project (Annex 1) using the same measures of the fiberglass swimming pools: 4 meters wide by 8 feet long.

The process of building a concrete swimming pool is "in situ", for the comparison of GHG emissions; its construction was considered as a manufacturing process, making the place of construction equivalent to the work place of manufacturing (the company).

There are several different ways to accomplish the construction of a concrete pool, by using or not excavation material, wooden molds or other materials and the concrete mixtures, up to the number of people involved in the work.

The basic steps for running a pool in reinforced concrete are:

- Land Survey
- Land Placement
- Placement feedback

- Execution of the external mold
- Assembly of the framework
- Placement of devices and pipes
- Installation of the internal mold
- Concrete
- Waterproofing
- Leaking Test
- Landfill and soil compaction
- Internal coating
- Outer coating

Calculating the emissions related to the construction of the pool in reinforced concrete, it will be taken into account only the factors of greater emission proportion, as it shows the item of scopes identification.

5.2.2. Scopes Identification

Scope 1 - Direct emissions by the construction site

- Power consumption of work location in kW/h.

Scope 2 - Indirect emissions by purchasing electricity

- Power consumption of worksite in kW/h.

Scope 3 - Indirect emissions by purchasing construction materials and employees' transportation.

- Emissions by cement manufacturing and transportation
- Emissions by steel manufacturing and transportation
- Emissions by mining and transporting sand and gravel
- Emissions for workers transportation

5.2.3. Calculations and tables

Scope 1

There are no meaningful direct emissions at the construction location.

Scope 2

There is an estimated time of 2 months, with an average monthly consumption of 450kWh for implementing the construction of a concrete swimming pool of 32 m2, reaching a total of 900 kWh (Table 12).

Table 12 - Power consumption, emission factor for the South / Southeast, **CO2** amount

	KWh	Factor*	Kg CO_2
Electricity used for the construction	900	0,000268	**0,2412**

Reference: National Energitic Balance 2005. Based on 2004 Final Report/Mines and Energy Ministry / Energetic Enterprise Research/RJ

Scope 3

Calculations of emissions from the main raw materials were performed using emission factors (Table 13).

Table 13 - Emission factors for construction.

	Kg CO_2
CO2 emission for cement bag (50 Kg)	48,44
CO2 emission for steal Kg	1,45
CO2 emission for m3 of sand or peeble	22,62

Reference: Stachera, 2006

Table 9 presents the research values made by Stachera, 2006 that takes into account the emissions from mining, ore transportation to the industry, emissions directly related to processing the raw material until it becomes raw material and its transportation to the commercial establishment.

Table 14 shows the amount of emissions related to the quantities of main materials used for constructing the pool.

Table 14 - Amount of material, **CO2** emission factors and amount of **CO2** emitted.

Material	Quant.	Uni.	Bags	Factor*	Kg CO_2
Cement	6.080	kg	122	48,44	5.890
Steel	636,56	kg		1,45	923
Sand	9,95	m3		22,62	225
Peeble	11,11	m3		22,62	251
Total emission for each gunite pool					**7.290**

*Stachera, 2006

5.2.4. Summary of emissions for the pool in reinforced concrete

According to the sum of scopes (Table 15), we obtained the total GHG emissions related to the swimming pool produced in reinforced concrete, of about 9131.2 kg of **CO2**.

Table 15 - Total of **CO2** emissions in the construction of a concrete swimming pool.

	Kg CO2
Scope 1	it doesn't exist
Scope 2	0,2412
Scope 3	7.290
Total	7.290,2

Reference: Author

6. CONCLUSIONS

The final analysis of the results shows a big difference between the GHG emissions related to the process of construction of the fiberglass swimming pool and the swimming pool in reinforced concrete.

According to this study, the fiberglass swimming pool issues during its construction process, emits approximately 223 kg of **CO2**, whereas the swimming pool built on reinforced concrete issues during its building process, emits about 7290.2 kg of **CO2**. Concluding, the concrete pool emits about 32 times more **CO2** than the fiberglass swimming pool during its construction process.

7. UNCERTAINTIES ASSOCIATED

Important considerations related to uncertainties on the estimations and calculations were done, to ensure the quality of information in the inventory of GHG emissions.

Uncertainty in the estimates: Information on the quantities of raw materials, fuels and journeys used in the estimation for accounting iGUi swimming pools in fiberglass, were provided by the general technician Mr. Irto Angeli de Souza, using an arithmetic average between the months of highest consumption and the ones of lower consumption.

We used a list, provided by Igui, to calculate the transportation of the swimming pool to the customer, the outlet locations, and thus elaborating an average of explored paths.

Estimations for the construction of the concrete swimming pool were performed by the Works Division in PUCRS (Annex 2), using the same measures of the fiberglass swimming pool (4mX8mX1, 5m).

Uncertainties in the parameters: Among the factors used, we can separate them by sources. The **CO2** emission factors for the GHG Protocol are based on studies leaded by IPCC, which takes into account the main factors to calculate and these facts are according to ISO standards. These parameters have a low rate of associated uncertainties.

The emission factor of BEN (National Energetic Balance) is related to the way of obtaining electric power, specific to the South and Southeast regions of the country, a parameter with medium rate of associated uncertainties.

The emission factor from Wallon Institute is based on a study case in Belgium, taking into account the European factors. Due to the similarity of the industrial processes of fiberglass manufacturing, and the lower emissions per kWh in Brazil the emission surpasses positively the amount of **CO2**, a parameter with high rate of associated uncertainty.

There was no literature to address the emissions calculation of polyester resin, so a consultation with the Industrial Manager of Cromitec, Mr. Eduardo Cangussu, was held based on the information about direct emissions from the factory, its electricity consumption and productivity, where calculations were carried out for the **CO2** emission factor per kg of resin. A parameter with high rate of uncertainty.

So it was held a consultation with the Industrial Manager of Cromitec, Mr. Eduardo Cangussu, based on the information about direct emissions from the plant, its electricity consumption and productivity, where calculations were carried out for the **CO_2** emission factor per kg of resin , a parameter with high rate of associated uncertainty.

The **CO_2** emission factors for construction were elaborated by Stachera in his study: "Assessment of **CO_2** emissions in construction: a study case of social housing in Parana". This study compared four other studies on **CO_2** emissions in construction, and creates an average parameter, a parameter with low levels of associated uncertainty.

8. PROJECT DISCLOSURE

The dissemination of the project results can freely be accomplished by iGUi respecting the datas integrity and the disclosure form described in this final report.

PUCRS will have the right to publicize the project and its results, in conferences, seminars, publications and other medias, with a written permission signed by iGUi.

9. BIBLIOGRAPHY

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10. SEARCHED SITES

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