Avoided Greenhouse Gases Emissions from Oil Recycling in the City of Florianopolis

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***Abstract*—**These Paper aims to demonstrate the *Reoleo* Project in Florianopolis, in the State of Santa Catarina, Brazil. The city has approximately 450 thousand people and the Project, idealized from the Commercial and Industrial Association of Florianopolis (ACIF) have an environmental education status and collects Kitchen oil from restaurants, homes, supermarkets and other establishments and recycle it, transforming it in other products. *Reoleo* has won the prize of the Guinness book of records for the amount of oil collection in one month in the city. The paper also discuss the evaluation of how much litters of oil the Reoleo have collected and how much the project contributed for the environment, avoiding the emission of thousands of tons of greenhouse gases (GHG), contributing for climate change.

***Keywords*—** Climate Change, Greenhouse gases emissions, Oil recycling.

I. Introduction

Climate change is one of the major challenges of our time and adds considerable stress to our societies and to the environment. Human interference with the climate system is occurring, and climate change poses risks for human and natural systems. The assessment of impacts, adaptation, and vulnerability in the Working Group II contribution to the IPCC's Fifth Assessment Report (WGII AR5) [1] evaluates how patterns of risks and potential benefits are shifting due to climate change. It considers how impacts and risks related to climate change can be reduced and managed through adaptation and mitigation.

Throughout history, people and societies have adjusted to and coped with climate, climate variability, and extremes, with varying degrees of success. Impacts of such climate-related extremes include alteration of ecosystems, disruption of food production and water supply, damage to infrastructure and settlements, morbidity and mortality, and consequences for mental health and human well-being. For countries at all levels of development, these impacts are consistent with a significant lack of preparedness for current climate variability in some sectors. [2]

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The preparation of a carbon footprint report is a very important step for an institution, company or event to contribute to the combating of the Climate Change and so, the emission of greenhouse gases that afflicts humanity since the beginning of the Industrial Revolution.

From shifting weather patterns that threaten food production, to rising sea levels that increase the risk of catastrophic flooding, the impacts of climate change are global in scope and unprecedented in scale. Without drastic action today, adapting to these impacts in the future will be more difficult and costly Knowing the profile of emissions from diagnosis secured by inventory, any organization can take the next step: to establish strategies, plans and goals for management and reduction of emissions of greenhouse gases, engaging in solving this enormous challenge to global sustainability [3].

The existence of projects to recycle different kinds of waste in Brazil is not a novelty. However, a few years ago, two factors have driven the recycling agricultural and agro-industrial residues. The first is that the use of waste is generally related to raw material cost. The second is about the environmental degradation resulting from the action of man on the environment, it is the operating environment for the production of products, is the impact of waste disposal in inappropriate places [4].

One of the products that are being recycled is the used cooking oil, widely used in homes and commercial establishments in Brazil. When discarded in the environment, this product may generate multiple environmental consequences.

When the waste cooking is dumped down to drains or sewers, the saturated oil accumulates in the sewer system causing blockages, odour, vermin problems, may also pollute watercourses leading to problems for wildlife and thus, can cause the emission of methane, one of the greenhouse gases.

The REÓLEO Recycling oil Project, from the Industrial and Commercial Association of Florianopolis (ACIF) in the State of Santa Catarina in Brazil, promotes to the community the collection of the dumped kitchen Oil, environmental education, and exercise the citizenship of the environmental problems concerning the disposal of used Kitchen Oil.

The Project has collected from the period of 2008 to 2012 1,11 million liters of used kitchen oil from the city of Florianopolis. Which instead, would be dumped in a inappropriate way, causing many problems as described before and the emission of Greenhouse gases [5].

This paper aims to describe the life-cycle of the kitchen oil in Brazil, the problems related to the unappropriated dumping and the avoided emission of greenhouse gases through the project form ACIF.

II. Life-cycle of cooking oil

The life-cycle of the used kitchen oil is defined by several steps involving: the production of the oil, covering all its transformations such as the use of the raw-materials until the final product, delivered to consumers. For that, its important to understand the influence on environment by the use of each component of this product and its manufacturing processes.

A. The extraction

The oils and fats are extracted from a variety of fruits, seeds, and nuts. The vegetables that are most used in Brazil are, Sunflower; cotton; soybeans; canola; palm, and corn oil that are extracted from growing procedures with different kind of technics. In the case of Palm oil, the trees requires a deep soil, a relatively stable high temperature and continuous moisture throughout the year. Soil fertility is less important than physical soil properties. Dry period of more than 2-3 months do not specifically damage vegetative growth, but affects seriously the production and quality of the fruits branches. Because industrial oil palm plantations need the clearance of a large areas they often require the expropriation of land and the cutting of extensive forest areas. Hence, the development of such plantations is usually associated with land tenure conflicts and problems of local land ownership on one hand and ecological problems, viz. biodiversity loss, on the other hand [6].

B. The industrialization of the oil

The preparation of raw materials includes husking, cleaning, crushing, and conditioning. The extraction processes are generally mechanical (boiling for fruits, pressing for seeds and nuts) or involve the use of solvent such as hexane. After boiling, the liquid oil is skimmed; after pressing, the oil is filtered; and after solvent extraction, the crude oil is separated and the solvent is evaporated and recovered. Residues are conditioned (for example, dried) and are reprocessed to yield by-products such as animal feed. Crude oil refining includes degumming, neutralization, bleaching, deodorization, and further refining. The refining industry undergoes color processes for quality control, control of the concentration of chlorophyll bleaching, filtration and hydrogenation [7].

C. Waste characteristics

Dust is generated in materials handling and in the processing of raw materials, including in the cleaning, screening, and crushing operations. For palm fruit, about 2–3 cubic meters of wastewater is generated per metric ton of crude oil(m3/t). The wastewater is high in organic content, resulting in a biochemical oxygen demand (BOD) of 20,000–35,000 milligrams per liter (mg/l) and a chemical oxygen demand (COD) of 30,000–60,000 mg/l. In addition, the wastewaters are high in dissolved solids (10,000 mg/l), oil and fat residues (5,000–10,000 mg/l), organic nitrogen (500–800 mg/l), and ash residues (4,000– to 5,000 mg/l). Seed dressing and edible fat and oil processing generate approximately 10–25 m3 of wastewater per metric ton (t) of product. Most of the solid wastes (0.7–0.8 t/t of raw material), which are mainly of vegetable origin, can be processed into by-products or used as fuel. Molds may be found on peanut kernels, and aflatoxins may be present [8].

III. The Reoleo Project

Since June 1998, the local authorities of Florianopolis have found that the Kitchen oil used in the restaurants, homes and food producers were disposed directly on the sewage, polluting the environment and causing severe damage into the underground sewage pipelines causing the overflow of the lifts at various points. For that, there have been local mobilization to change this course.

In July 2002, the project was implemented to environmental education in the neighborhood of Lagoa da Conceição. The project involved six schools of the region. Children from 1st to 8th grade were presented to the project through lectures and environmental education. In 2005 the project was also implemented over the other regions of the city, providing environmental education and the collection of used oil.

In 2007 and early 2008, the *Reoleo project* focused its attention on developing a methodology for the collection of household waste oil. In this sense, Voluntary Delivery Points were deployed called Environmental Collection Points -PEVs l by the city, through partnerships with local entrepreneurs.

from 2008 and so on, the *Reoleo Project* focused its disclosure through the participation in trade fairs and events of all possible types, aiming to promote to diverse audience, being circulated to over 15 thousand people and to promote the Environmental Education in the city of Florianópolis with the so called program "Recycling is Educate" aiming the importance of recycling and giving a critical view about the environment and socialization.

A. Oil Collection

There is a specific company that its duty is the responsibility for the collection of the cooking oil in so-called Voluntary Delivery Points (PEVs), scattered throughout the city of Florianópolis. For the operation of the collection they use two trucks that make daily gathering of the cooking oil looking for their products throughout the city. These trucks circulate approximately 100 miles in their daily collection routes.

The used oil is disposed into 100 liters gallons after the collection and are storaged at the Company's central collection stock in Florianópolis. When there is sufficient amount of gallons (approximately 50) another truck comes from the city of Curitiba (300 kilometers away) collects all the gallons and takes them to the company headquarters for the oil to be processed into cleaning products. This process occurs approximately 4 times per month.

The establishments where the collections are made are almost restaurants, schools, hospitals, associations and collection points for the community in general. It is collected an average of 700 – 1,000 liters per day, and the oil collected is stored in proper containers and packed in Florianópolis until it accumulates a volume of about 8,000 liters, corresponding to approximately 50 gallons which will then be transported to the Companies plant in Curitiba, Paraná.

B. Guinness Book

The Reoleo Project achieved in the early 2013 the milestone of 2 million liters of vegetable oil collected and recycled. The program, created in July 1998, collects on average 28,000 liters of saturated waste every month in Florianópolis, delivered by communities, bars, restaurants and hotels that use the product in large quantity.

In February, the program developed by ACIF placed Florianópolis in the Guinness Book as the city that recycles cooking oil over the world. The goal now, according to the Office of Communications Authority, is investing more in environmental education [9]

IV. Greenhouse gases Emissions for the oil collection

The process of gathering the cooking oil through trucks is considered emitter of greenhouse gases. Because of using combustion engines powered by diesel, are considered as direct sources of móbile emission. The monthly accounting of these emissions is show in table 1.

Table 1
Direct Emission From Gathering And Transport Of Cooking Oil

TRANSPORT	PERIODICITY day/month	consumed KM/LITERS	Liters consumed per year
Ford cargo 815e 2011	20	6,5	5.904
Volkswagen 8.140d98	20	5,5	6.984
MB 2013	3 a 4 vezes	4	6.480
Total Diesel consumed			**19.368**

Table II
Emission factor of fuel used for cooking oil transport

Fuel		Lower calorifc value	Density	Fatores de Emissão (kgGEE/un.)		
		(kcal/kg)	(kg/unite)	CO_2	CH_4	N_2O
Diesel oil	Liters	10.100	0,84	2,67	0,00014	2,10E-05

Source [10]

Table III
Total emissions of scope 1

Element	Direct mobile combustion per year	Direct mobile combustion per month
CO_2 (t)	49,145332	4,095444
CH_4 (t)	0,004489	0,000374
N_2O (t)	0,000392	0,000033
HFC (t)		
PFC (t)		
SF_6 (t)		
CO_2e (t)	**49,361169**	**4,113431**
CO_2 - Biomass	2,420097	0,201675

To make the gathering and transportation of the Reoleo Project of cooking oil, are used automotive mean, mobile emissions were considered, ie, there are emission of greenhouse gases. These emissions correspond to a total of 49. 36 tonnes of CO2 equivalent per year or 4.11 tonns of CO2 equivalent per month. Thus, to accurately the avoided emissions, these values will be subtracted from the cooking oil is ceasing to emit into the atmosphere. For a better analysis of the calculations, the calculations are attached to this report.

A. Avoided emissions of cooking oil

The Reóleo Project consists of the collection of used cooking oil for homes, restaurants, supermarkets and other commercial establishments. This selective collection avoids the eviction of this oil on the environment and other sites that may degrade the natural ecosystems. Thus, this study aims to calculate how much greenhouse gases that the oil could generate if it were arranged irregularly on the environment.

To make the calculation of these emissions it was necessary to do a laboratory analysis and identify the physico-chemical properties of cooking oil collected. First, it was necessary to do a study of the major fatty acid cooking oil marketed in Santa Catarina, which are: soybean oil, corn oil, sunflower oil and cotton oil [11].

As evidenced, there are different properties for cooking oil. Considering that the oil is collected in different regions and different institutions it has low homogeneity and there are a number of factors that can change the composition of the oil collected. These factors can be highlighted:

- The temperature of oil use;
- The amount of times the oil was reused;
- The types of food that were prepared;
- The oil itself used, if soybean, corn, sunflower, canola, cotton and others.

So it's easy to understand the high diversity of the collected material, which is necessary to implement some pre-analytical steps for further analysis that presents the actual information content as a whole, validating the information obtained for all the oil being them: determine the physical and chemical parameters of oil collected according to customer's request.

• Evaluate the results from the analytical procedures to validate the composition of the material collected.

• Highlighting the emission factor of methane gas from the anaerobic decomposition, where the oil was discarded in sewers.

B. Methodology of the oil collection

As evidenced, the material of interest, used cooking oil has a high diversity in their characteristics, but an important point to Reóleo design is the presence of different carbon structures in their molecular composition, and after used is also estimated that there is a big difference in the provision and quantity of these carbonaceous structures in the oil, a factor that may lead directly to the amount of greenhouse gases, methane and carbon dioxide, formed after anaerobic decomposition of the gases.

On the day of the collection of the oil there had been about 35 barrels of 100 liters of oil each, and there were collected from 8 barrels oil that had greater visual difference arising from the factors presented above, use time, temperature of use, type of use and type of oil.

The flowchart shows the procedures performed in this work.

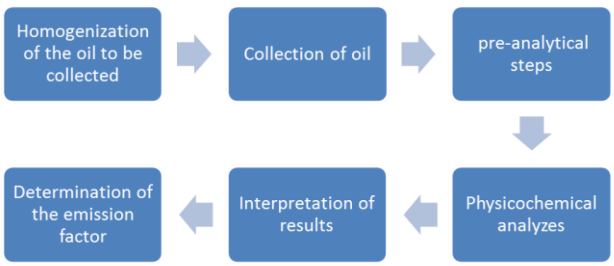

Fig. 1 Procedures performed in this work

V. Methodology for the Oil Analysis

The various carbon structures presented in the oil have different physical and chemical properties, the difference in density between these structures makes the disposal, there of varies in the barrel, the bottom getting denser structures in between the middle and the top the less dense along with an embedded layer that is disposed on the surface. So there is no one-step homogenization undertakes final results with the veracity of the material as a whole [12].

The parameters investigated were the viscosity and density of the material, these properties compared to that with the new oil (not used) lets say if there is similarity of the material or not with the cooking oil, if confirmed the similarity oil fits into the standard of IPCC (Intergovernmental Panel on Climate Change) [13].

The experiments were carried out with the support of specific equipment of laboratories of the Chemistry Department of the Federal University of Santa Catarina.

VI. Results

With these considerations it is possible to demonstrate, in this study, the amount of greenhouse gases from waste frying oils from the collection of GHG of the REÓLEO program.

A. Average density of the oil

Procedures for new cooking oil and the oil collected were repeated, and the collected oil to a duplicate was made and another due to the above acid treatment as carbon structures may be present in the form of carbonates amending properties that wish to find out about the oil.

TABLE IV
RESULTS OBTAINED FROM THE DENSITY MEASUREMENT SAMPLES

Sample	Average density (g/mL)
New cooking oil	0,972
Oil colleted 1	1,013
Oil collected 2	0,981
Oil collected 1- acid treatment	1,009
Oil collected 2 – acid treatment	0,977

Average density of collected oil without acid treatment: 0,997 g. mL-1

Average density of collected oil without acid treatment: 0,993 g.mL-1

Overall Average oil samples collected : 0,995 g,mL-1

Deviations of the new cooking oil are: 2,6% ; 2,2% e 2,4 % respectively.

Average deviation: 2,4%. Therefore, the deviation was not significant, and the density was within the standards of the International Panel on Climate Change, which provides up to 5% deviation.

B. Chemical Oxygen Demand - COD

TABLE V
RESULTS OBTAINED FROM THE EXPERIMENTS FOR THE DETERMINATION OF CHEMICAL OXYGEN DEMAND - COD.

Sample	n ° mole of O_2	Mass of O_2
1	$2{,}85.10^{-3}$ mol	$9{,}12.10^{-2}$ g
2	$2{,}60.10^{-3}$ mol	$8{,}32.10^{-2}$ g
Average	$2{,}725.10^{-3}$ mol	$8{,}72.10^{-2}$ g

COD = 8,72.10-2 g of O_2

DQO --------- 1,00 mL of oil

x ------------1000 mL (1L) of oil

x = 87,2 g de O_2 to 1L of oil

From the data collected, calculations following the standards and IPCC methodologies to estimate the amount of greenhouse gases emitted per liter of oil, specifically methane were initiated.

C. Total of organic material in disposed water

This category of analysis was first performed to identify the amount of organic material found in the sewers for the reality of Florianopolis. In this case, the approach to the properties of the oil collected was performed.

TOW = P . DBO. 0,001. I . 365

- TOW : total organic in wastewater kg de BOD / year
- P : population of the city or country
- I : correction factor of BOD which is originated from industry

In our calculations are disregarded : P , I , 365 (days)

remaining :
TOW = DBO. 0,001 ; of which was adapted from the COD so:
TOW = 87,2 g . 0,001
TOW = 0,0872 kg

D. Emission Factor

This calculation is the estimated global warming potential than a liter of cooking oil has on the environment through anaerobic decomposition (without oxygen), expressed in Methane CH4.

EFj = B0 . MCFj

Being B0 maximum amount of CH4 can be produced by oil (this type of approach oil usually refers formula is the maximum amount of CH4 produced per kg of BOD Thus:

B0máx = 1,0 L of oil. 62,5 %
- First convert the volume (L) kg from Oil density

Doil = 0,995 kg / L ; Soon:
B0máx = 1,0 L . 0,995 kg / L. 62,5 %
B0máx = 0,995 kg . 0,625
B0máx = 0,622 kg of CH4 produced from 1.0 L oil.

Recalling that B0máx = is the maximum capacity in accordance with the studies of Environmental Preservation Center, Kyoto University, Japan and methodology calculation Chapter 6 of the IPCC Guidelines for inventories of greenhouse gases-Wastewater treatment and discharge.

EFj = B0máx . MCFj

The MCFj is the correction factor from Table 6.3 of Chapter 6 of the IPCC Guidelines, the case for anaerobic decomposition in sewers, the correction factor is in the range 0.8 to 1.0. That is we use 0.9 as the average.

Like this:
EFj = B0máx .MCFj
EFj = 0,622 kg . 0,9
EFj = 0,5598 kg of CH4 for 1 liter of oil.

For every 1 liter of cooking oil discarded incorrectly, to degrade the drain it has a potential emission ships in 0.5598 methane. As the global warming potential of methane is 21 times greater than that of carbon dioxide (CO2) emission factor of 1 liter of cooking oil is equivalent of 11.7558 kilograms of CO_2 equivalent.

E. Total Emissions avoided

With the emission factor measured, it is possible to estimate how much the city of Florianópolis is avoiding releasing into the atmosphere the greenhouse gases due to the gathering of cooking oil through Reoleo project. For the total of 1.14milion litters collected from July 2008 to September 2012, there have been avoided 13.4 thousand tons of CO2.

TABLE VI
AMOUNT OF COOKING OIL COLLECTED IN LITERS

Amount of cooking oil collected in liters					
	2008	2009	2010	2011	2012
January		16.740	27.590	28.205	41.710
february		14.900	18.520	30.170	27.680
March		12.090	19.550	29.120	28.040
April		14.850	17.470	25.470	28.080
May		12.220	16.490	25.750	19.320
June		15.840	15.650	33.560	28.540
July	12.090	13.710	22.750	25.410	18.780
August	9.230	19.930	20.250	19.890	32.470
September	9.790	11.760	23.670	34.950	18.670
October	14.382	23.490	19.020	25.270	0
November	11.540	19.790	27.050	28.300	0
December	16.760	18.800	30.430	38.320	0
total	**73.792**	**194.120**	**258.440**	**344.415**	**243.290**
Overall total until september of 2012				**1.114.057**	

VII. CONCLUSION

The present results show that the *Reoleo project* from ACIF has a lot to contribute for the Climate Change. The amount of oil recycled during this study was on the period of July 2008 to December 2012. There have been collected in this period 1.14 million liters of used Kitchen oil, resulting 13,4 thousand tons of avoided CO2 that would be released in the atmosphere from the oil which would be disposed inappropriate into the environment.

Thus, this project is very important to maintain a great amount of recycled oil, and to give environmental education to citizens. The Commercial and Industrial Association in order to promote this project and reduce the amount of garbage into the sewage have worked following the United Nations Climate Change goals, to strengthening the ability of countries, particularly developing countries, to integrate climate change responses into national development processes.

The *Reoleo Project* have helped to communicate the key messages on climate change, clearly to ensure decision makers, those who advise them, and that the public have access to relevant climate change science and information.

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