Application of LCSA in Used Cooking Oil (UCO) waste management

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Abstract Used Cooking Oil (UCO) is a domestic waste generated as the result of cooking and frying food with vegetable oil. Due to a lack of standardized collecting systems, there is a low recuperation of UCO waste. Considering the calorific value of vegetable oil, a possible way to recover the waste generated from UCO is the production of biodiesel. The present paper aims to compare the sustainability focused on social and environmental analysis of three domestic UCO collection systems: through schools, door to door, and through urban collecting centers, in order to determine which systems should be promoted for collecting UCO in Mediterranean countries. The results indicate that environmentally viable alternatives not always contribute in social development. For the three collection systems studied, when a system has a positive social behavior the environmental impact and economic costs are larger.

Key words (abstract): Used Cooking Oil (UCO), Life Cycle Assessment (LCA), Life Sustainability Cycle Assessment (LSCA). Waste management.

1.Introduction

Used Cooking Oil (UCO) is a domestic waste generated as the result of cooking and frying food with vegetable oil. It is classified by the European waste catalogue (EC/532/2000) with CER number 200125. In Mediterranean countries, it is estimated that the generation of UCO is 5 kg per person per year [1]. Due to a low recuperation rate of UCO waste, a great part is removed through the sewage system causing problems in wastewater treatment plants. A current application of

UCO waste is to produce biodiesel which serves as a waste treatment and renewable source of energy. UCO can be a potential source for biodiesel production, with adequate incentives, and almost 70% of the used cooking oil could be recovered [2].

Until now, biodiesel production applying UCO as raw material has been analyzed in deep under the environmental point of view and potential biodiesel production [2]. Life Cycle Assessment (LCA) has been the most frequent methodology applied to study the efficiency and benefits of using UCO as a raw material to produce biodiesel [3,4]. LCA evaluates potential impacts throughout the life cycle of a product, process or activity, from the extraction of raw materials through production and use, to final disposal [5].

The collection of domestic oil depends on several key factors: economic profit to cover economic costs of the waste management system, environmental awareness by local authorities, the interest to promote environmental measures and social benefits such as environmental education of citizens and jobs creation. According to this, another assessment methodology as Life Cycle Sustainability Assessment (LCSA) is necessary to consider all these key factors.

In recent years there has been an increasing interest to include social aspects into life cycle assessment of products and systems. One of the results is the publication of the UNEP/SETAC Life Cycle Initiative Guidelines for Social Life Cycle Assessment of Products. Social Life Cycle Assessment (S-LCA) is a systematic process using best available science to collect best available data on and report about social impacts (positive and negative) in product life cycles from extraction to final disposal [6]. Research in Social Life Cycle is recent, there are some methodological guides to evaluate each impact subcategory, but there are few cases studies and so far and the methodology is still being developed [7].

2. Objective

The present paper aims to compare the sustainability of three domestic UCO collection systems in cities: door to door (DTD), schools (SCC) and urban collecting centers (UCC), in order to determine the environmental, economic and social impact applying S-LCA, and to obtain a sustainable view of the different UCO collection systems and an assessment of the appliance of S-LCA methodology. The paper also aims to compare systems designed to be economically efficient towards others with a social vocation.

3. Methodology

The methodology applied in this paper is LSCA (Life Sustainability Cycle Assessment). LSCA consists on the integration of Environmental Life cycle Assessment (E-LCA), Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA) [8]. Societal assessment is viewed by some authors [9] and organizations as a complement to Life Cycle Assessment and Environmental Life Cycle Costing [10] also as a third component of measuring sustainability development, defined by Brundtland [11] as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

3.1. Environment assessment

To perform the environmental analysis the methodology selected was E-LCA, the software used was SimaPro 7.2 with ecoinvent database 2.0. The impact categories included in the study are mid-point indicators, according to CML 2001. It was only taken into account the characterization.
The score for each impact category was assigned by multiplying the amount of substance emitted by the corresponding characterization factor.
Optional phases of normalization and weighting are excluded in order to avoid subjectivity in the analysis.

3.2. Social Assessment

In S-LCA, not only quantitative data is used, but also semiquantitative and qualitative data., meaning that data is represented by a 'yes'or 'no', or represented on a scale or scoring system [12]. When conducting an S-LCA it is important to address the quality and integrity of the data to ensure the reliability and the validity of the results and to be able to draw the right conclusions. The geographical location is of great importance in S-LCA.

The UNEP/SETAC [12] methodology has listed indicators according to stakeholder categories: worker, consumer, local community, society and companies throughout the life cycle of the product.

However, as companies and organizations involved in the systems studied in this paper are located in Europe, some indicators are not applicable in this territorial context.

In this study, according to the functional unit, the geographic location, and the characteristics of the three systems studied, the chosen social indicators are listed below:
a) Working hours of employees with special needs
b) Total number of employees
c) Employees with employees with special needs
d) Employees with higher education
e) Employees with basic education
f) Equal opportunities (sex)
g) Equal opportunities (employees with special needs)
h) Infantile education
i) Local employment
j) Public commitments to sustainability issues
k) Contribution to economic development.

Some indicators have been adapted from the UNEP/SETAC list in order to consider all the relevant social aspects that are involved in the three systems studied for example: Infantile education and employees with special needs.

Data used to calculate social indicators has been obtained from the entities and companies that currently are applying these UCO collection systems.

3.3. Economic assessment

Regarding to economic assessment, three types of costs have been considered.
a) Production cost of containers,
b) Representative salary of employers categories and
c) The fuel cost related to transport stages.
As the systems under study are located in Catalonia (North-East of Spain), the currency selected is euro (€) and costs assumed are valid for 2011.

3.4. Functional unit

The functional unit of the study is collecting the amount of UCO available in the neighborhood of an area with 10,000 inhabitants during one year in Barcelona, Catalonia (North-East of Spain).

3.4.1. Reference flows

The potential UCO generated for 10,000 inhabitants of Barcelona neighborhood is 37,757 liters. Taking into account that the systems analyzed present different UCO collection efficiencies, the amount of final UCO collected and containers needed are the following:

The door to door *(DTD)* system requires 2,025 collection containers with a capacity of 1 liter to collect 21,600 liters of UCO. The School Collection Center *(SCC)* requires 4,000 collection containers to collect 24,000 liters of UCO and finally for Urban Center Collection *(UCC)* requires 2,100 containers to collect 25,200 liters of UCO. The amount of UCO collected is not the same for each system because every system has different collection efficiency.

3.5. System description

It has been performed a comparative assessment between three UCO collection systems, currently all of them are being developed in some municipalities of Catalonia:

a) *DTD system:* UCO is stored for consumers in a special container of one liter at their houses, once a month a special collection service (carried out by workers with a degree of disability) collects the filled container with UCO from houses and gives a new empty container. The UCO collected is sent to a Special Working Centre (SWC) and is deposed in a storing container of 1,000 liters. The empty one liter containers are washed with a special dishwasher in order to be reused. The employees that work in the cleaning and storing centre also are people with a degree of disability. When the storing containers of 1,000 liters are filled a tanker truck transports the UCO to a biodiesel Plant (BDP).

b) *SCC system:* Schools become a useful access point to collect UCO, where students bring a container of one liter filled with UCO directly from their houses and take a clean empty container. Once a month containers are collected from the schools and are transported with a van to SWC, where the UCO is stored in a containers of 1.000 liters. The empty containers of a liter are washed with a special dishwasher in order to be reused. The employees that work in the cleaning and storing centre are people with a degree of disability. When the storing containers of 1,000 liters are filled a tanker truck transports the UCO to a BDP.

c) *UCC system:* Collects municipal waste in small quantities, so people who gather UCO in their houses can bring it to this collection points using a container of one liter, and empty it in a big storing containers of 1.000 liters placed in the UCC, then people back home with the empty container and it is washed by the users at home in order to be reused.. When the storing containers of 1,000 liters are full, a truck transports the UCO to a BDP. People go to UCC in a frequency of once a month.

Fig 1 shows the three systems studied and the stages involved.

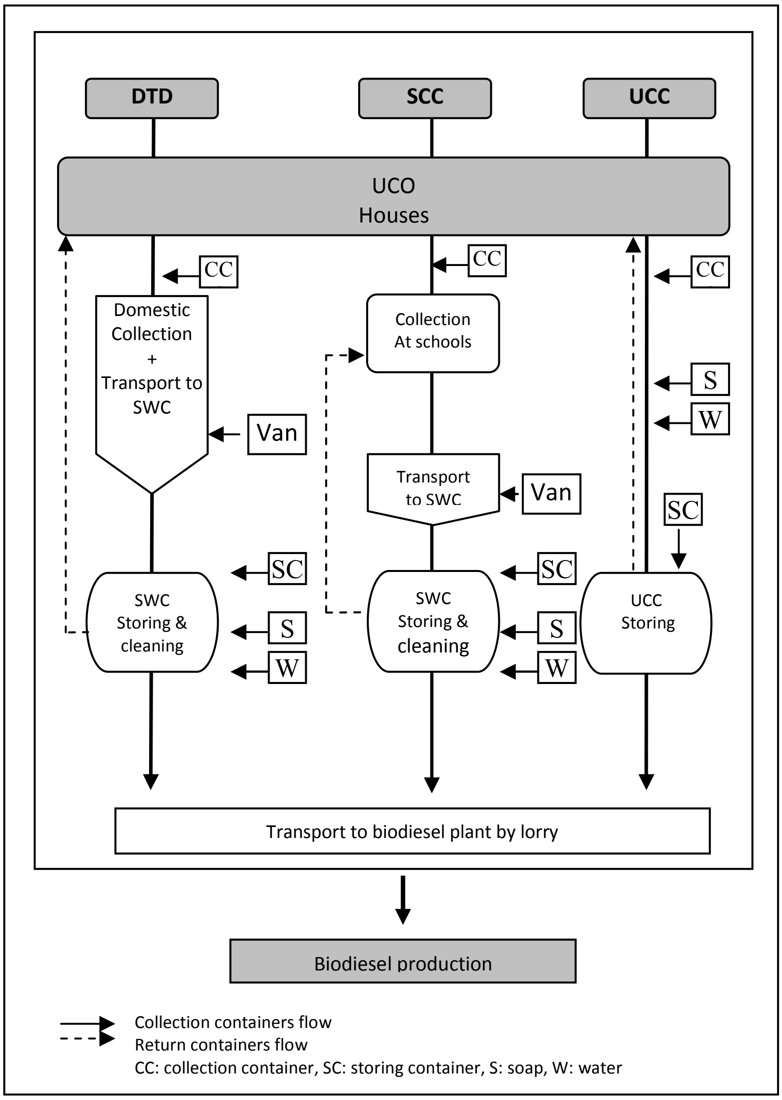

Fig.1: boundaries of the three collection systems under study

3.6.Inventory

The following section presents environmental, social and economic data of the three systems under study. Table 1 shows the data related with the environmental inventory.

Tab.1: Environmental Inventory of three UCO collection systems

Inputs	Units	DTD	SCC	UCC
Collection containers				
Collection container	number	2,025	4,000	2,100
PP collection container	kg	101	200	105
HDPE storing container	kg	259	288	302
UCO transport to storing center				
Transport to SWC	kgkm	1,724,612	2,129,150	-
Cleaning stage				
Plastic dishwasher	kg	1	1	1
Steel dishwasher	kg	6	6	5
Soap cleaning	kg	51	50	34
Water cleaning	*l*	12,150	12,000	14,238
Cleaning	kWh	633	625	261
UCO transport to BDP				
Transport to BDP	kgkm	8,566,042	10,575,360	11,659,334

Collection and Storing container stage

The collection container and the storing container used have the same characteristics for the three systems. Collection container has a capacity of 1 liter; it is made of propylene and has a lifetime of 2 years. Storing container has a capacity of 1,000 liters; it is made of high density polyethylene and has a lifetime of 5 years. The SCC system needs major number of collection containers because there is only one collection day of UCO per month at schools, it makes necessary to provide the same number of empty containers than the number of the filled containers collected. This does not occur in DTD and in UCC systems, because in the case of DTD the collection of UCO is daily attended so it means that UCO is collected and returned progressively during the month so less number of empty containers is required to give service during collection days. In UCC the user is the owner of the collection container and it decides the frequency of going to collection center and there is not container exchange.

UCO transport to storing stage

UCO collected in containers of 1 liter is accumulated in bigger containers of 1,000 liters in SWC in DTD and SCC systems. The UCC system is carried out in the same urban collection center. In DTD and SCC systems, the distance of collection transport stage is assumed to be 5 km. As the amount collected in SCC is higher than DTD (see section 3.1.1 Reference flows), a major number of transports has to be carried out in order to bring UCO generated for the system. In the UCC system it is assumed there is no transport stage between collection and storing stage, because the collection center is near to the citizens' houses and it can be reached by walking.

Cleaning stage
DTD and SCC systems integrate a cleaning service where the collection containers are cleaned in industrial dishwashers. In UCC, the cleaning stage is a responsibility of the citizens and the analysis considers a distribution of 60% using dishwasher and 40% hand washing (BALAY, 2009).
UCO transport to Biodiesel plant stage
The same distance, 100 km, for the three systems has been considered. Nevertheless SCC needs more transport than the other systems due to major UCO amount collected in this system (see section 3.1.1 and table 1).

4.Results and discussion

4.1 Environmental results

The results in table 2 and figure 2 show that the SCC system has the highest environmental impact in all categories, due to the fact that this system demands more transport steps and more collection containers than the other systems. UCC system presents the lowest environmental impacts because no transportation was involved in the collection containers step; it is supposed that citizens go to UCC on foot.

Tab.2: Environmental indicators of life cycle assessment of three systems

Indicator	Units	DTD	SCC	UCC
AD	kg Sb eq	55.07	69.06	44.73
AC	kg SO2 eq	26.27	31.91	24.09
EU	kg PO4--- eq	7.82	9.57	7.34
GW	kg CO2 eq	6,875.35	8,510.98	5,651.11
ODP	kg CFC-11 eq	0.001	0.0013	0.008
HT	kg 1,4-DB eq	2,549.25	3,111.33	2,524.86
WAE	kg 1,4-DB eq	1,144.25	1,381.71	1,119.02
MAE	kg 1,4-DB eq	2,294,869.64	2,798,558.05	2,283,038.82
TE	kg 1,4-DB eq	54.93	58.26	45.55
PO	kg C2H4	2.03	2.45	2.00
ED	MJ eq	138,146.16	172,189.35	138,708.29

AD: Abiotic depletion, AC: Acidification, EU: Eutrophication, GW:Global warming (GWP100) ODP: Ozone layer depletion, HT: Human toxicity, WAE: Fresh water aquatic ecotox, MAE: Marine aquatic ecotoxicity, TE: Terrestrial ecotoxicity, PO: Photochemical oxidation, ED: Enegy demand

Figure 2 shows the different environmental impact categories for each collection system: DTD, SCC and UCC, distinguishing between transport stages and the other life cycle stage. The transport impact contribution includes all the transport stages: collection transport and transport to biodiesel plant.

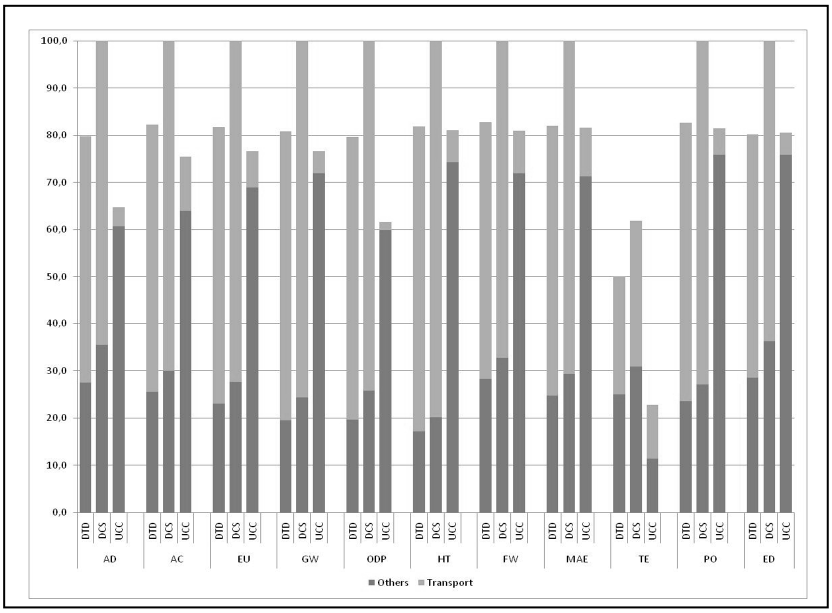

Fig.2: Impact categories for DTD, SCC and UCC collection systems

4.2 Social results

Table 3 shows the social indicators calculated for the three systems under study.

Tab.3: Social indicators of Social Life Cycle Assessment of the three systems.

Social Indicators	DTD	SCC	UCC
Total Employees	55	20	14
Total working hours	92,843	29,156	18,226
Employees with disability	38	8	0
Employees Higher education	9	5	2
Employees Basic education	46	15	12
Equal opportunities (sex)	100%	100%	100%
Equal opportunities (disability)	83%	25%	0%
Infantile education	1%	100%	10%
Local employment	100%	100%	100%
Public commitments to sustainability issues	100%	100%	100%
Contribution to economic development	100%	100%	100%

The results of table 3 show that DTD is the system with highest number of employees, the highest number of employees with special needs, the highest number of employers with basic education and total working hours. As in DTD system UCO collection is directly done from citizens' houses it means that more number of employees is involved in all stages. As the work is carried out by employers with special needs in DTD system; extra coordinating and supporting personal is necessary. This system also has greater social benefits promoting infantile education and equal opportunities than the other two systems studied.

SCC system also presents employers with special needs but only in storing and cleaning stage. This system performs better results in infantile education than DTD and UCC systems. SCC also contributes to equal opportunities in employees with disability with 83% (see table 3).

UCC presents the lowest social results, this system has the minor number of employees and has no employees with disability, even so it has a small contribution of 10% in infantile education. To manage an Urban Collection Center, where several wastes are collected, some knowledge and degree of responsibility are required, this implies the impossibility of generate jobs for employees with disability because.

Note that UCO collection systems that present collection frequencies larger and grouped or managed by availability of citizens reduce the total working hours and number of employees.

4.3 Economic results

Table 4 shows the results of economic analysis for each collection system. DTD system presents highest management cost because requires major number of employees. SCC system presents higher cost for the collection container manufacturing, because this system needs more collection containers to carry out the UCO gathered. UCC system presents lower management cost because it needs less number of employees, even this system has no transport implied in the collection containers step the cost of transport is higher because it generates more UCO so more trips to biodiesel plant are required.

Tab.4: Economic indicators of life cycle cost of the three systems

Economic cost €	DTD	SCC	UCC
Personal	706,707	328,200	248,000
Transport	231	254	260
Collection container	643	1.271	667
Storing container	44	44	44
Total cost	707,626	329,769	248,972

5. Conclusions

Comparative results between the three collection systems studied: DTD, SCC and UCC, indicate that when a system under study has a positive social behavior it presents a larger environmental and economic cost; it is the case of DTD system. However, when a system has a lower environmental impact, the social component is weaker; it is the case of UCC and SCC systems. So the results indicate that environmentally viable and economically efficient alternatives not always contribute in social development.

UCC system implies fewer employees so it is difficult that this collection system can contribute to promote the social component. However DTD is a local and personalized service carry out by workers with a degree of disability which means more employees and more qualified staff to coordinate it, so that benefits the social development. Even so SCC system also presents positive social results and a lower economic costs than DTD system, the environmental impact is higher than DTD because SCC needs more number of collection containers and more van travels to collect the UCO.

Regarding the environmental impact, note that the collection transport step implies the highest environmental impact especially due to the type of vehicle used.

In order to reduce this impact an improvement measure could be integrating a route for collecting the UCO from various schools with a vehicle with greater capacity and reduce the number of trips. Another measure to reduce the transport stages should be close to the citizens' houses more collection points. As major is the UCO accumulation in collection points more efficient is its management and transport.

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