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Title: Biodiesel production as an alternative to reduce the environmental impact of University food courts

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INTRODUCTION

SEMARNAT

SECRETARÍA DEL MEDIO AMBIENTE Y RECURSOS NATURALES

- It is necessary to strengthen a comprehensive waste management under the circular economy approach, integrating this vision into educational processes to promote environmental management in national and international academic institutions (green schools) (SEMARNAT, 2020).

LIFE CYCLE PERSPECTIVE TO SOLID WASTE MANAGEMENT

UNAM (Güereca *et al.*, 2013)

UAM (Mendoza *et al.*, 2019)

Reducing environmental footprint

Figure 1. Negative environmental impacts of waste cooking oil (WCO).
Source: (Hartini *et al.*, 2020.)

"... implementing the management and adequate disposal of residual animal and/or plant fats and oils, seeking to consider the adoption of management measures, to prevent and reduce environmental impacts and harmful health effects"

NADF-012-AMBT-2015

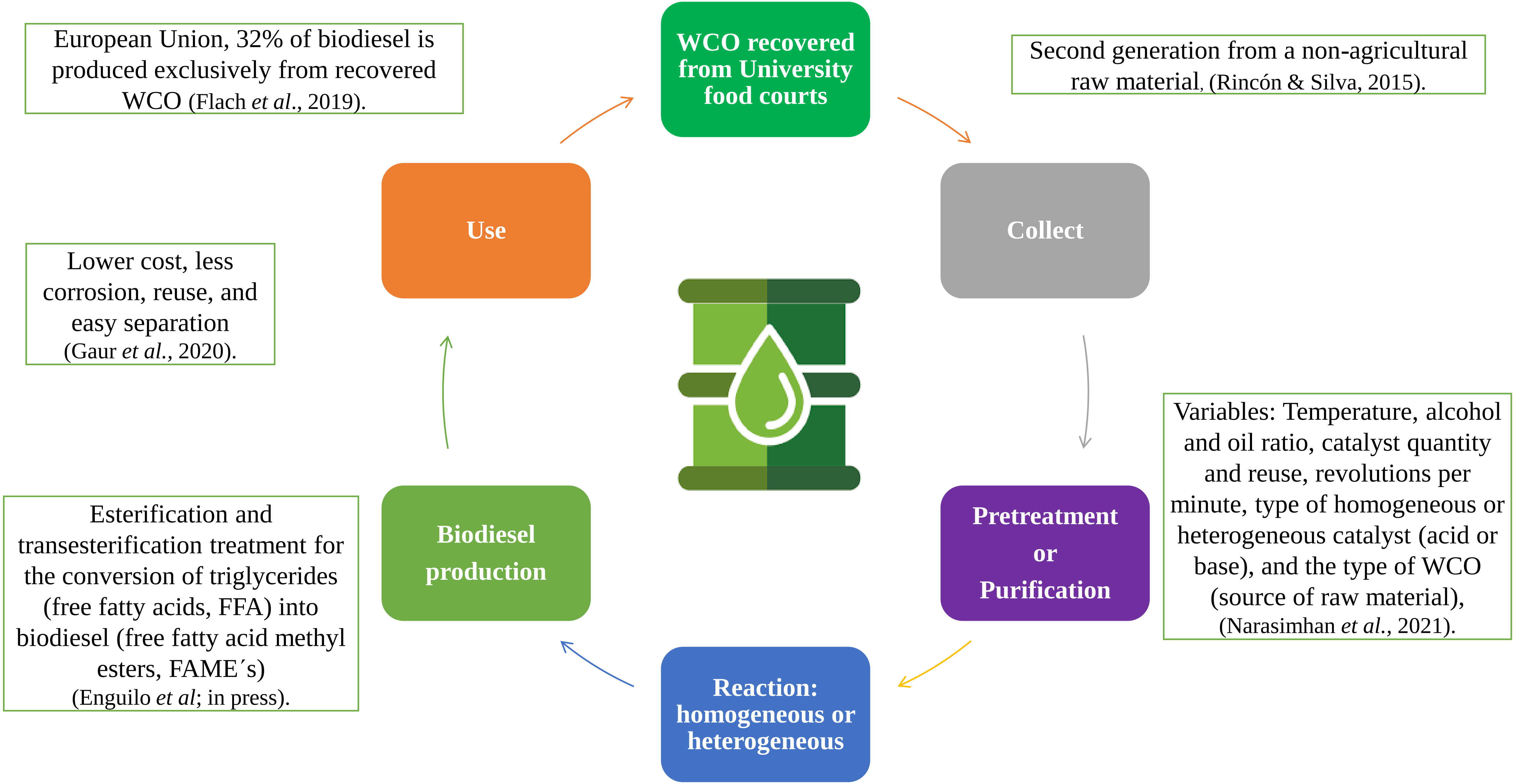

Figure 2. Green circular economy model of waste cooking oil management.

METHODOLOGY

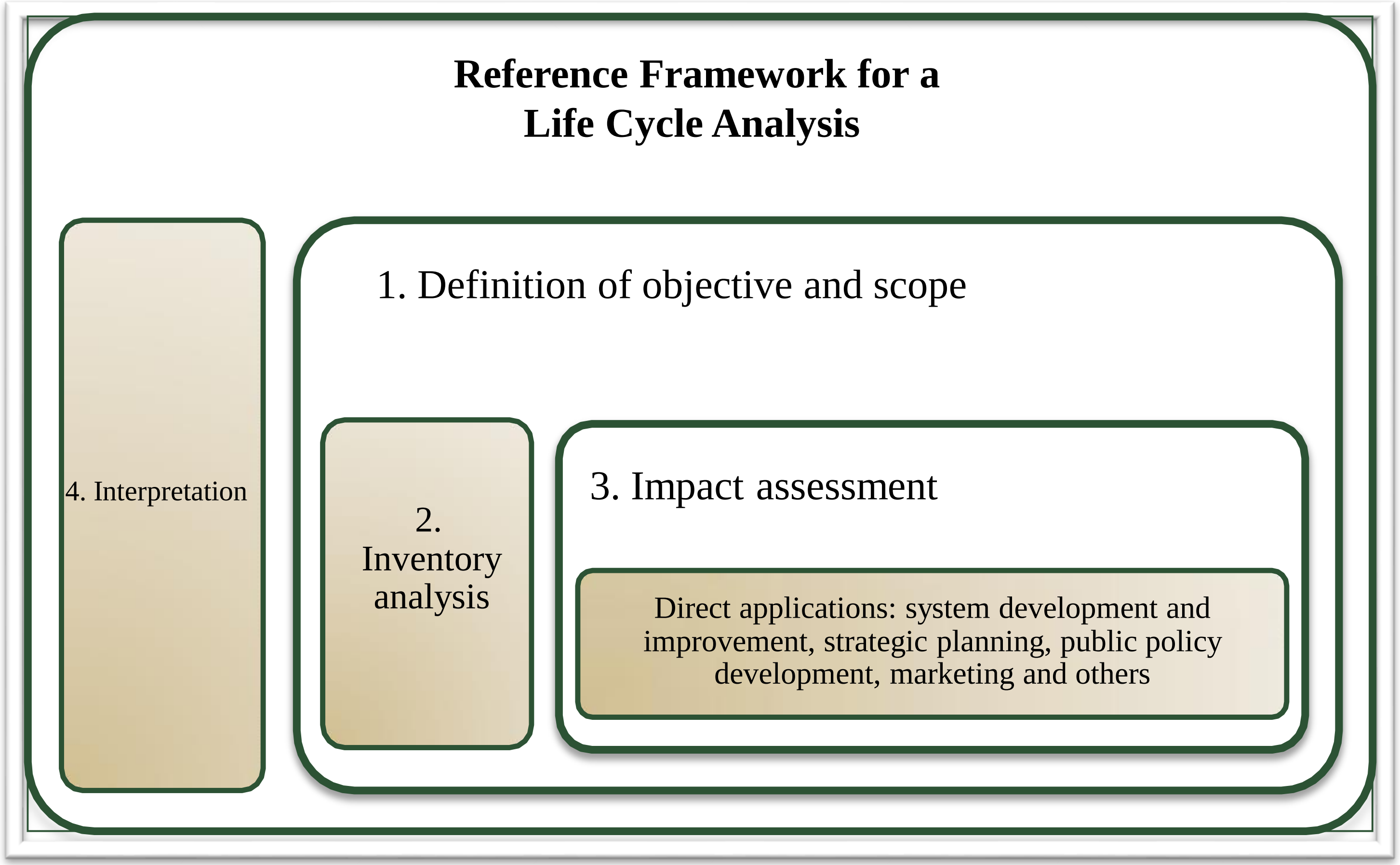

Figure 3. Reference Framework for a Life Cycle Analysis (LCA).
Source: (ISO 14044, 2006)

- Software: **SimaPro 9.1.0.11 PhD.**
- **Ecoinvent** database.
- The method was **CML-IA baseline C3.06/EU25, midpoint assessment,** with **eleven impact categories**: Abiotic Depletion Potencial (ADP, elements), Abiotic Depletion Potencial (ADP, fossil fuels), Global Warming Potential (100 years) (GWP), Ozone Layer Depletion (ODP), Human Toxicity (HT), Freshwater Aquatic Ecotoxicity (FWAE), Marine Aquatic Ecotoxicity (MAE), Terrestrial Ecotoxicity (TE), Photochemical Oxidation (PO), Acidification (A) and Eutrophication (E). The interpretation, a heterogeneous process (scenario 1) was compared with a homogeneous process (scenario 2), data reported by (Talens et al., 2010) were used for the homogeneous process.
- The **endpoint impact assessment** (Ecosystem Quality, Human Health Damage and Resource Availability) was carried out using the **ReCiPe 2016 Endpoint (H) V1.04 / World (2010) H/A.**

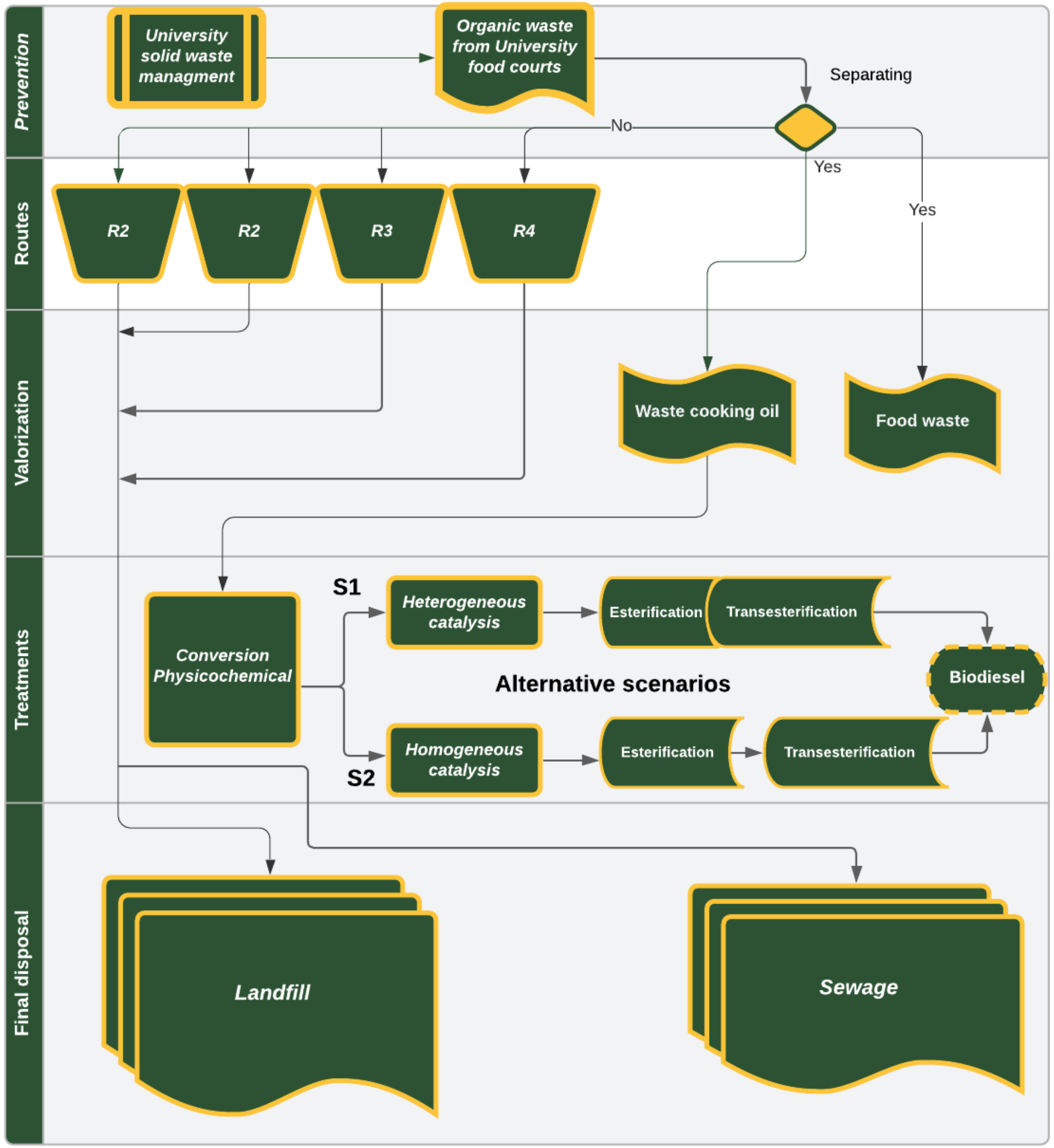

Figure 4. Integral Management System of Organic Waste from University food courts, with alternative scenarios. Source: own study.

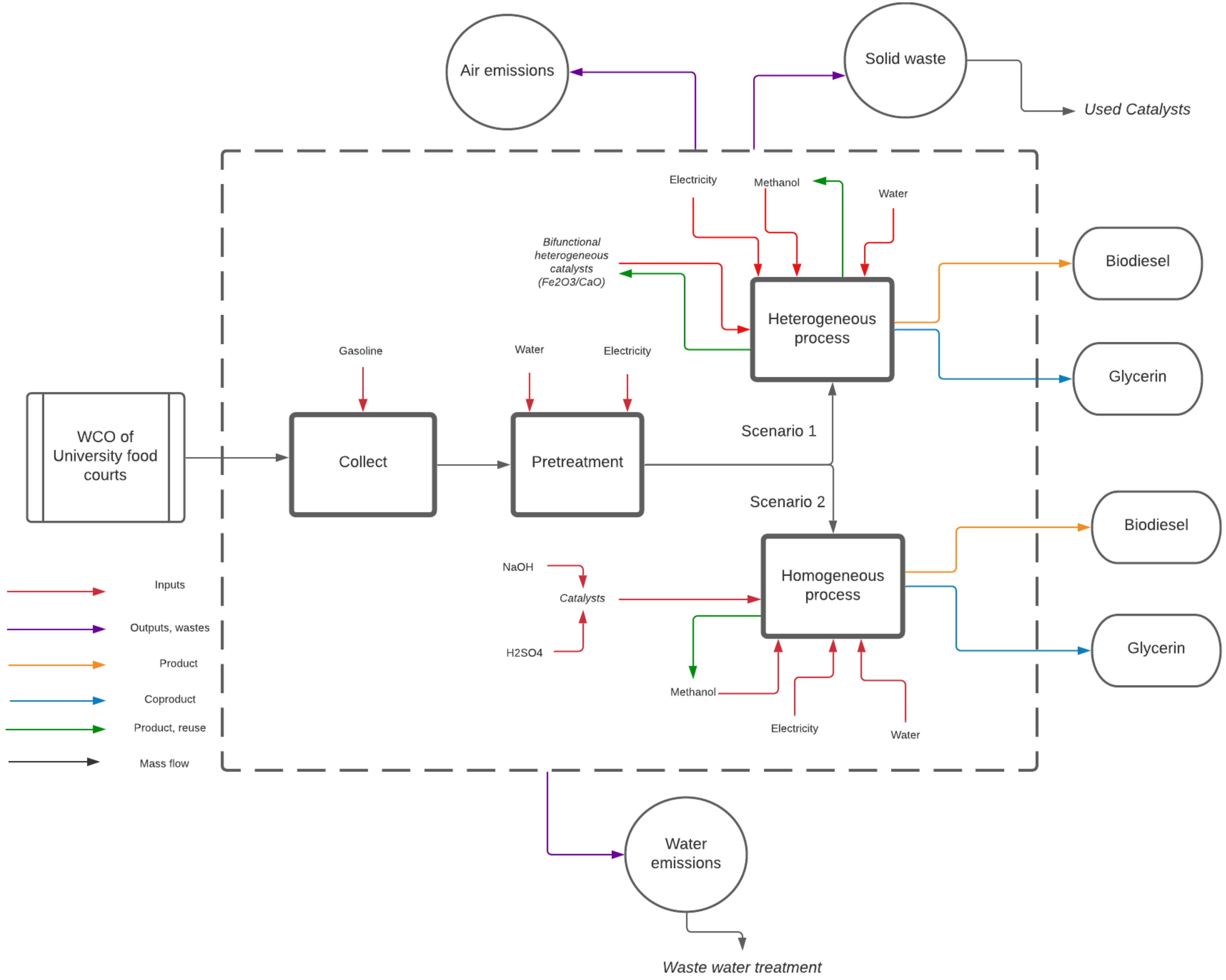

Figure 5. System boundary for the management of waste cooking oil in the University food courts of the UAEMéx, through a heterogeneous process (scenario 1) or homogeneous process (scenario 2). Source: own study.

RESULTS

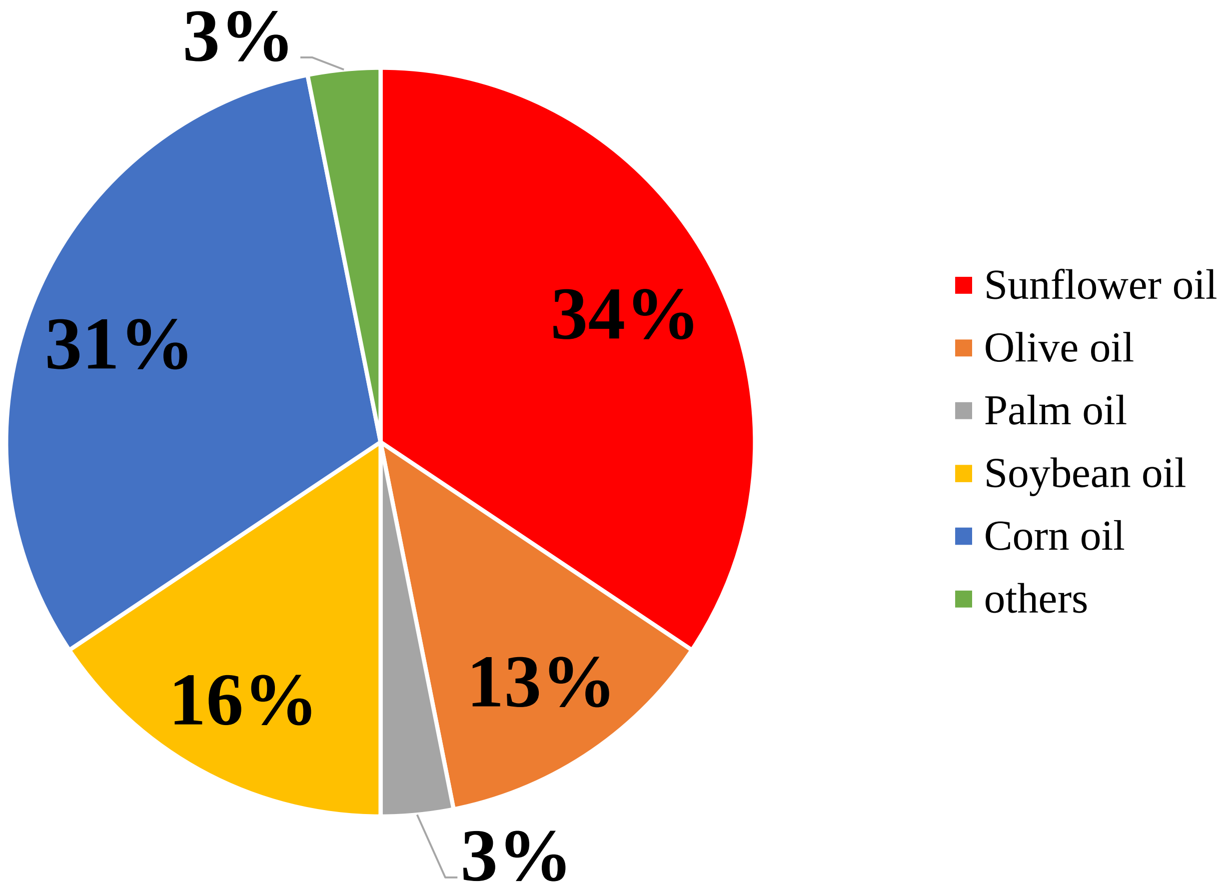

Figure 6. Percentage of consumption by type of oil in the University food courts of the UAEMéx.
Source: own study.

Table 1. Inventory analysis according to the functional unit (1 L) in biodiesel production with a heterogeneous process.

Stage	Input				Output			
	Flow	Parameter	Amount	Unit	Flow	Parameter	Amount	Unit
Collect	Energy	Gasoline	0.128	tkm	Middle flow	WCO	1.100	L
	Raw material	WCO	1.100	L				
Pre treatment	Energy	Electricity consumption	0.722	kWh	Middle flow	WCO	1.100	L
	Raw material	Potable water	0.745	L	Residue	Waste water	0.745	L
		WCO	1.100	L				
Reaction	Energy	Electricity consumption	11.20	kWh	Product	Biodiesel	1.000	L
	Raw material	WCO	1.100	L				
		Pig iron (Fe_2O_3)	0.005	kg	Co product	Glycerine	0.100	L
		Lime hydraliuc (CaO)	0.079	kg	Residue	Waste water	0.819	L
					Reciclable product	Methanol	0.209	L
		Water, deionised	0.819	L	Reusable product	Bifuntional catalysts (Fe_2O_3/CaO)	0.084	kg
		Methanol	0.232	L				

Table 2. Environmental impacts in the collection, pretreatment and heterogeneous reaction stages, using the CML-IA baseline method V3.06/EU25 for 1 L biodiesel.

Impact category	Unit	Collect	Pretreatment	Heterogeneous reaction	TOTAL
ADP (elements)	kg Sb_{eq}	5.34E-06	1.72E-06	2.94E-05	3.64E-05
ADP (fossil fuels)	MJ	3.39	5.98	105.56	114.93
GWP	kg $CO_{2\ eq}$	0.24	0.46	8.91	9.61
ODP	kg CFC-11 $_{eq}$	3.87E-08	3.46E-08	6.10E-07	6.83E-07
HT	kg 1,4-DB $_{eq}$	0.06	6.99E-02	1.23	1.36
FWAE	kg 1,4-DB $_{eq}$	2.12E-03	8.18E-03	0.14	0.15
MAE	kg 1,4-DB $_{eq}$	44.50	136.01	2387.89	2568.40
TE	kg 1,4-DB $_{eq}$	4.11E-04	2.47E-03	0.04	0.05
PO	kg $C_2H_{4\ eq}$	9.02E-05	7.91E-05	1.55E-03	1.72E-03
A	kg $SO_{2\ eq}$	1.07E-03	1.96E-03	0.03	3.76E-02
E	kg $PO_{4\ eq}$	1.67E-04	1.96E-04	3.45E-03	3.81E-03

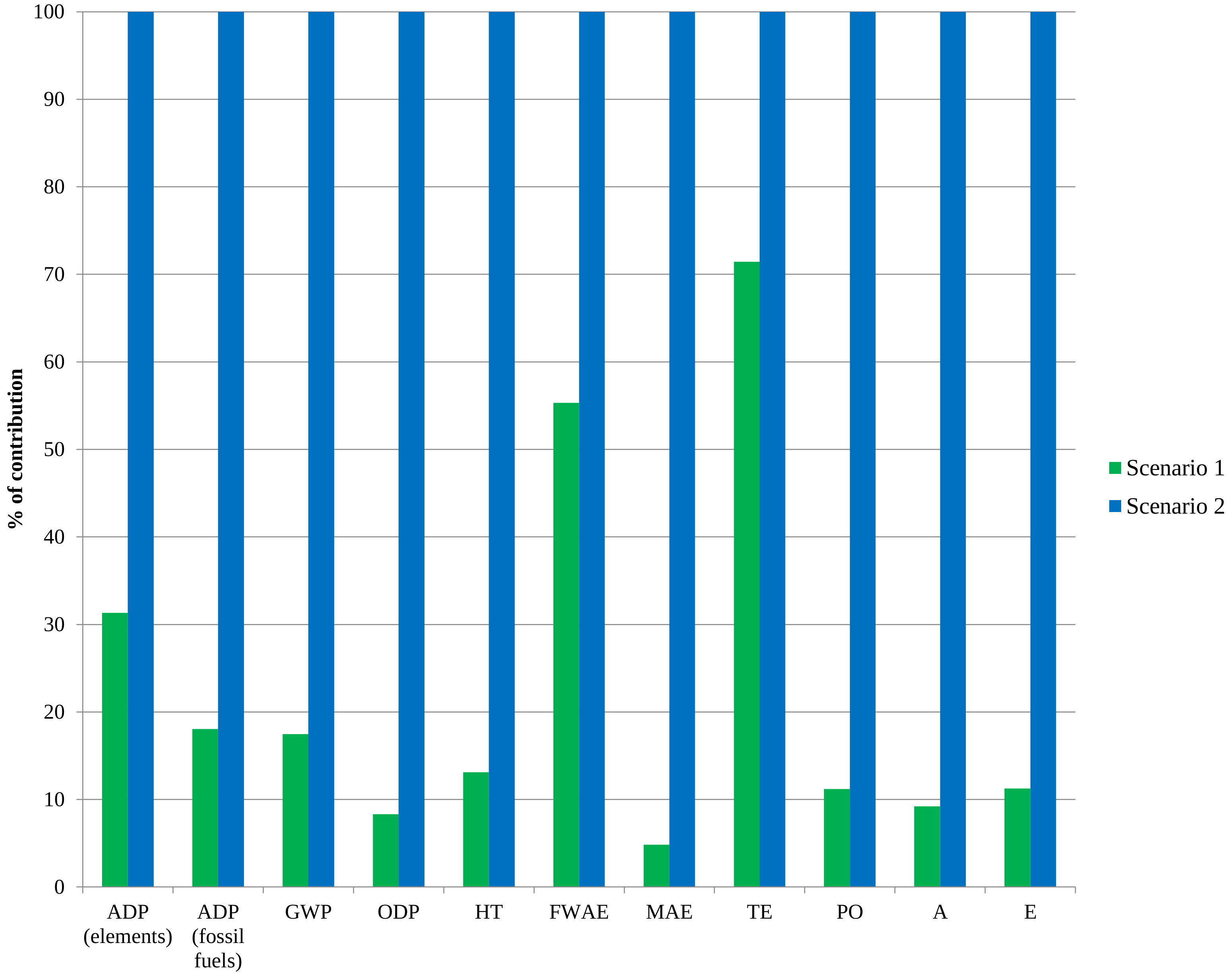

Figure 7. Percentage contribution of the midpoint impact categories for the heterogeneous process (scenario 1) and the homogeneous process (scenario 2) using the CML-IA baseline method V3.06/EU25. Source: own study.

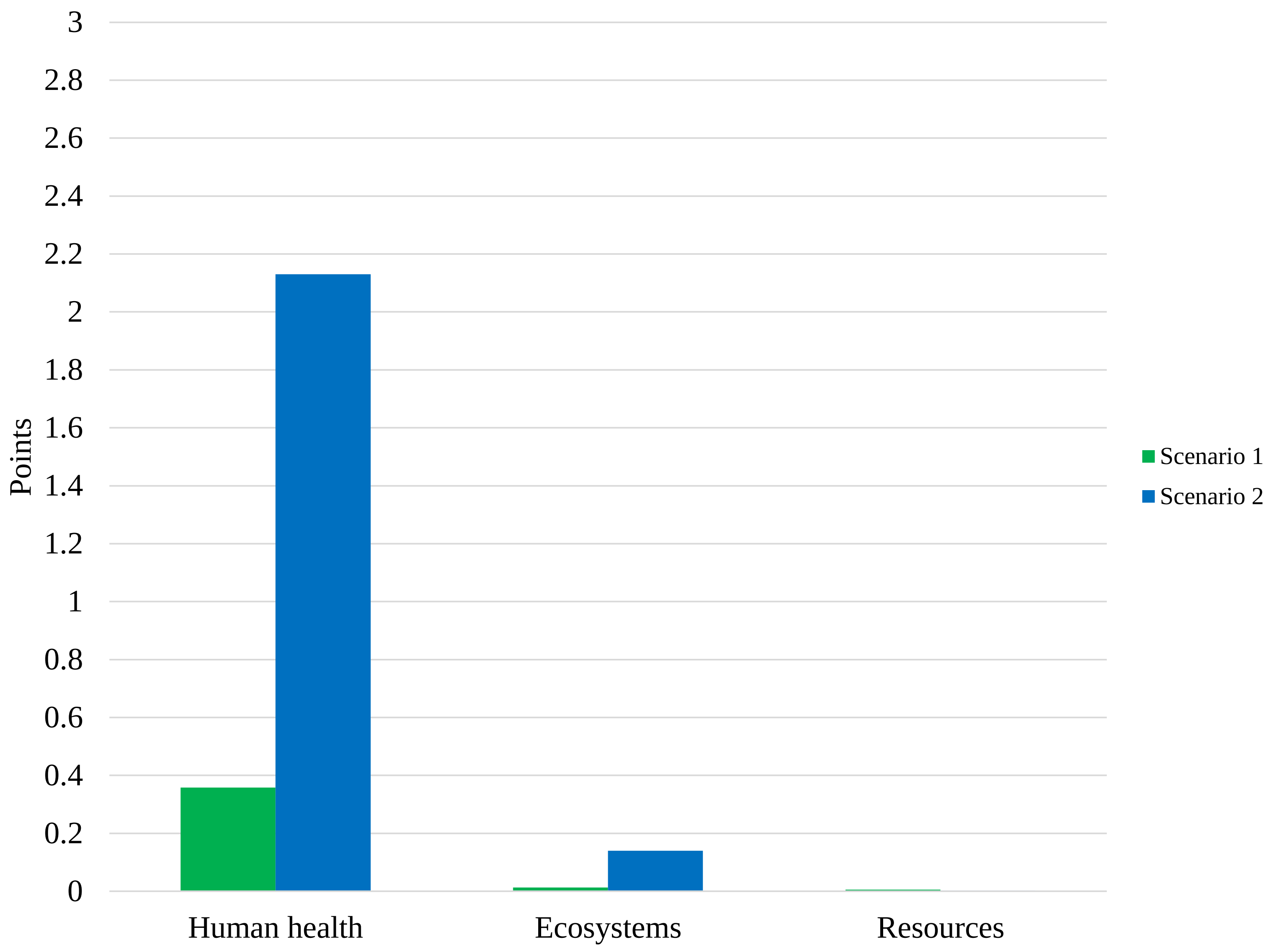

Figure 8. Endpoint impacts for alternative scenarios using ReCiPe 2016: heterogeneous process (scenario 1) and homogeneous process (scenario 2).
Source: own study.

CONCLUSIONS

- ✓ The type of oil consumed in **the University food courts** of the UAEMéx is mainly **sunflower** and is converted into residual oil when subjected to cooking under elevated temperatures; this was the raw material to produce biodiesel under a **heterogeneous process**. In this regard**,** this was the raw material to produce biodiesel under a heterogeneous process. The **initial environmental load is zero** because it is a residue, it should be noted that the impact was not quantified from the stage of cultivation or extraction of the oil, which makes **the process studied sustainable.**

- ✓ Within the system boundary, it was established that the collection of waste cooking oil had the least contribution in the impacts studied, then the pretreatment stage. In the reaction stage for the heterogeneous process, the energy consumption due to **electrical and thermal** demands resulted in the greatest environmental impacts in the following categories: **abiotic depletion potential (fossil fuels) (105.56MJ), 100-year global warming (8.91 kg $CO_{2\ eq}$) and marine water ecotoxicity (2387.89 kg 1.4-DB eq).**

- ✓ In the heterogeneous reaction step, the **bifunctional catalyst (Fe_2O_3/CaO) replaces H_2SO_4 and NaOH,** performing in a single step the esterification and transesterification, **consuming less electricity at the activation of the catalyst** that is at least **three times reused** without calcining again; **methanol is recovered** for recycling during the reaction; as for glycerin, it is purified, which gives the process a **circular economy** approach that ensures the **sustainability of biodiesel production**.

CONCLUSIONS

- ✓ With respect to the end-point environmental impacts, the homogeneous process has greater to **human health damage with 1.77 points** more than the heterogeneous process. This process is mainly affected by emissions from waste disposal and electricity consumption.

- ✓ The **carbon footprint for the heterogeneous process is lower by 82.52%** compared to the homogeneous process. This contributes to the mitigation of greenhouse gases and compounds, as it replaces fossil fuels, maintains carbon sinks and prevents deforestation.

- ✓ The identified areas of opportunity were the reduction of electricity consumption **using renewable energies such as solar photovoltaics**; the environmental sustainability of the process from the energy generated by the production of **biodiesel and the energy consumed; the economic and environmental valorization of glycerin.**

- ✓ In the University food courts, it is suggested to conduct environmental **education campaigns** in the collection sites to efficiently perform this stage with **a pretreatment (purification of impurities**), as well as standardizing a process that allows sampling to verify the initial quality of waste cooking oil and a collection route that guarantees the **recycling of waste cooking oil.** Finally, it was also concluded that a **program of management of waste cooking oil in the UAEMéx** should be implemented in order to **reduce the carbon footprint of the University food courts.**

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