LIFE CIRC-ELV

BOOSTING CIRCULAR ECONOMY OF PLASTICS FROM END-OF-LIFE VEHICLES THROUGH RECYCLING INTO HIGH ADDED-VALUE APPLICATIONS

Deliverable D_C1.1. Life Cycle Assessment (LCA) report

Deliverable Name: Life Cycle Assessment (LCA) report

Version Number: 1

Lead Beneficiary: AIMPLAS

Grant Agreement nº: **LIFE17 ENV/ES/000438**

Start Date/Duration: September 2018 / 44 Months

Due date: 30 April 2022

Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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LIST OF ABBREVIATIONS

ELV	End-of-Life Vehicle
ATF	Authorised Treatment Facility
PP	Polypropylene polymer
HDPE	High Density Polyethylene polymer
ND	Non-destructive

1. Summary and Objectives

LIFE CIRC-ELV project aims to develop a new management model for End-of-Life Vehicles (ELVs). This new model is focussed on the plastics that are present in ELVs for increasing their recovery ratio and their quality in an early stage, so they are suitable for recycling. Therefore, a new business model would arise for recycled plastics coming from ELVs, which is intended to be techno-economic and environmentally sustainable.

This deliverable is aimed for assessing the environmental impacts of the new LIFE CIRC-ELV method for extracting plastics at the Authorized Treatment Facility (ATF) level when compared to the current scenario where these large plastic parts remain in the depolluted End-of-Life Vehicle (ELV) hulk.

2. Methodology

The environmental assessment performed within this deliverable followed the international standards of application for Life Cycle Assessment: ISO 14040 (Environmental management – Life cycle Assessment – principles and framework) and ISO 14044 (Environmental management – Life cycle assessment – Requirements and guidelines).

Besides, regulated by ISO 14025 (Environmental Labels and Declarations – Type III Environmental Declaration – Principles and Procedures), Environmental Products Declaration (EPDs) present relevant and verified environmental information about products and services from a life cycle analysis perspective. These documents are based on Product Category Rules (PCRs), which are documents that provide rules, requirements, and guidelines for developing an EPD for a specific product category.

3. Development

A Life Cycle Assessment (LCA) is an environmental assessment methodology that allows environmental aspects and potential impacts (by identifying and quantifying energy, materials used and wastes released to the environment) of a product or service to be analysed and quantified over time of its entire life cycle, that is, from the acquisition of raw materials, through production, transportation and distribution, use, re-use, final treatment, to its disposal; and to identify and evaluate opportunities to affect environmental improvements.

According to ISO standards, LCA consists of four phases: Goal and scope definition, Life Cycle Inventory analysis, impacts assessment, and results interpretation. The development of these phases is detailed separately below.

3.1. Goal and scope

The present study aimed to calculate the environmental impacts of two different scenarios for ELV and compare them each to other. Each scenario is divided into two parts: *ELV treatment* and *Plastic Production*. ELV treatment encompasses all the processes needed to treat an ELV, and Plastic Production encompasses the processes needed to make a new product by using HDPE and PP. This is ascribed to the fact that the system boundaries shall include plastic production beyond ELV management to cover the benefits of extracting plastics at the ATF site for they to be recycled into new products.

Impact assessment results will be presented as per 1.000 ELVs, for they to be comparable. This functional unit was selected because is one of the objectives agreed within the LIFE CIRC-ELV project.

The first analysed scenario is the 'Reference scenario' which is the current scenario that ATFs are using for depolluting ELVs (before LIFE CIRC-ELV implementation).

Presently, the ELVs treatment method consists of different processes which are represented at Figure 1. This scenario starts by handling ELVs, taking off all the profitable pieces that can be reused or sold (like bumpers, lights, doors and so on), and depolluting the polluted parts. Once this is done, the car hulk is pressed at the pressing machine to make it smaller and easier to transport. Then, it is transported to a shredding facility where the pressed hulk is shredded. Finally, the pieces that cannot be recycled (beyond metals) finish their life at a landfill.

Within the reused parts, some bumpers are included, making some environmental impact credits (these credits are not calculated in this study).

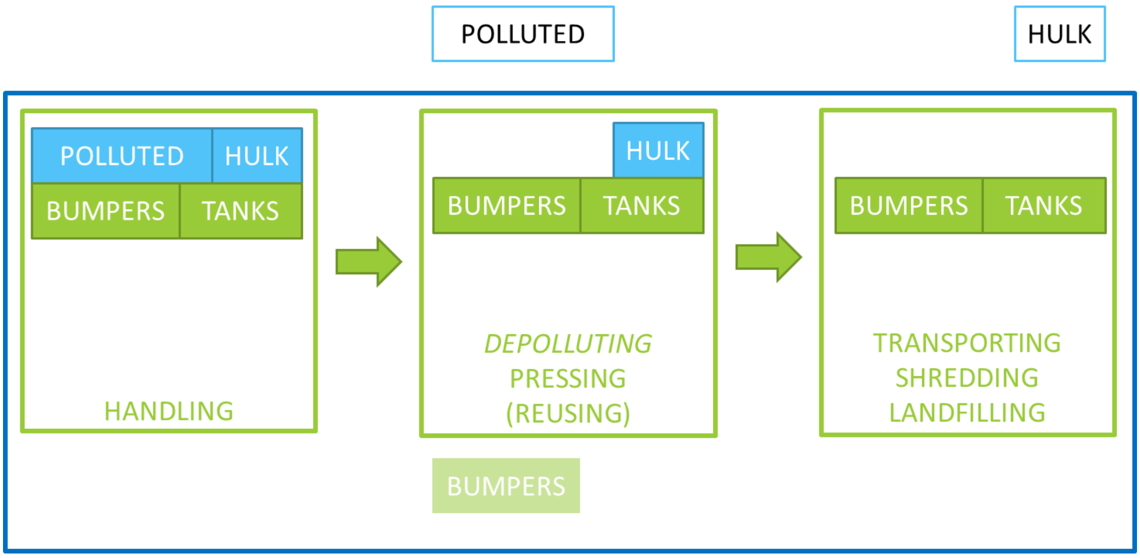

Figure 1. ELV treatment processes for Reference scenario.

In Figure 2, the Plastic Production processes are represented for the Reference scenario. In this scenario, only virgin raw materials are used to make a new product.

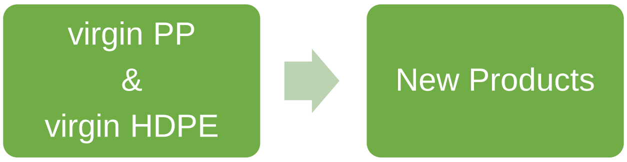

Figure 2. Plastic Production processes for Reference scenario.

On the other hand, the second scenario is the 'LIFE CIRC-ELV scenario'.

This new scenario has processes representing the management of an ELV (Figure 3) according to the LIFE CIRC-ELV model. It starts by handling ELVs, like the current scenario, but instead of pressing the ELV hulk after it is depolluted, PP bumpers and HDPE fuel tanks plastic parts are collected before they enter the shredding facility. These plastic parts are pressed to make easier their transport to the pre-treating. The pre-treating is divided in shredding, washing, and drying. This will be the end of the ELV treatment for the LIFE CIRC-ELV scenario.

Some of the bumpers are reused in this scenario, making some environmental impact credits (these credits are not calculated in this study).

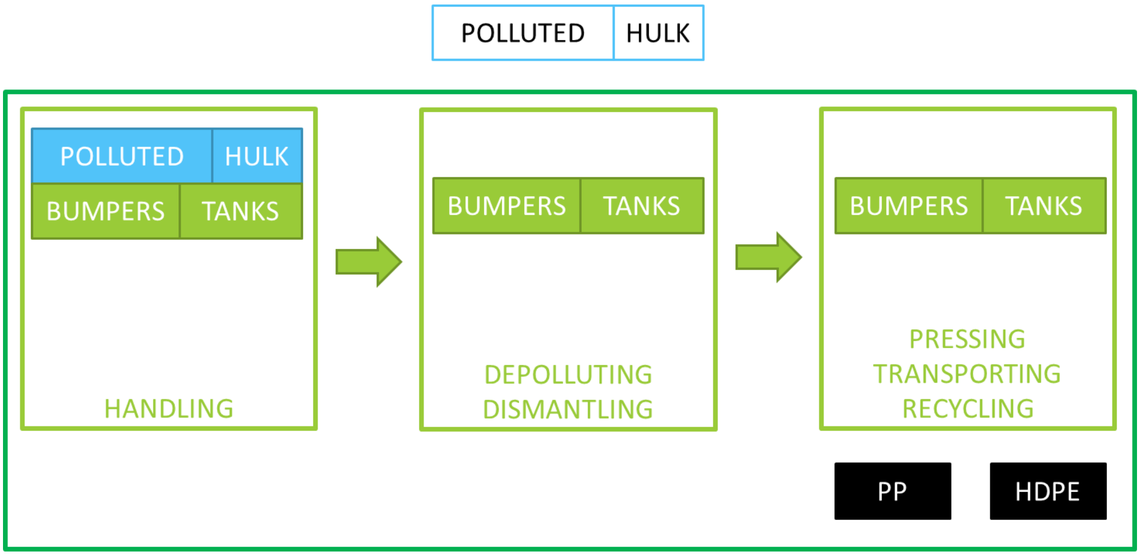

Figure 3. ELV treatment processes for the LIFE CIRC-ELV scenario.

After the pre-treating (Figure 4), the plastics go to the compounding process where they can be recycled to make new materials or products.

For the new products to be made with recycled plastics, it is not technically feasible to use 100% recycled plastics: recyclates from ELVs need to be mixed with virgin raw materials at the compounding process to make a new recycled product.

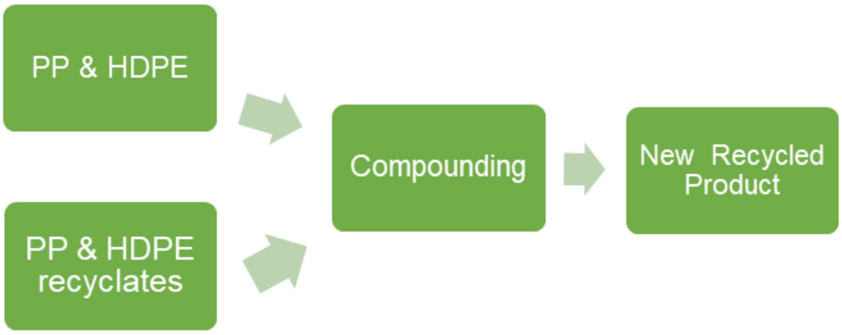

Figure 4. Plastic Production processes for the LIFE CIRC-ELV scenario.

3.2. Life Cycle Inventory

Primary data was collected from DESGUACE CORTÉS yearly reports. Each constituent of the category for the inventory was weighted as the values of the unit (kg, kWh…) needed. The inventory for the different scenarios is presented below.

Table 1. Cortés primary data.

	Value	Units
ELVs in	11.749	units/year
ELVs in	11.848,8	tonnes/year
ELVs out	9.138,3	tonnes/year
Hazardous waste	247,4	tonnes/year
Non-hazardous waste	1.773,6	tonnes/year
Recovered materials	687,9	tonnes/year

Table 2. Inventory of bumpers based on CORTÉS data.

	Value	Units	Observations
Potential bumpers	23.498	units/year	Not all *ELVs in* have 2 bumpers. Total bumpers are 75% of ELVs in.

	Value	Units	Observations
Bumpers for reusing	3.008	Units/year	These are reused back as spare parts for used cars. The 17% of the total bumpers are reused.
Electrical energy (screw drivers)	1,8	kWh/year	This energy refers to the energy needed for extracting bumpers for reusing.
Bumpers weight	4,30	kg/bumper	Mean value

Table 3. Inventory of fuel tanks based on CORTÉS data.

	Value	Units	Observations
Potential fuel tanks	11.749	units/year	Not all *fuel tanks* are made of HDPE but metal. Total fuel tanks are 95% of ELVs in.
Fuel tanks weight	6	kg/fuel tank	Mean value

Table 4. Distance from Desguace CORTÉS to the shredder and to a recycler in Buñol (Spain).

Processes	Value	Units
Distance to shredder	47,5	km
Distance to recycler	29,85	km

Table 5. Inventory of the energy and fuel used during all processes.

	Value	Units	Observations
Pressing (hulk)	5.874,5	L/year	Fuel/year
Forklift	440,6	L/year	Fuel/year

	Value	Units	Observations
Shredder (ELVs)	31,76	kWh/tonne	From paper[1]
Press (bumpers)	0,00375	kWh/kg plastic	Power: 7,5 kWh; Time: 0,25 h; Bale:500 kg
Shredding (plastic)	0,0322	kWh/kg plastic	From paper[2]
Washing (plastic)	0,0005	kWh/kg plastic	From paper[2]
Compounding	0,6	kWh/kg plastic out	
Drying (plastic)	0,058	kWh/kg plastic	
Diesel energy	40	MJ/L	

Table 6. Efficiencies for shredding, washing, and compounding.

Processes	Value	Units
Shredding (plastics)	90	%
Washing (plastics)	95	%
Compounding	85	%

[1] El Halabi, E., Third, M., and Doolan, M., (2015): *Machine-based Dismantling of End of Life Vehicles: A Life Cycle Perspective*. Procedia CIRP. 29. 651-655. 10.1016/j.procir.2015.02.078.

[2] Liljenström, C., and Finnveden, G., (2015): *Data for separate collection and recycling of dry recyclable materials.* KTH royal Institute of Technology, TRITA-INFRA-FMS, 2015:04.

Table 7. Inventory of the materials needed for the washing process.

Processes	Value	Units
NaOH	0,0103	kg NaOH/kg plastic in
Detergent	0,00076	kg/kg plastic in
Water	0,0023	m^3 water/kg plastic in

Table 8. Inventory of the different processes for 'ELV treatment' at Reference scenario.

Processes	Value/1.000 ELV	Units	Observations
Handling ELVs	1,50E+03	MJ	Diesel has been considered because the machine used works with diesel.
Pressing (hulk)	2,00E+04	MJ	Diesel has been considered because the machine used works with diesel.
Transport	5,25E+02	tkm	It has been assumed that the transport is carry on by a lorry 3,5-7,5 metric ton, euro 6.
Shredding	3,51E+02	kWh	The machine used works with electricity. As it is a small-medium industry in Spain, it has been considered that the electricity is medium voltage for Spain.
Landfilling	1,10E+04	kg	It has been assumed a landfill for inert waste in Europe.
Reusing	1,53E-01	kWh	The machine used works with electricity. As it is a small-medium industry in Spain, it has been considered that the electricity is medium voltage for Spain.

Table 9. Inventory of the different processes for 'New Product' at Reference scenario.

Processes	Value/1.000 ELV	Units	Observations
PP virgin	1,29E+04	kg	The material considered is virgin polypropylene.
HDPE virgin	1,66E+04	kg	The material considered is virgin polyethylene, high density

Table 10. Inventory of the different processes for 'ELV treatment' at CIRC-ELV scenario.

Processes		Value/1.000 ELV	Units	Observations
Handling ELVs		1,50E+03	MJ	Diesel has been considered because the machine used works with diesel.
Dismantling		4,47E+02	kWh	The machine used works with electricity. As it is a small-medium industry in Spain, it has been considered that the electricity is medium voltage for Spain.
Pressing (plastics)		4,14E+01	kWh	The machine used works with electricity. As it is a small-medium industry in Spain, it has been considered that the electricity is medium voltage for Spain.
Transport		3,30E+02	tkm	It has been assumed that the transport is carry on by a lorry 3,5-7,5 metric ton, euro 6.
Pre-treating	Shredding	3,56E+02	kWh	The machine used works with electricity. As it is a small-medium industry in Spain, it is considered that the electricity is medium voltage for Spain.
	Washing	4,97E+00	kWh	The machine used works with electricity. As it is a small-medium industry in Spain, it has been considered that the electricity is medium voltage for Spain.
	Water	2,29E-02	kg	It has been assumed that the water used is water decarbonised for Spain.
	NaOH	1,02E+02	kg	It has been considered sodium hydroxide, without water, in 50% solution state.
	Detergent	7,55E+00	kg	It has been considered soap.
	Drying	5,48E+02	kWh	The machine used works with electricity. As it is a small-medium industry in Spain, it has been considered that the electricity is medium voltage for Spain.
Reusing		1,53E-01	kWh	The machine used works with electricity. As it is a small-medium industry in Spain, it has been considered that the electricity is medium voltage for Spain.

Table 11. Inventory of the different processes for 'New Product' at CIRC-ELV scenario.

Processes		Value/1.000 ELV	Units	Observations
Virgin raw materials	PP virgin	1,07E+04	kg	The material considered is virgin polypropylene.
	HDPE virgin	1,46E+04	kg	The material considered is virgin polyethylene, high density

Processes		Value/1.000 ELV	Units	Observations
Recyclates materials	PP recyclates	4,57E+03	kg	The material considered is recycled polypropylene.
	HDPE recyclates	4,87E+03	kg	The material considered is recycled polyethylene, high density
Compounding		2,08E+04	kWh	The machine used works with electricity. As it is a small-medium industry in Spain, it has been considered that the electricity is medium voltage for Spain.
Landfilling		7,11E+03	kg	It has been considered a landfill for inert waste in Europe.

3.3. Life Cycle Impacts Assessment & Interpretation of results

Datasets for impacts assessment were taken from the ecoinvent database (available within the SimaPro software for the calculation). Besides, literature data were used to model the inventories of the materials, processes, energy, and transport operations included in the LCI.

The impact assessment was conducted in this study by applying the impact assessment method EPD (2018) V1.03, which is incorporated within the LCA software SimaPro. This method is used for the creation of Environmental Product Declarations (EPDs), as publishes on the website of the Swedish Environmental Management Council (SEMC).

The impact category used is presented at Table 12 with a summary of the abbreviation used for each impact.

Table 12. Summary of the abbreviation used for the impact categories.

Abbreviation	Impact category	Unit
AP	Acidification potential	kg SO_2 eq
EP	Eutrophication potential	kg PO_4^{3-} eq
GWP	Global warming potential	kg CO_2 eq
POP	Photochemical oxidant potential	kg NMVOC
ADP	Abiotic depletion potential – elements	kg Sb eq
ADPF	Abiotic depletion potential – fossil fuels	MJ
WS	Water Scarcity Footprint	m^3 eq
ODP	Ozone layer depletion	kg CFC11 eq

As described in the Goal and Scope, two different assessments were performed. Accordingly, they will be discussed below in separated sections. Besides, the final phase of the LCA, related to the interpretation of results, will be also conducted together with the environmental assessment for enhance clarity.

Absolute values for each impact category are presented per 1.000 ELVs, as described in the Goal and Scope section.

3.3.1. Reference scenario

According to method selected for assessing the environmental impacts, 8 different impact categories are obtained. Different impact categories have different units and values (Table 12), so in Figure 5 it is presented the percentual contribution of each process to each impact category. The contribution processes to these impact categories are presented for the ELV treatment at Reference scenario based on Cortés data. This scenario was modelled by the materials described in Table 8 for 1.000 ELV.

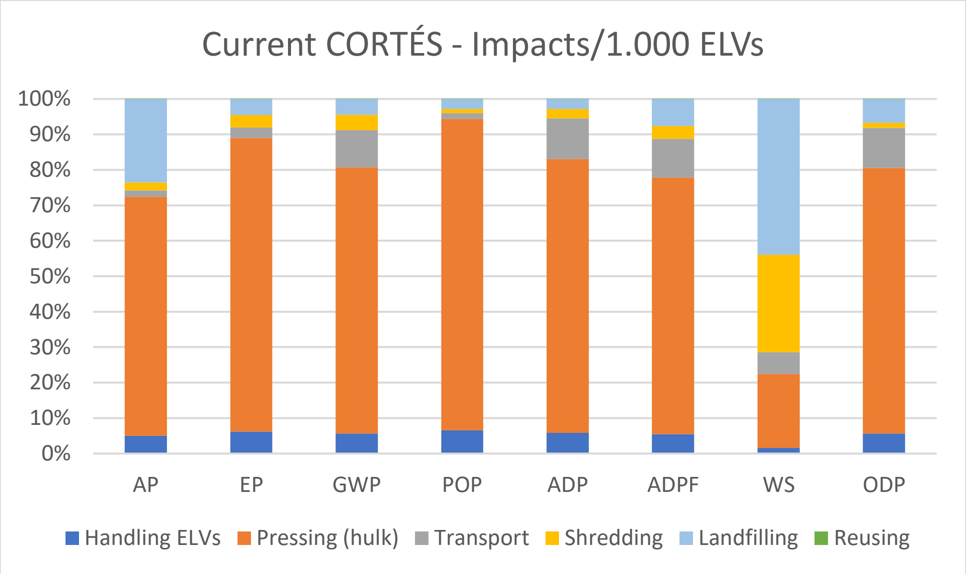

Figure 5. Process contribution to the total environmental impacts for Treatment ELV at the Reference scenario per 1.000 ELVs (based on Cortés data).

When analysing this Reference scenario focussing on the processes contributing the most to the environmental impacts (Figure 5), the hulk pressing contributes in more than 70% to the overall impact categories. This is due to the amount of energy used which comes from a fossil fuel as is the diesel. Nevertheless, this process is not the most contributing at WS category impact. In this one, the most contributing are landfilling and shredding. Landfilling also contributes to AP impact with more than 20%, but it has a low impact to GWP category.

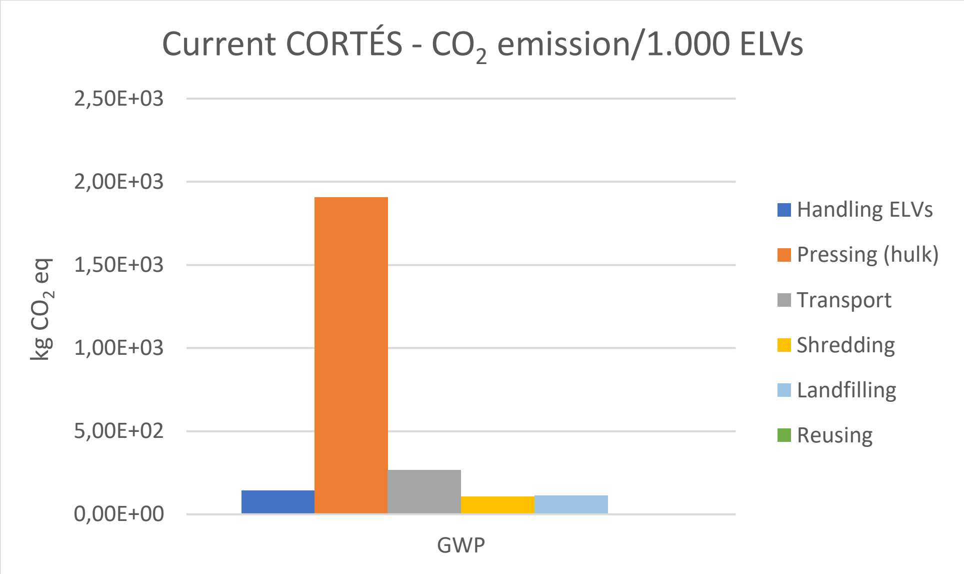

Figure 6. Process contribution to the CO_2 emission for Treatment ELV at the Reference scenario per 1.000 ELVs (based on Cortés data).

On the other hand, Figure 6 shows CO_2 emissions (kg CO_2 eq/1.000 ELVs) for each process, being the hulk pressing the one with highest impact with 1.907 kg CO_2 eq/1.000 ELVs. As previously detailed, this is due to diesel fuel used in this process. The next one with a high impact is the transport, which also uses diesel (266 kg CO_2 eq/1.000 ELVs). Approximately, a total of 2.500 kg CO_2 eq are emitted every 1.000 ELVs.

In Figure 7 it is presented the percentual contribution of each process to each impact category for the New Product at Reference scenario based on Cortés data. This scenario was modelled by the materials described in Table 9 for 1.000 ELV.

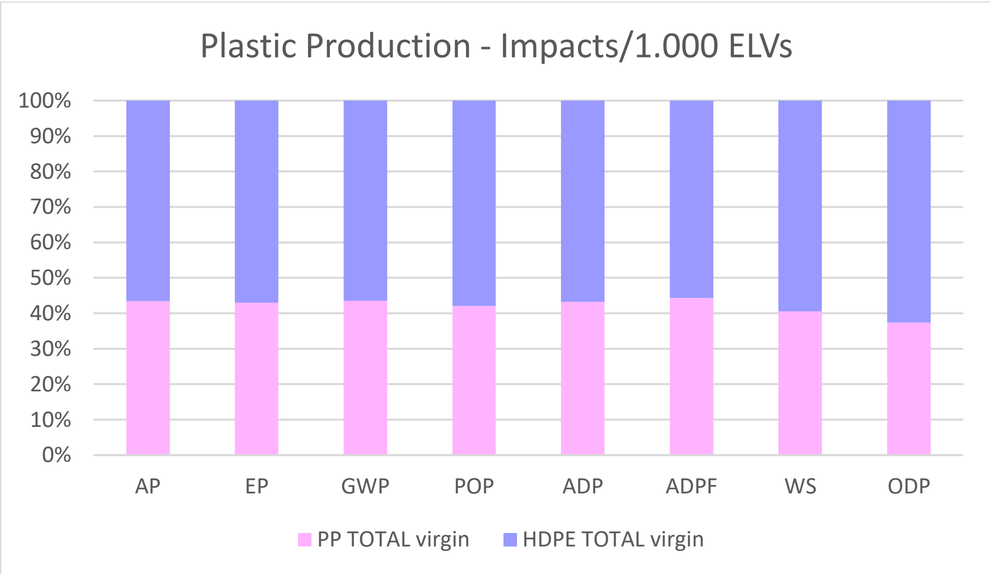

Figure 7. Process contribution to the total environmental impacts for Plastic production at the Reference scenario per 1.000 ELVs (based on Cortés data).

Environmental impacts shown between virgin PP and virgin HDPE are quite similar. Nevertheless, Figure 8 shows that HDPE has more CO_2 emissions than PP.

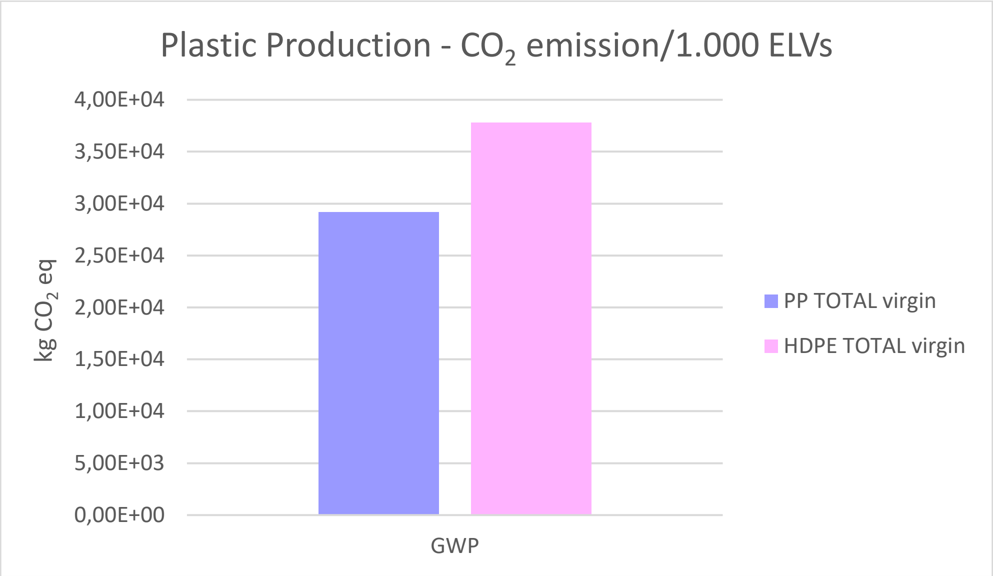

Figure 8. Process contribution to the CO_2 emission for Plastic Production at the Reference scenario per 1.000 ELVs (based on Cortés data).

Approximately, a total of 67.000 kg CO_2 eq are emitted every 1.000 ELVs in this current scenario for Plastic Production.

3.3.2. LIFE CIRC-ELV scenario

The method selected for assessing the environmental impacts is the same as described before. There are 8 different impact categories with different units and values (Table 12). The contribution processes to these impact categories are presented for the ELV treatment at the LIFE CIRC-ELV scenario based on Cortés data. This scenario was modelled by the materials described in Table 10 for 1.000 ELV.

Accordingly, the environmental assessment is analysed below.

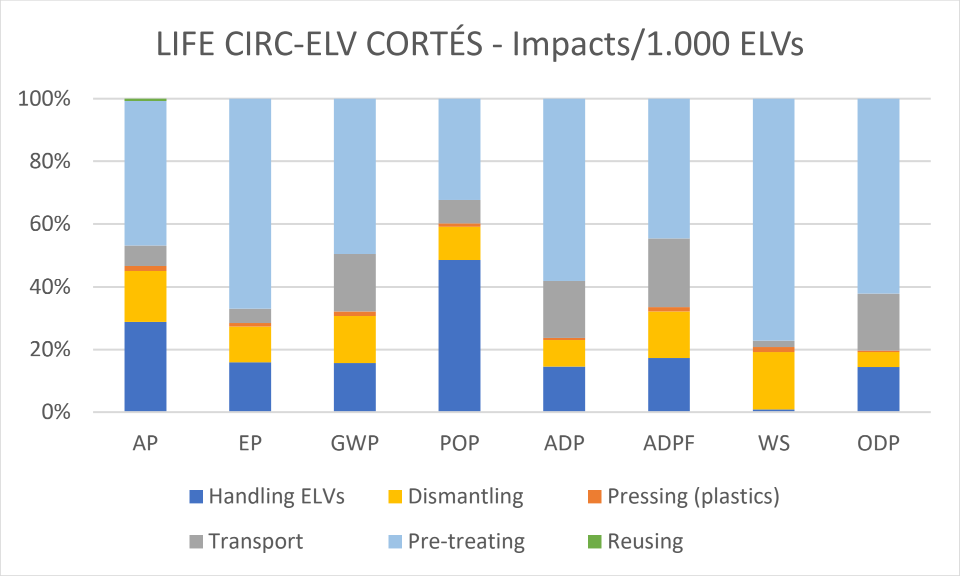

Figure 9 Process contribution to the total environmental impacts for Treatment ELV at the CIRC-ELV scenario per 1.000 ELVs (based on CORTÉS data).

In Figure 9 it is presented the percentual contribution of each process to each impact category. In this scenario, the process that contributes the most to environmental impacts is the pre-treating with approximately a 50% to the overall impact categories. Pre-treating consists of other processes (Table 10), one of them with a notable contribution (drying). This is due to the electricity needed for this process, which has a high environmental impact because it comes from a non-renewable source.

Handling is the other process with a big contribution to some impact categories like POP and AP category with almost a 20%. Dismantling and transport also contribute with a considerable impact to all the categories. As in the pre-treatment, the environmental impact of dismantling is due to electricity's impacts because it is used a non-renewable energy.

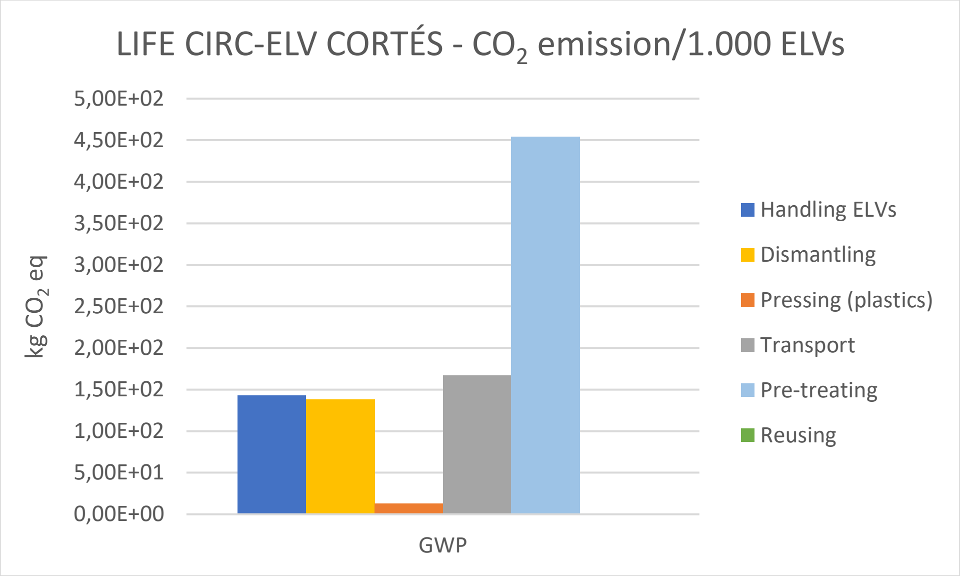

Figure 10. Process contribution to the CO_2 emission for Treatment ELV at the CIRC-ELV scenario per 1.000 ELVs (based on Cortés data).

Figure 10 shows CO_2 emissions (kg CO_2 eq/1.000 ELVs) for each process, being the pre-treatment the one with highest impact with 454 kg CO_2 eq/1.000 ELVs followed by the transport (167 kg CO_2 eq/1.000 ELVs), handling (143 kg CO_2 eq/1.000 ELVs) and dismantling (138 kg CO_2 eq/1.000 ELVs). Approximately, a total of 925 kg CO_2 eq are emitted every 1.000 ELVs in this new scenario for ELV treatment.

Figure 11 presents the percentual contribution of each process to each impact category for the Plastic Production at LIFE CIRC-ELV scenario based on CORTÉS data. This scenario was modelled by the materials described in Table 11 for 1.000 ELV.

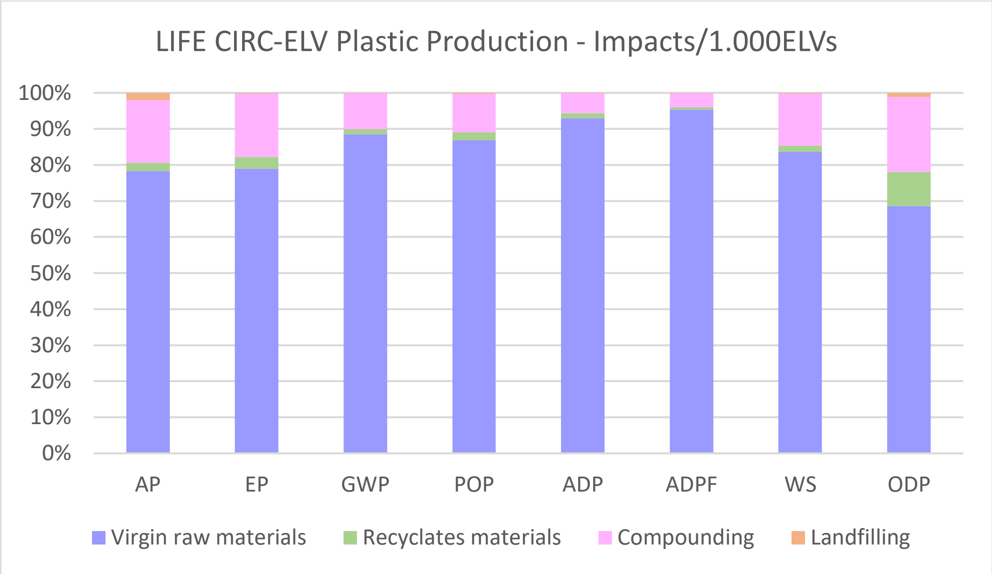

Figure 11. Process contribution to the total environmental impacts for Plastic production at the LIFE CIRC-ELV scenario per 1.000 ELVs (based on CORTÉS data).

As previously detailed, to make a new plastic product from PP and HDPE recyclates, it is needed virgin PP and HDPE in a great percentage. The process that contributes the most to environmental impacts is the virgin raw materials with approximately a 70% to the overall impact categories.

Compounding is the other process with a big contribution to the impact categories with a 10-20%. The environmental impact of compounding is due to electricity's impacts.

Recyclate materials have a minor contribution to the impact categories, being the ODP the most affected by them. This is ascribed to the fact that impacts burdened to the recyclates come from the LIFE CIRC-ELV process where they are collected and sorted. This is fully explained in the following section where both scenarios are compared.

On the other hand, landfilling contribution is despicable in comparison.

In Figure 12, it is shown the CO_2 emissions (kg CO_2 eq/1.000 ELVs) for each process.

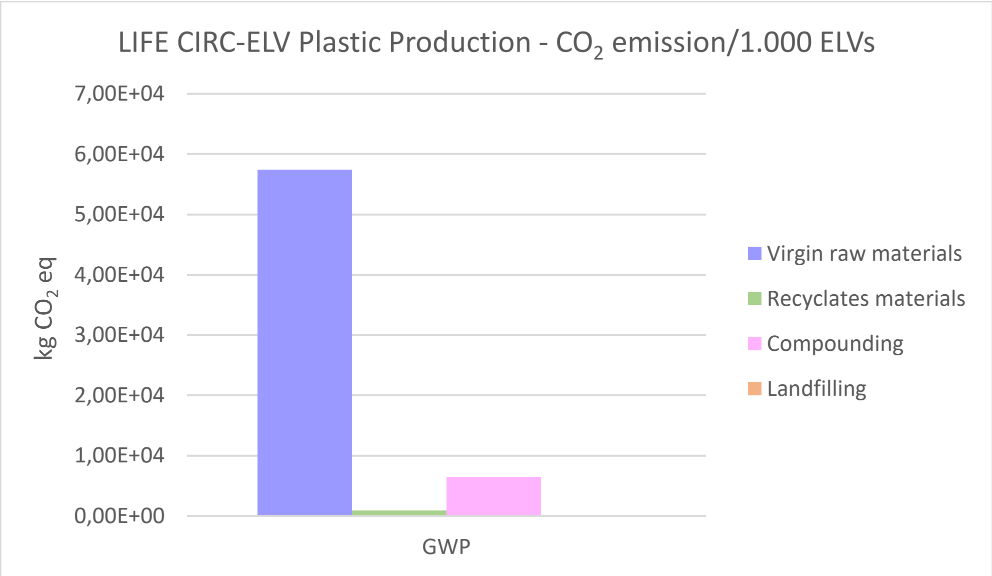

Figure 12. Process contribution to the CO_2 emission for Plastic Production at the LIFE CIRC-ELV scenario per 1.000 ELVs (based on Cortés data).

Virgin raw materials is the one with highest impact with 57.400 kg CO_2 eq/1.000 ELVs while the compounding process is 6.430 kg CO_2 eq/1.000 ELVs. Approximately, a total of 64.800 kg CO_2 eq are emitted every 1.000 ELVs in this new scenario for Plastic Production.

3.3.3. Scenarios assessment

The environmental impacts of the new ELV plastics recycling chain (LIFE CIRC-ELV scenario) will be compared to the impacts of current treatment routes (reference scenario) for ELV plastics to calculate the environmental savings that can be achieved with the project.

In Table 13 and Table 14, total environmental impact values have been summarised for each category for the two scenarios (Reference and LIFE CIRC-ELV).

Table 13. Environmental impact quantification of the different categories for Reference scenario.

Reference scenario

Impact category	*ELVs treatment*	*Plastic Production*	*Total*
AP *(kg SO_2 eq)*	3,55E+01	2,47E+02	2,83E+02
EP *(kg PO_4^{3-} eq)*	5,18E+00	5,73E+01	6,25E+01
GWP *(kg CO_2 eq)*	2,54E+03	6,70E+04	6,96E+04
POP *(kg NMVOC)*	3,70E+01	2,38E+02	2,75E+02
ADP *(kg Sb eq)*	1,31E-02	3,97E-01	4,10E-01
ADPF *(MJ)*	3,51E+04	2,12E+06	2,16E+06
WS *(m^3 eq)*	2,72E+02	3,01E+04	3,04E+04
OPD *(kg CFC^{-11} eq)*	4,15E-04	1,35E-03	1,76E-03

Table 14. Environmental impact quantification of the different categories for LIFE CIRC-ELV scenario.

LIFE CIRC-ELV scenario

Impact category	*ELVs treatment*	*Plastic Production*	*Total*
AP *(kg SO_2 eq)*	6,17E+00	2,71E+02	2,77E+02
EP *(kg PO_4^{3-} eq)*	2,03E+00	6,22E+01	6,43E+01
GWP *(kg CO_2 eq)*	9,15E+02	6,48E+04	6,58E+04
POP *(kg NMVOC)*	5,02E+00	2,35E+02	2,40E+02

LIFE CIRC-ELV scenario

Impact category	*ELVs treatment*	*Plastic Production*	*Total*
ADP *(kg Sb eq)*	5,21E-03	3,66E-01	3,71E-01
ADPF *(MJ)*	1,10E+04	1,91E+06	1,92E+06
WS *(m^3 eq)*	5,21E+02	3,09E+04	3,14E+04
OPD *(kg CFC^{-11} eq)*	1,61E-04	1,69E-03	1,85E-03

ELVs treatment

The main impacts for the current scenario (Reference scenario) are from pressing the depolluted hulk, handling (which has a low impact contribution to all the categories), transport (which contributes to GWP, ADP, ADF and OPD) and landfilling (mainly present at AP and WS categories).

On the other hand, at LIFE CIRC-ELV scenario, these impacts have been displaced due to processes are not the same. For example, pressing is not as relevant in this scenario; pre-treatment is more relevant. This is ascribed to the fact that the new LIFE CIRC-ELV model allowed to split the plastic stream to be managed separately. The main impacts then are from pre-treating and handling, followed by dismantling and transport. All these processes are the most contributing ones in all the categories.

This fact allowed to have plastic recyclates with lower environmental impacts than virgin plastics. The LIFE CIRC-ELV model allowed to have recyclates as outputs of the ELV management model (beyond the polluted issues and the depolluted hulk – see Figure 3). In that assessment, allocation of impacts to these two plastic streams (PP and HDPE recyclates) allowed having a share of the overall LIFE CIRC-ELV impacts. Accordingly, after treating 1.000 ELVs, 915 kg CO_2 are emitted (Table 14) and 62.8 and 67 tonnes of PP and HDPE respectively are obtained as recyclates. Thus, obtaining plastic recyclates from ELVs following the LIFE CIRC-ELV method implies that these recyclates are obtained emitting just 0.1 kg CO_2 per kilogram of recyclate. Just of comparison, virgin PP or HDPE are obtained emitting more than 2 kg CO_2/kg of polymer.

In both scenarios, the reusing impacts are the same because the number of bumpers reused is the same. These impacts are despicable in comparison to the other processes.

Plastic Production

The main impacts for Reference scenario are from the virgin materials used to make the new product. In the same way, the main impacts for the LIFE CIRC-ELV scenario are from the virgin materials used too. This is ascribed to the fact of the different impacts coming from the use of virgin polymers or recyclate plastics described previously.

Although the main impact are the virgin materials, this new scenario has more processes for the Plastic Production. So other impacts for the new scenario are compounding and recycled materials (which has a low impact contribution to all the categories).

On the other hand, fewer products end up in landfills (thus landfilling impact is reduced) considering that more materials are recycled.

Total

For both scenarios, the main impacts are from the Plastic Production in all the environmental impact categories.

In figures below, CO_2 emissions/1.000 ELV (GWP category) and MJ/1.000 ELV (ADF category) are represented for both scenarios.

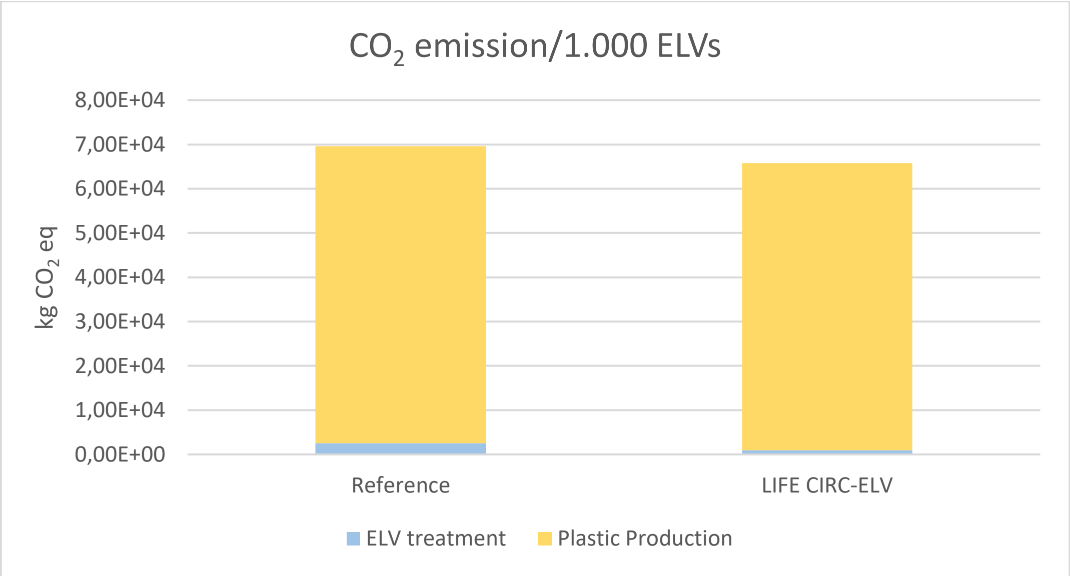

Figure 13. Total contribution to the CO_2 emission for the Reference and LIFE CIRC-ELV scenario per 1.000 ELVs (based on Cortés data).

Figure 13 shows that LIFE CIRC-ELV scenario has a positive effect on the environmental impact in Global Warming Potential category with less emissions (5% less). As previously detailed, the main effects are from the Plastic Production. However, since these plastics are made of recyclates with lower CO_2 emissions, less CO_2 is emitted when new plastic products include recyclates coming from LIFE CIRC-ELV model.

In Figure 14 the ELV treatment contribution to the CO_2 emissions for both scenarios is presented.

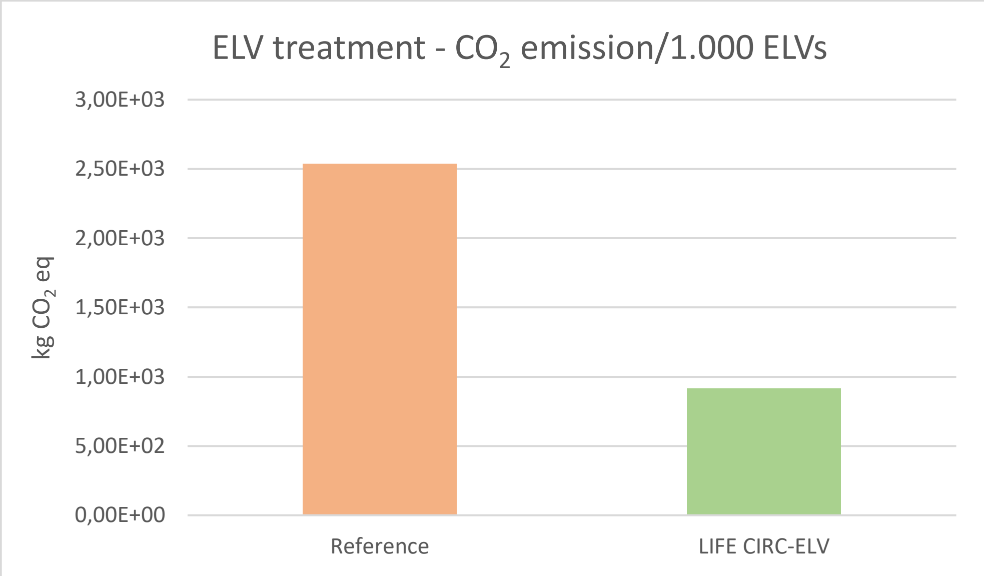

Figure 14. ELV treatment contribution to the CO_2 emission for the Reference and LIFE CIRC-ELV scenario per 1.000 ELVs (based on Cortés data).

As in Figure 13, Figure 14 shows that the impact of the processes from LIFE CIRC-ELV scenario are lower than the ones from Reference scenario (64% lower). On the other hand, impacts from Plastic Production are just 3% lower at the new scenario (Figure 15) because they are dominated by the use of 70 % of virgin plastics.

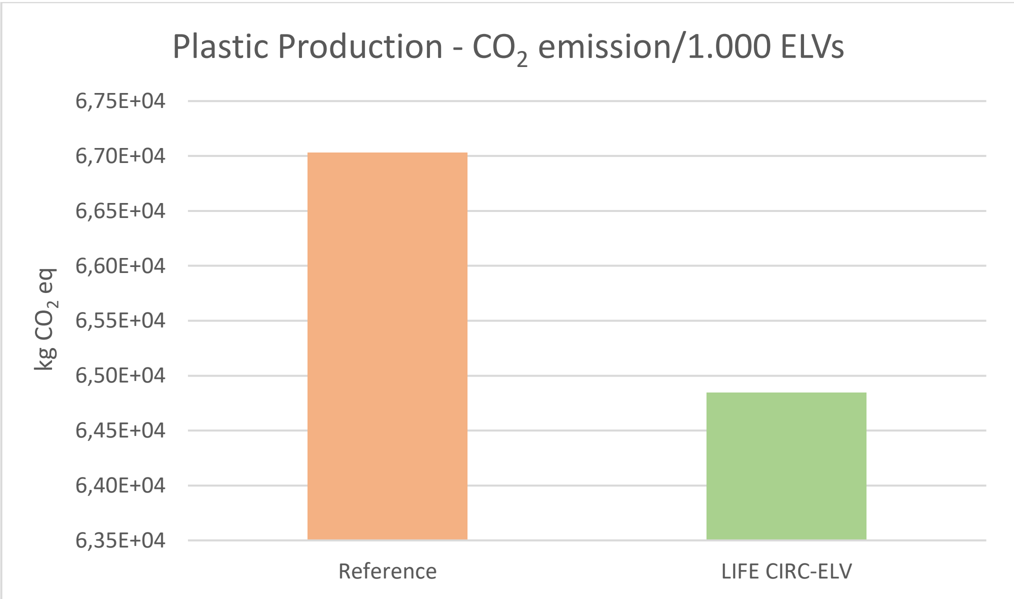

Figure 15. Plastic Production contribution to the CO_2 emission for the Reference and LIFE CIRC-ELV scenario per 1.000 ELVs (based on Cortés data).

Figure 16 shows that, in this case, LIFE CIRC-ELV scenario has also a positive effect on the environmental impact in Abiotic Depletion – Fossil Fuels category with less emissions (11% less). As previously detailed, the main effects are from the Plastic Production.

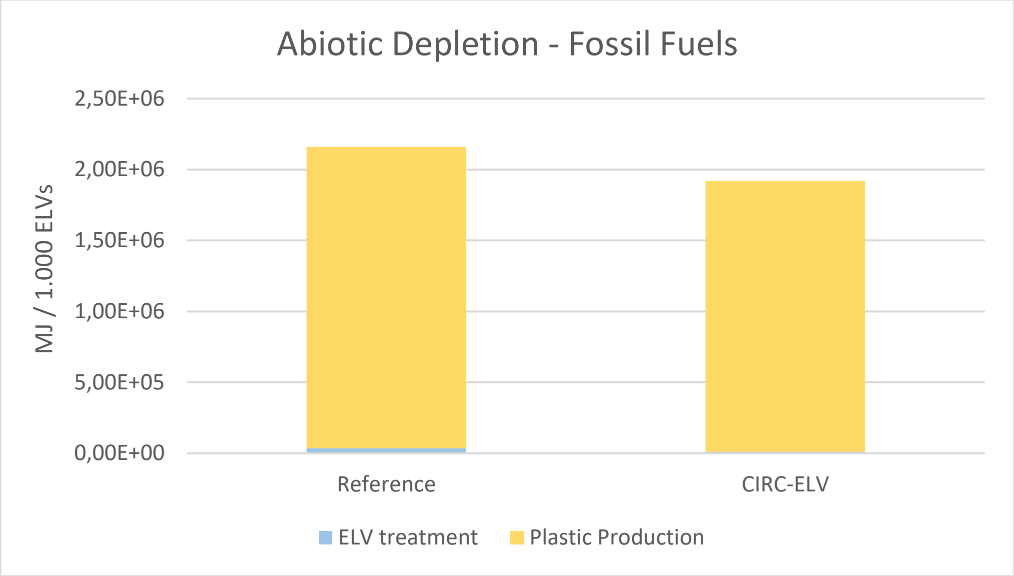

Figure 16. Total contribution to the abiotic depletion – fossil fuels for the Reference and LIFE CIRC-ELV scenario per 1.000 ELVs (based on Cortés data).

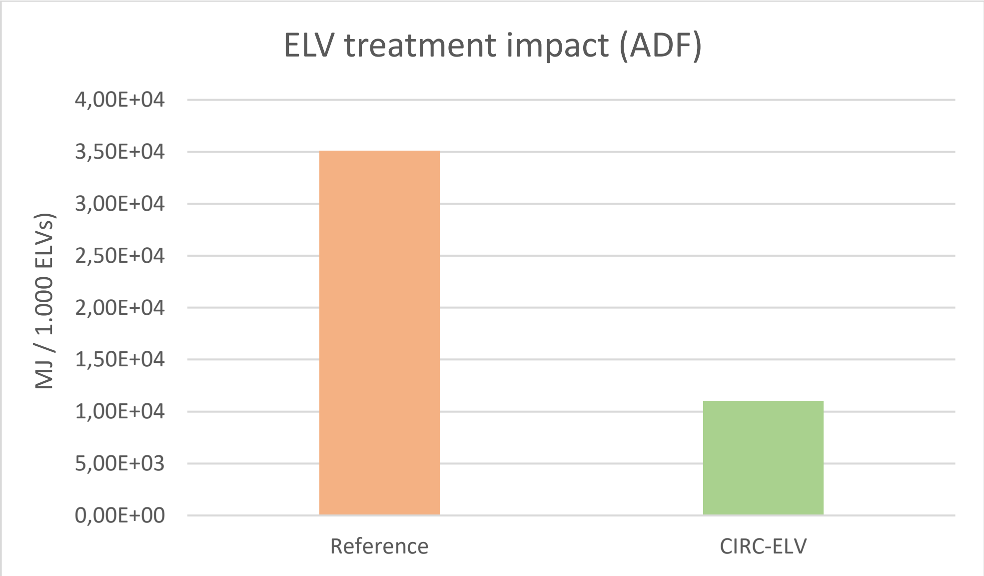

Figure 17. ELV treatment contribution to the abiotic depletion – fossil fuels for the Reference and LIFE CIRC-ELV scenario per 1.000 ELVs (based on Cortés data).

In Figure 17 it is presented the ELV treatment contribution to the ADF category for both scenarios. The impact of the processes from LIFE CIRC-ELV scenario are lower than the ones from Reference scenario (69% lower). On the other hand, impacts from Plastic Production are a 10% lower at LIFE CIRC-ELV scenario (Figure 18).

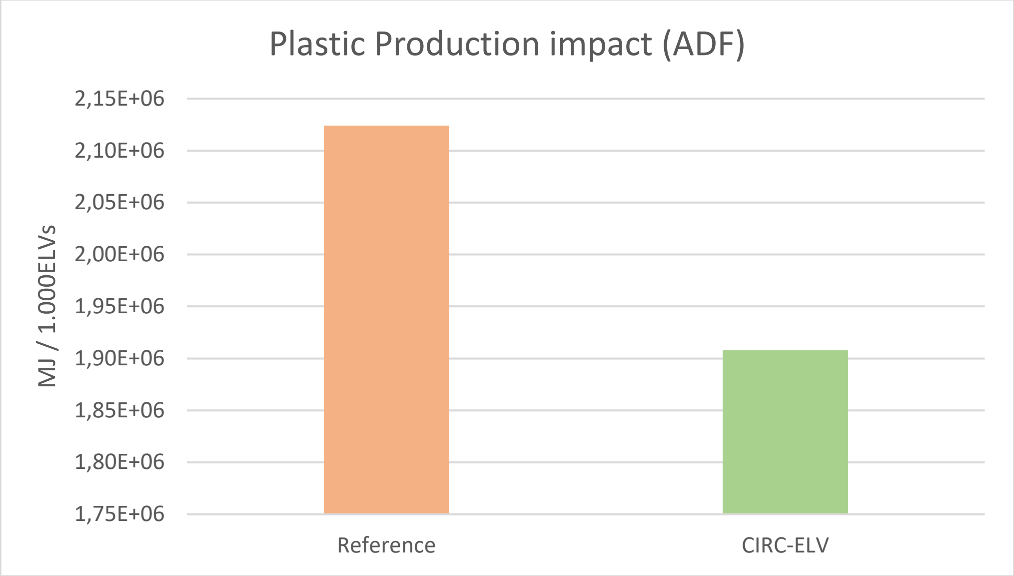

Figure 18. Plastic Production contribution to the abiotic depletion – fossil fuels for the Reference and LIFE CIRC-ELV scenario per 1.000 ELVs (based on Cortés data).

All the above impacts are based on what only a 30% of the PP and a 25% of the HDPE are recycled due to nowadays these are the percentage that can be used to make a technically viable new product. In Figure 19, it is presented the reduction of the impacts (impacts saving) for Global Warming Potential and Abiotic Depletion - Fossil Fuels if more than a 30PP-25HDPE% could be recycled for the Plastic Production.

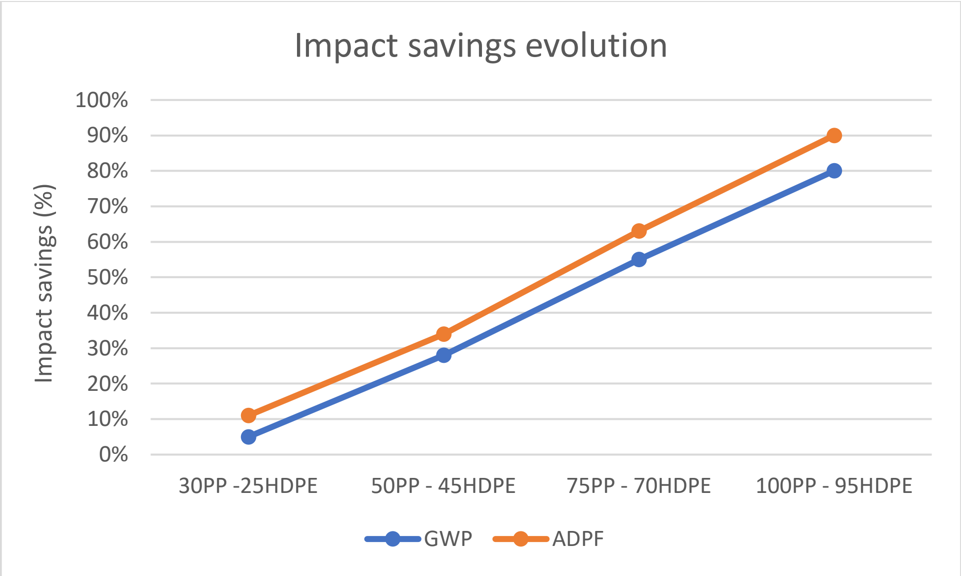

Figure 19. Impact saving evolutions depending on the percentage of the material recycled.

If all the PP and HDPE could be recycled, impact savings would be an 80% for GWP and a 90% for ADF. This is ascribed to the fact that the overall impacts are dominated by the use of virgin plastics in the combined boundary ELV management + Plastic production. Thus, when recyclates increase, the need for virgin plastics in new products decreases and the same for the emissions (GWP) and energy demand (ADPF).

4. Case study comparison

In this section different French ATF cases will be compared to the one analysed before (Desguace Cortés). For this, energy values have been compared for each centre, considering the electricity (kWh) and the fuel (L) necessaries (including the transport of long distances).

Seven bumper removal scenarios and another seven fuel tank removal scenarios have been studied (Table 15). All the scenarios are based on the LIFE CIRC-ELV model.

Table 15. Scenarios studied for bumper and tank removal.

Bumper removal scenario	Fuel tank removal scenario
1- Villeton ND	1- Cortés Destructive Trial 1
2- Gizzi ND	2- Cortés Destructive Upgrade
3- MPA Destructive	3- Buorgogne Destructive Trial 1
4- Cortés Destructive Trial 1	4- Buorgogne ND trial 2
5- Cortés Destructive Trial 2	5- ATF shredder 3 D
6- Buorgogne D Trial 1	6- MPA Destructive
7- Buorgogne ND Trial 2	7- ATF 3 ND

First, the energy used for the bumper removal scenarios will be analysed, and then the energy used for the tank removal.

The energy has been divided in electricity (kWh) and fuel (L).

Table 16. Energy used for the bumper removal scenarios.

Bumper removal scenario	Total Electricity (kWh/1.000 ELVs)	Total Fuel (L/1.000 ELVs)	Fuel from transport (L/1.000 ELVs)
1- Villeton ND	11.890	287.170	287.100
2- Gizzi ND	13.170	376.880	376.860
3- MPA Destructive	13.170	353.280	353.100
4- Cortés Destructive Trial 1	9.300	10.350,5	9.850,5
5- Cortés Destructive Trial 2	11.150	10.300,5	9.850,5
6- Buorgogne D Trial 1	11.700	353.260	353.100
7- Buorgogne ND Trial 2	11.820	376.860	376.860

The method selected for assessing the environmental impacts is the same as the one used on the previous sections, so 8 different impact categories are obtained. Different impact categories have different units and values (Table 12). In Figure 20 a comparison of the relative contribution for each scenario for the impacts coming from electricity is presented. Each column reflects which of the scenarios has more (or less) impact value for each impact category for the electricity consumed during bumper removal.

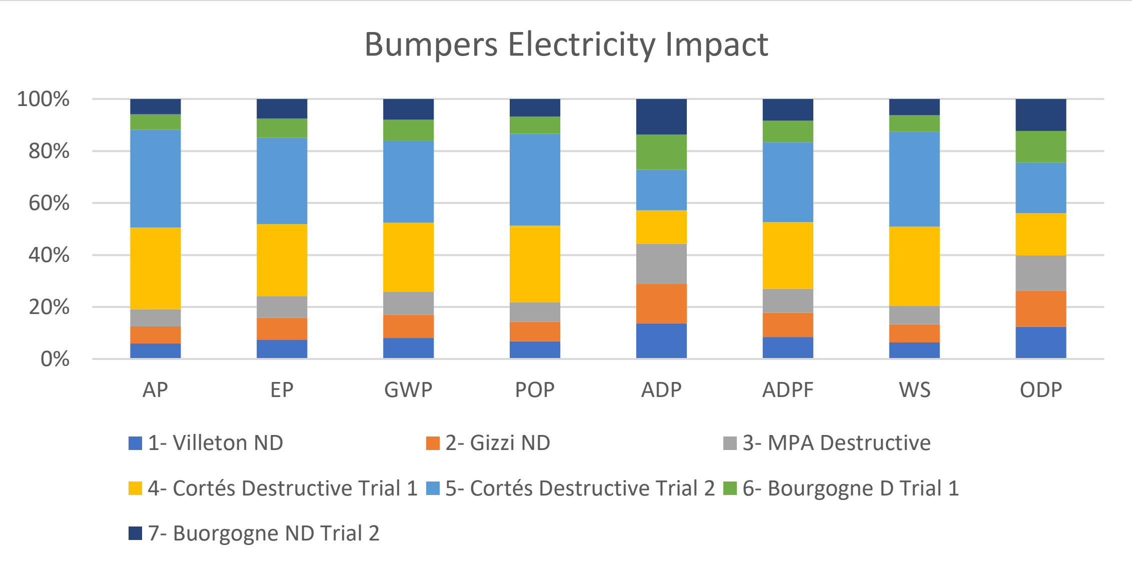

Figure 20. Scenarios contribution to the total environmental impacts for electricity at bumper removal scenarios per 1.000 ELVs.

The scenarios which contribute the most to all the category impact are the Cortés scenarios due to the electricity that it is used in them has more environmental impacts (Spanish electricity mix). On the other hand, the French scenarios use French electricity mix which has less impacts, according to the database used for assessing such impacts.

Figure 21 shows the percentual contribution of each scenario to each impact category for the fuel consumed during bumper removal scenarios.

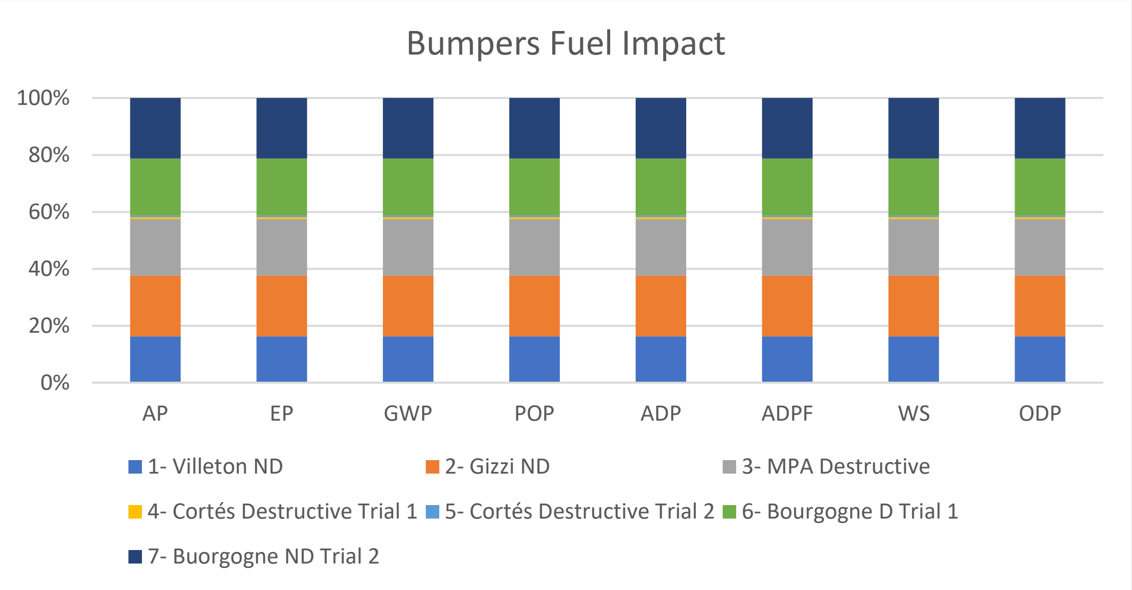

Figure 21. Scenarios contribution to the total environmental impacts for fuel at bumper removal scenarios per 1.000 ELVs.

As it is seen in Table 16, the use of fuel is mainly due to transportation, so when less distance is needed for transport, less fuel it will be used. In Cortés scenarios it is supposed that the transport is about 30 km (approximately), reducing the fuel consumption. On the other scenarios the transport is about 1.000 km (approximately).

In Figure 22 it is shown the percentual contribution of each scenario to each impact category for total energy consumed (electricity and fuel) during bumper removal different scenarios.

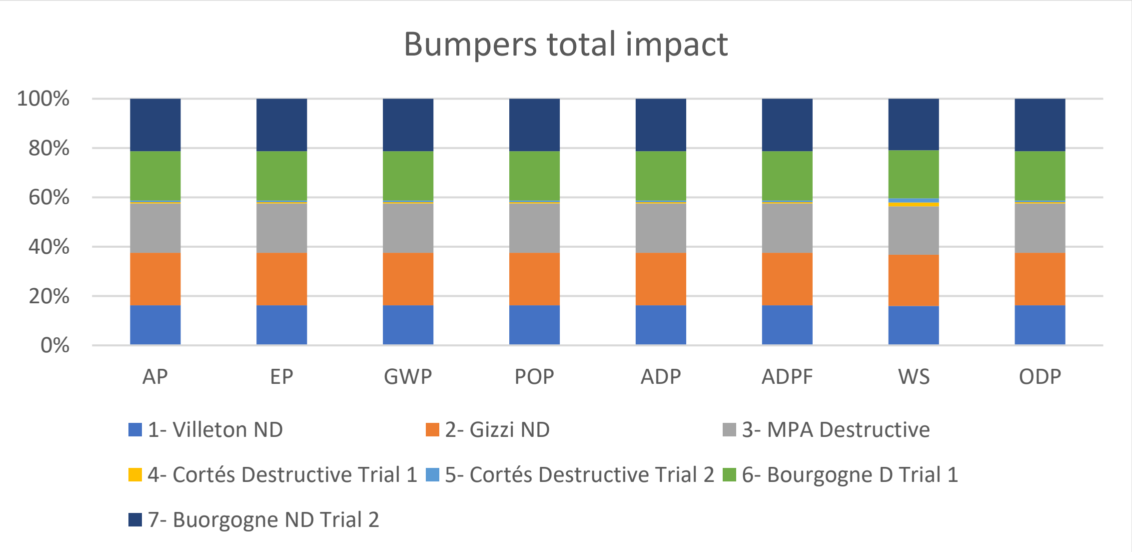

Figure 22. Scenarios contribution to the total environmental impacts for energy at bumper removal scenarios per 1.000 ELVs.

As the environmental impacts of fuel have greater contribution in total energy than the impacts of electricity, values in Figure 22 are dominated by those presented in Figure 21.

In Table 17 it is presented the energy used for each fuel tank removal scenario. The energy has been divided in electricity (kWh) and fuel (L).

Table 17. Energy used for the fuel tank removal scenarios.

Tank removal scenario	**Total Electricity** (kWh/1.000 ELVs)	**Total Fuel** (L/1.000 ELVs)	**Fuel from transport** (L/1.000 ELVs)
1- Cortés Destructive Trial 1	12.240	10.140,5	9.850,5
2- Cortés Destructive Trial 2	10.550	10.130,5	9.850,5
3- Buorgogne D Trial 1	10.940	281.430	281.160
4- Buorgogne ND Trial 2	11.220	264.690	264.660
5- ATF shredder 3 D	12.600	231.040	231.000
6- MPA Destructive	5.400	336.690	336.600
7- ATF 3 ND	11.000	460.390	460.390

Eight different impact categories are obtained according to the method used. Since different impact categories have different units and values (Table 12) Figure 23 presents the same comparison previously made for bumpers, but for fuel tanks.

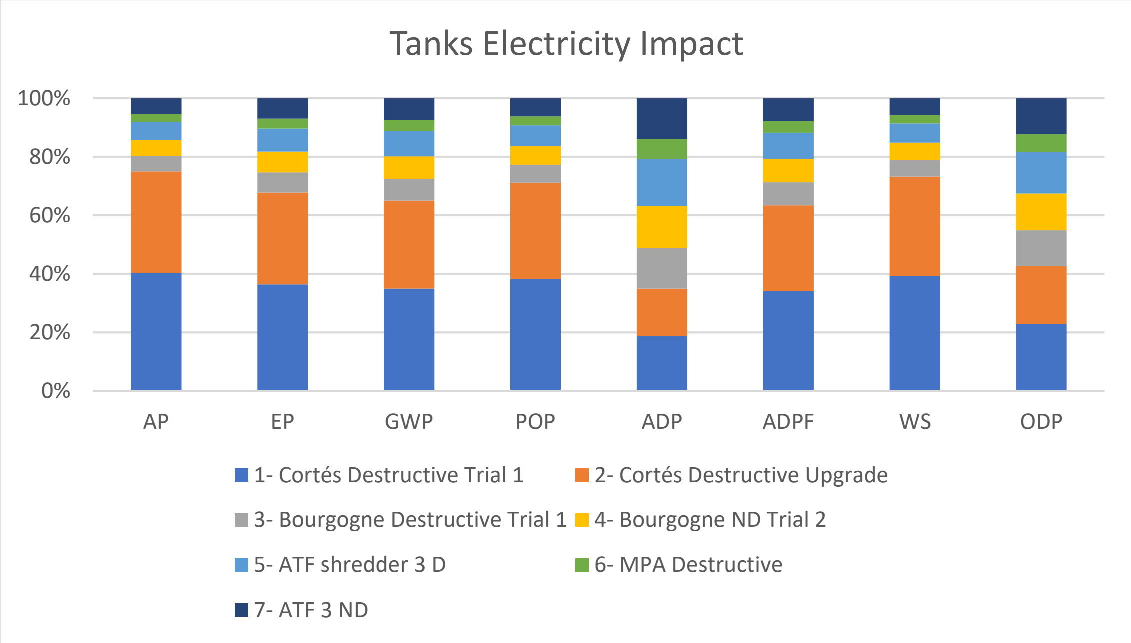

Figure 23. Scenarios contribution to the total environmental impacts for electricity at tank removal scenarios per 1.000 ELVs.

The scenario which contributes the most to all the category impact are the Cortés scenarios (as in bumper removal scenarios) due to the electricity that it is used in them has more environmental impacts (Spanish electricity mix). On the other hand, the French scenarios use French electricity mix which has less impacts, as previously described for bumpers.

Figure 24 shows the percentual contribution of each scenario to each impact category for fuel consumption during fuel tank removal scenarios.

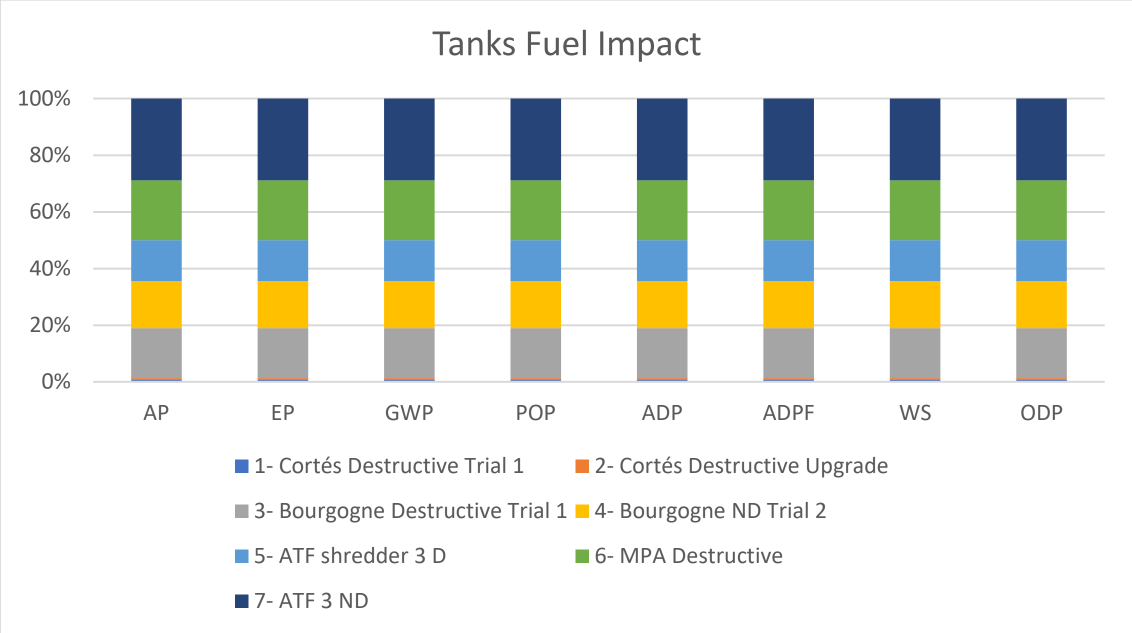

Figure 24. Scenarios contribution to the total environmental impacts for fuel at tank removal scenarios per 1.000 ELVs.

As in the case before, the use of fuel is mainly due to transportations (Table 17). In Cortés scenarios it is supposed that the transport is about 30 km (approximately), and the other scenarios the transport is about 1.000 km (approximately). Because of this, the scenarios with more distance needed for transport need more fuel which means more environmental impacts.

In Figure 25 it is shown the percentual contribution of each scenario to each impact category for total energy consumption (both electricity and fuel) for fuel tank removal scenarios.

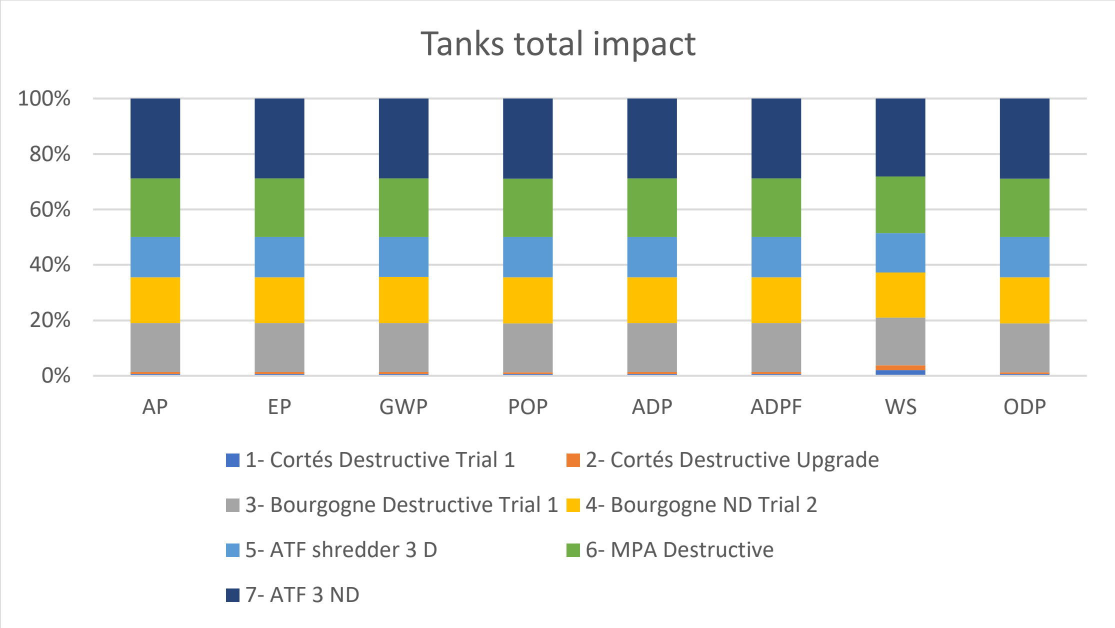

Figure 25. Scenarios contribution to the total environmental impacts for energy at tank removal scenarios per 1.000 ELVs.

The scenarios with more environmental impacts are the ones with more transport because in this case the impact of fuel has greater weight in total energy than the impacts of electricity. This could be reduced if the centres found recyclers near the ATF, so less transport would be required.

5. Conclusions

The main conclusions derived from life cycle assessment of the different scenarios could be expressed as that the processes to recycle plastic from cars bumpers and cars fuel tanks have a lower impact on the environment than the current scenario, so the LIFE CIRC-ELV project allows to decrease the total environmental impacts of each impact category studied.

On the other hand, since new products made of recycled plastics need for having relatively high percentage of virgin plastics, impacts for these products are dominated by the virgin plastics itself. According to the LIFE CIRC-ELV model for removing bumpers and fuel tanks, including pre-treatment of these recyclates to be ready for recycling, these recyclates have one-fold lower CO_2 emissions than the virgin plastics, Thus, if new products could be fabricated with higher contents of recyclates from ELVs, they could reduce 80% for global warming potential.

Furthermore, 7 scenarios for different ATFs (including French ones) were analysed for bumper removal and for tank removal. The impact comparison showed that all the French ATF have similar electricity consumption to the Cortés scenario. Overall impacts are dominated by the fuel consumption needed to transport removed plastics to the pre-treatment centre: French model works based on a logistic facility for collecting all plastics from different ATFs across France (and linked to the INDRA's network), while CORTÉS used a near recycler to do so. Then, logistics for recovered plastics is an issue to boost the overall environmental impacts of the Frenchs ATFs.