recycler c'est protéger

Study summary: the environmental benefits associated with the incorporation of recycled plastics from WEEE

ECOSYSTEM SUMMARY

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Version 1.0

Contents

Note:

This summary is based on the results of the study undertaken by Deloitte Développement Durable for **ecosystem** dating from 26 March 2021 on the benefits of recycled plastics from WEEE. This summary was produced by **ecosystem** and is published under its sole responsibility.

Introduction

ecosystem is an eco-organisation accredited by the French authorities to provide end-of-life management for household and professional waste electrical and electronic equipment (WEEE), lighting equipment and small extinguishers (PAE). As such, **ecosystem** organises and coordinates the collection of this equipment, its decontamination and recycling. In 2021, more than 700,000 tonnes of WEEE, used lighting equipment and small extinguishes were collected by **ecosystem** and its partners.

*Figure 1 - Illustration of WEEE streams covered by **ecosystem***

Electrical and electronic equipment (EEE) is complex by nature and comprises numerous materials including various plastics (e.g.: ABS, PS, PP, PC-ABS, PC, PMMA, PET, POM, PA, etc.). At the end of its life, this EEE undergoes various steps to separate and sort its constituent materials. All along this chain, from the collection of equipment to the regeneration of plastics, the technical, regulatory and economic trade-offs (associated, for example, with the proportion of different plastics in the waste stream) undertaken by sorting operators and plastics regenerators, result in a focus on only recycling some of the plastics originally present in products reaching the end of their lives. The plastics overwhelmingly regenerated within the WEEE sector are thus:

- polyolefins, and more specifically **polypropylene** (PP), which does not contain a charge or is weakly charged,
- styrenes, and more specifically **polystyrene** (PS) and **acrylonitrile butadiene styrene** (ABS), which do not contain a charge or are weakly charged.

All these collection, sorting, decontamination and regeneration steps represent an environmental cost associated with emissions (of greenhouse gases, particles, etc.) and consumption (of fossil resources, mineral resources, etc.). However, this environmental cost remains lower than that associated with the production of equivalent virgin plastic.

To quantify the actual impacts and provide evidence to justify this statement, **ecosystem** conducted a **comparative study of the environmental impacts of recycled plastics from WEEE and equivalent virgin plastics**. The aim of this study is to **produce reliable benchmark data, which will provide support for projects involving the incorporation of recycled plastics into new products**.

This summary sets out the methodology used and presents the key results obtained. For any questions relating to this study, please contact **ecosystem**: weee-lci@ecosystem.eco

1. Methodological principles

1.1 Functional area and system boundaries

The functional area examined in this study is the: **"Production, transport and injection moulding of pellets to obtain one tonne of recycled plastic from WEEE /or/ virgin plastic"**. This functional area includes the step of processing the pellets to obtain a part. This enables sensitivity analyses to be conducted, in order to verify the effect of various assumptions:

- Hypothetical case where it would be necessary to use a larger quantity of recycled plastic (e.g.: the addition of ribs to the part in the event that the material is less strong),
- Hypothetical case where the injection moulding of recycled plastic could result in greater energy consumption (e.g.: drying due to the absorption of moisture by recycled pellets).

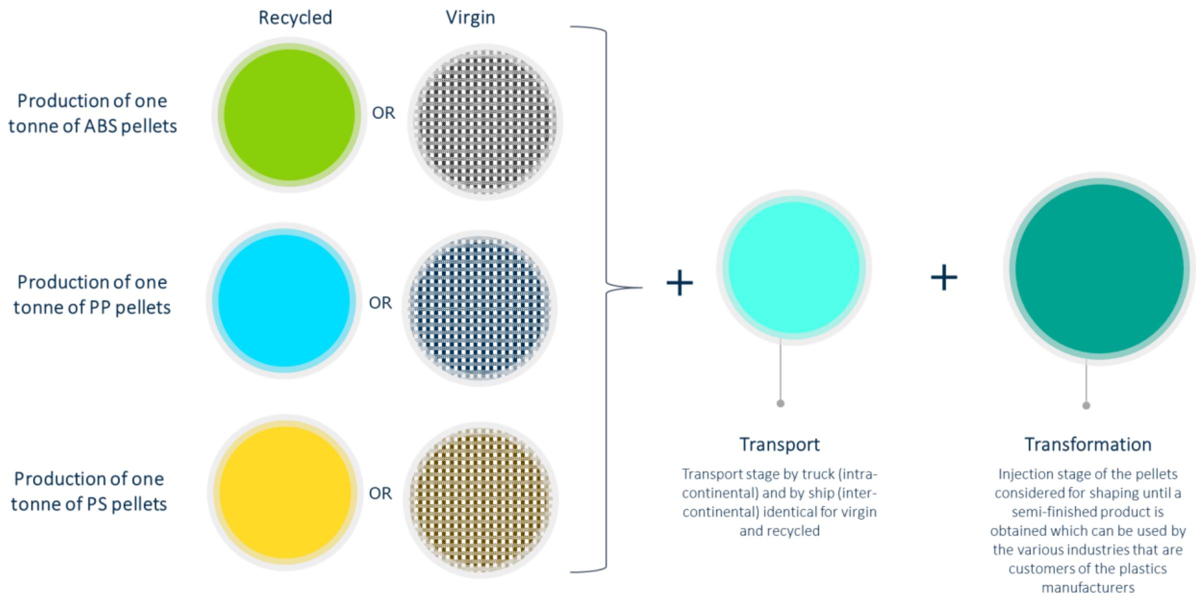


Figure 2 - Functional area and boundaries of the system studied

This study focuses solely on recycled plastics originating from the recycling of WEEE.

1.2 Cases studied for comparison

The production of plastic materials, followed by processing of these materials to create plastic parts, forms part of a complex chain of operators and could take place in various geographic zones. For this study, a number of scenarios were examined:

- Case 1: Production of recycled pellets in Europe and injection moulding in France,
- Case 2: Production of recycled pellets in Europe and injection moulding in Europe,
- Case 3: Production of recycled pellets in Europe and injection moulding in Asia,
- Case 4: Production of recycled pellets in Asia and injection moulding in Asia,
- Case 5: Production of recycled pellets in Asia and injection moulding in Europe.

All these scenarios were studied. However, as the robustness of the data used to model scenarios 3, 4 and 5 is moderate, this summary only presents the final results for cases 1 and 2. For all questions relating to the other scenarios, please contact **ecosystem**: weee-lci@ecosystem.eco

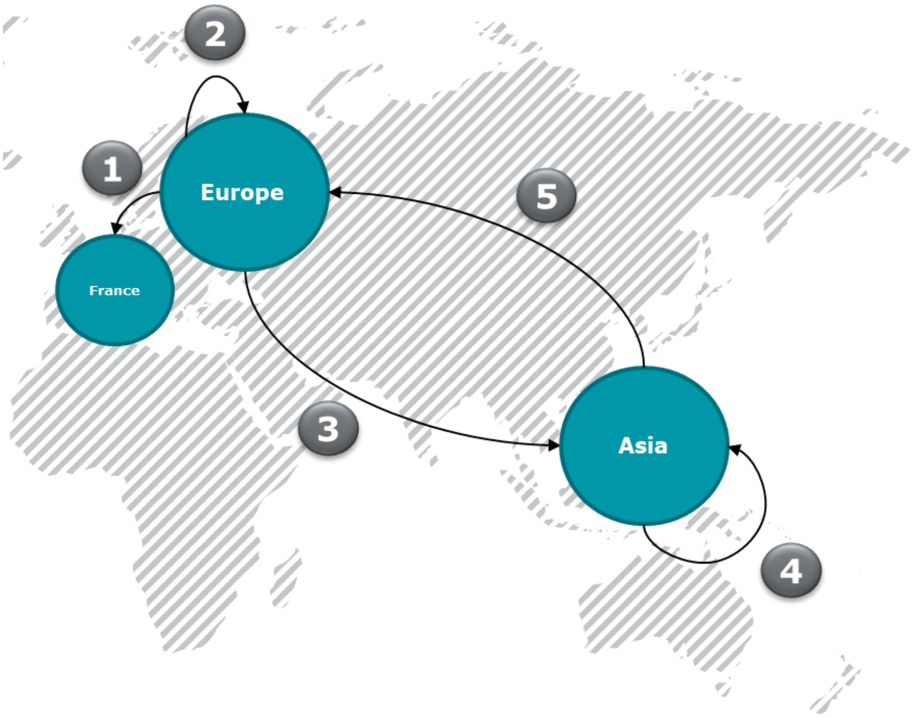


Figure 3 – Cases studied for comparison, depending on the pellet production and injection moulding locations.

1.3 Data sources

1.3.1 Data for assessing the impact of the production of recycled plastics from WEEE

To aid the eco-design of equipment and projects involving the incorporation of recycled plastics, **ecosystem** has created a database of Life Cycle Inventories (LCIs) for recycled plastics from WEEE. This data enables the impacts on the environment of the production of plastics from WEEE to be quantified.

Three types of recycled plastics are modelled: **PP, PS** and **ABS**. These are the main recycled plastics produced from WEEE.

To ensure that this data is entirely representative, with the contribution of various operators within the chain, **ecosystem** has modelled all the production processes for these recycled plastics, covering all the steps from the WEEE collection point to the final regeneration of these plastics.

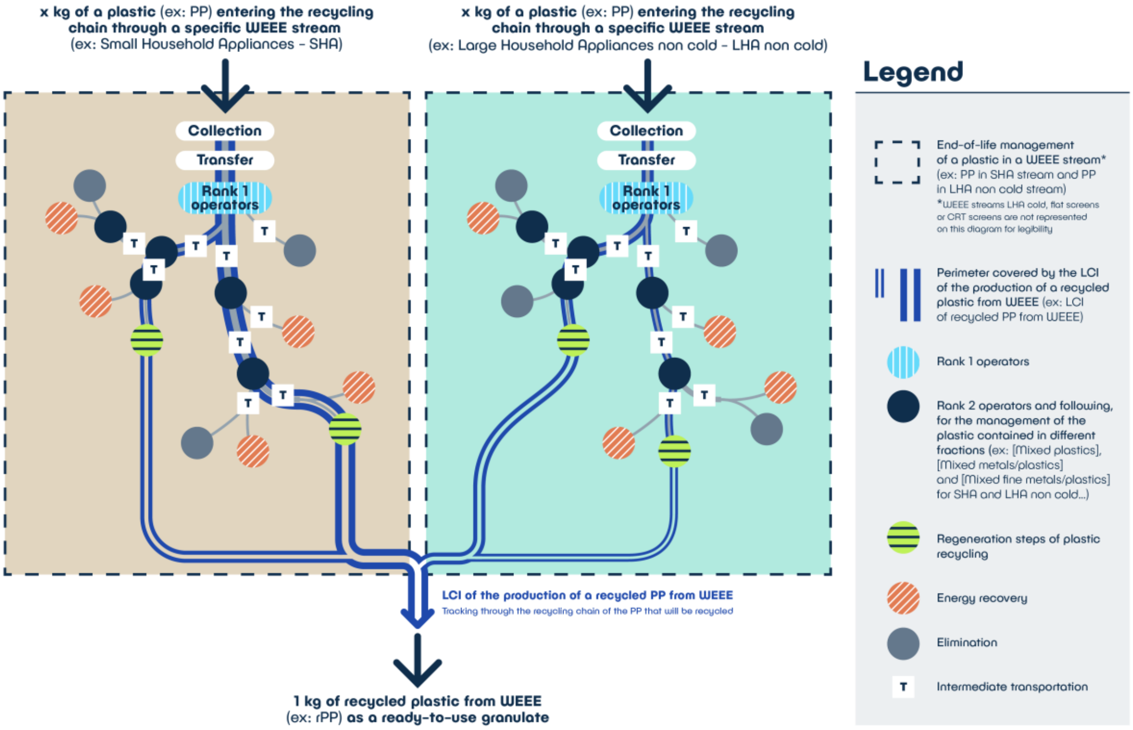


Figure 4 – Diagram of the various steps in the recycling chain modelled in these LCIs

This database is **open and free to access**. It can be used by equipment manufacturers, for example, in their LCA assessments, to model products incorporating recycled plastics from WEEE. This database is also used within the framework of this study to calculate the environmental impacts of the production of parts in recycled plastics from WEEE.

To download this data or to find out more about the methodology: https://www.ecosystem.eco/en/article/environmental-footprint-recycled-plastic

1.3.2 Choice of inventories used within modelling and robustness

For each of the steps within the scope (production of recycled or virgin plastic pellets, transport, processing), the following table summarises the choice of inventories used and the data sources.

Step	Geographic zone	Database - Inventory	Reason for selection	Robustness
Production of pellets – recycled	Europe	**ecosystem (see § 1.3.1)** **ABS**: N0 | [Recycled plastics]_Production ¤ ABS system **PP**: N0 | [Recycled plastics]_Production ¤ PP system **PS**: N0 | [Recycled plastics]_Production ¤ PS system	Representative inventories for the production of recycled plastics originating specifically from WEEE. These inventories represent the impacts associated with all steps through which the plastics pass, from the collection of WEEE in France, to their regeneration in Europe.	**Very good**

Production of pellets – virgin	Europe	**Plastics Europe** **ABS**: Acrylonitrile butadiene styrene (ABS)/EU-27 **PP**: Polypropylene, PP, granulate, at plant/RER **PS**: Polystyrene granulate (PS)/EU-27	Two types of inventories are available for modelling the production of virgin pellets and are widely used: the LCIs from Plastics Europe and the LCIs from Ecoinvent. The inventories from Plastics Europe were chosen (more recent LCIs, similar modelling to LCIs for recycled plastics, etc.).	**Good**
Transport – lorry	Europe	**ecoinvent** – Transport, freight, lorry >32 metric tons, EURO5 {RER}| transport, freight, lorry >32 metric tons, EURO5 | Cut-off, U **Assumption**: Transport distance = 500 km flat rate per lorry	Representative inventory for the European geographic mix. The EURO 5 standard corresponds to 1st registration between 2011 and 2015, therefore, it is viewed as representative of European technologies.	**Good**
Injection moulding	France	**ecoinvent** (adapted electricity mix in France) - Injection moulding {RER}| processing | Cut-off, U	Representative inventories for injection moulding in Europe. (The other available inventories aggregate the steps of virgin material production with the injection moulding step and it is not possible to separate them).	**Good**
	Europe	**ecoinvent** - Injection moulding {RER}| processing | Cut-off, U		**Very good**

Table 1 - Summary of inventories used for modelling cases 1 and 2

Additives taken into account: additives can be added during the course of the process, to give plastics certain properties. Small quantities of certain additives are taken into account in the modelling of these "average" plastics:

- **For recycled plastics**: in order to guarantee the properties expected by their clients, regenerators of recycled plastics frequently use a formulation with the addition of various additives, in particular masterbatch and impact modifiers. The recycled plastics studied include a carbon black (black colour - for PP and ABS) or titanium dioxide (white colour - for PS) type masterbatch. In the case of PS, an SBS type impact modifier is also modelled.
- **For virgin plastics**: The modelling of virgin plastics contains some additives, but neither the quantity nor the nature of these additives are specified in the data descriptions, for reasons of confidentiality. However, the inventories for virgin plastics state that these additives are present in a sufficient quantity to use the plastic, but that others may be added for precise specifications.

The study focuses on these "average plastics", and does not model specific cases of plastics with a high additive content (for fireproofing, for example).

1.4 Choice of impact categories and characterisation methods

The selection of impact categories studied is based on categories recommended by the JRC (European Joint Research Centre) and the assessment of environmental challenges for the WEEE sector (for more details, please refer to: https://www.ecosystem.eco/en/article/assessment-environmental-impact). For each of these categories, the impact models used are based on the recommendations of the European PEF method (Product Environmental Footprint).

Impact category	Unit	Characterisation method
Climate change	kg CO_2-eq	Baseline model of 100 years of the IPCC (based on IPCC 2013)
Resource use, fossils	MJ	ADP for energy carriers, based on van Oers et al. 2002 as implemented in CML, v. 4.8 (2016)
Resource use, minerals and metals	kg Sb-eq	ADP for mineral and metal resources, based on van Oers et al. 2002 as implemented in CML, v. 4.8 (2016)
Ozone depletion	kg CFC-11-eq	Steady-state ODPs as in (WMO 2014 + integrations)
Photochemical ozone formation, human health	kg NMVOC-eq	LOTOS-EUROS model (Van Zelm et al, 2008) as implemented in ReCiPe 2008
Acidification	mol H+ eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)
Human toxicity (cancer + non-cancer)	CTUh	USEtox model 2.1 (Fankte et al, 2017)
Particle matter	Disease incidence	PM method recommended by UNEP (UNEP 2016)

Table 2 - Summary of impact categories and models studied

Two significant limitations should be noted:

Human toxicity: there are strict limits for this indicator. These arise from both uncertainties relating to some primary data for inventories, affecting toxicity (e.g.: imperfect knowledge or modelling of direct emissions [channelled or diffuse] of pollutants that could occur during successive steps in the recycling chain) and inherent uncertainties of the methodology.

Particle formation: The limits for this indicator arise from the primary data for inventories (e.g.: in the case of recycled plastics, imperfect knowledge of dust emissions that could occur during successive steps in the recycling chain, both in terms of their quantification, their granulometry and emission compartments – air, water, soil).

Therefore, the results relating to these two impact categories must be treated with caution. They are greyed out in the rest of this document.

2 Results of impacts

This section presents the results of impacts obtained for each of three types of plastics studied: PP, PS and ABS, based on the two cases "Production in Europe followed by injection moulding in France" (Case 1) and "Production in Europe followed by injection moulding in Europe" (Case 2).

2.1 Results of impacts for PP

The following tables present the detailed results of impacts for PP for the two cases studied (Cases 1 and 2).

		Case 1 – Production in Europe followed by injection moulding in France of a tonne of recycled or virgin PP							
		Impacts with recycled PP				Impacts with virgin PP			
Impact category	FR unit	Production	Transport	Processing	Total	Production	Transport	Processing	Total[1]
Climate change	kg CO_2-eq	439	46	487	**971**	1,660	46	487	**2,200**
Resource use, fossils	MJ	9,520	711	25,500	**35,700**	71,100	711	25,500	**97,300**
Resource use, minerals and metals	kg Sb-eq	0.0003	0.0008	0.0074	**0.0085**	0.0001	0.0008	0.0074	**0.0083**
Ozone depletion	kg CFC-11-eq	0.00007	0.00001	0.00016	**0.00024**	0.00004	0.00001	0.00016	**0.00022**
Photochemical ozone formation, Human health	kg NMVOC-eq	1.33	0.21	1.32	**2.86**	5.54	0.21	1.32	**7.06**
Acidification,	mol H+ eq	2.06	0.19	1.78	**4.03**	5.15	0.19	1.78	**7.12**
Human toxicity (cancer + non-cancer)	CTUh	0.000004	0.000001	0.000004	**0.000009**	0.000008	0.000001	0.000004	**0.000013**
Particle matter	Disease incidence	0.000024	0.000004	0.000014	**0.000042**	0.000065	0.000004	0.000014	**0.000083**

Table 3 - Details and comparison of the impacts of production in Europe and transport and processing in France of recycled or virgin PP

		Case 2 – Production followed by injection moulding in Europe of a tonne of recycled or virgin PP							
		Impacts with recycled PP				Impacts with virgin PP			
Impact category	FR unit	Production	Transport	Processing	Total	Production	Transport	Processing	Total
Climate change	kg CO_2-eq	439	46	983	**1,470**	1,660	46	983	**2,690**
Resource use, fossils	MJ	9,520	711	20,700	**31,000**	71,100	711	20,700	**92,600**
Resource use, minerals and metals	kg Sb-eq	0.0003	0.0008	0.0082	**0.0093**	0.0001	0.0008	0.0082	**0.0091**
Ozone depletion	kg CFC-11-eq	0.00007	0.00001	0.00014	**0.00022**	0.00004	0.00001	0.00014	**0.00019**
Photochemical ozone formation, Human health	kg NMVOC-eq	1.33	0.21	2.41	**3.95**	5.54	0.21	2.41	**8.16**
Acidification,	mol H+ eq	2.06	0.19	4.70	**6.95**	5.15	0.19	4.70	**10.00**
Human toxicity (cancer + non-cancer)	CTUh	0.000004	0.000001	0.000009	**0.000014**	0.000008	0.000001	0.000009	**0.000017**
Particle matter	Disease incidence	0.000024	0.000004	0.000019	**0.000047**	0.000065	0.000004	0.000019	**0.000088**

Table 4 - Details and comparison of the impacts of production in Europe and transport and processing in Europe of recycled or virgin PP

[1] *The values recorded in red are those for which the impacts obtained with virgin plastic exceed the impacts obtained with recycled plastic by more than 50%.*

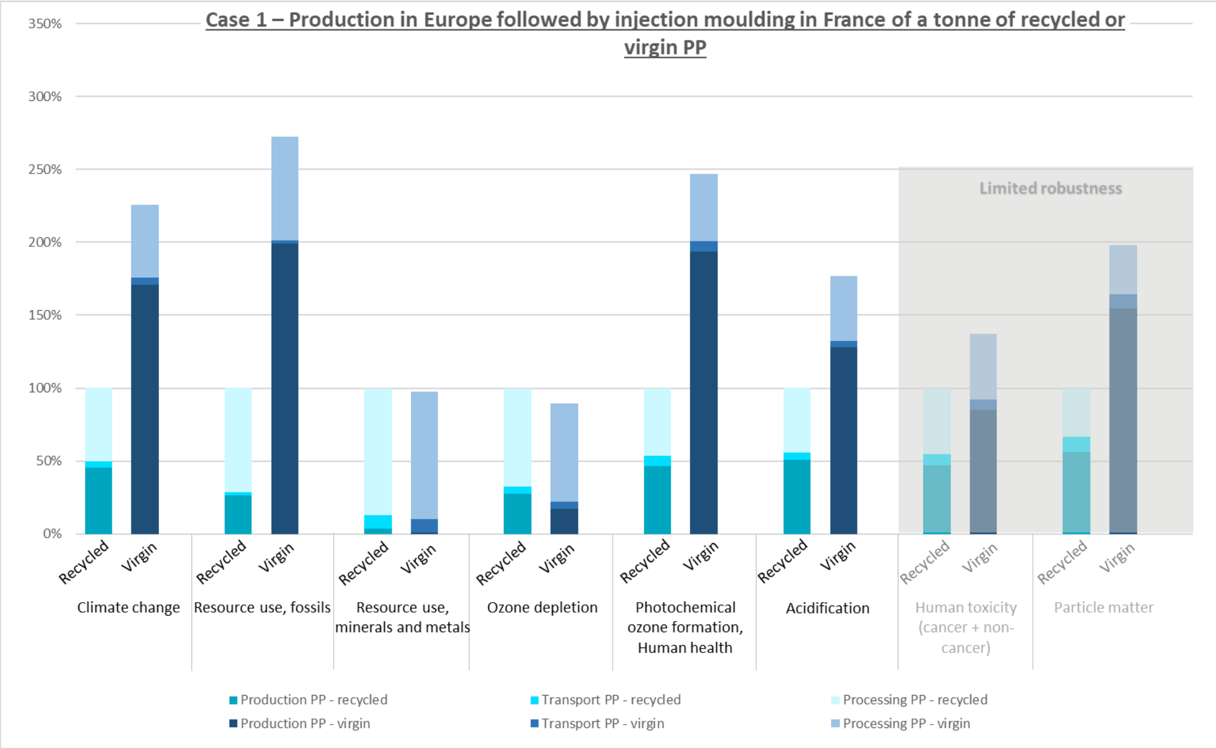


Figure 3 - Details and comparison of the impacts of production in Europe and transport and processing in France (Case 1) of recycled or virgin PP, based on 100%

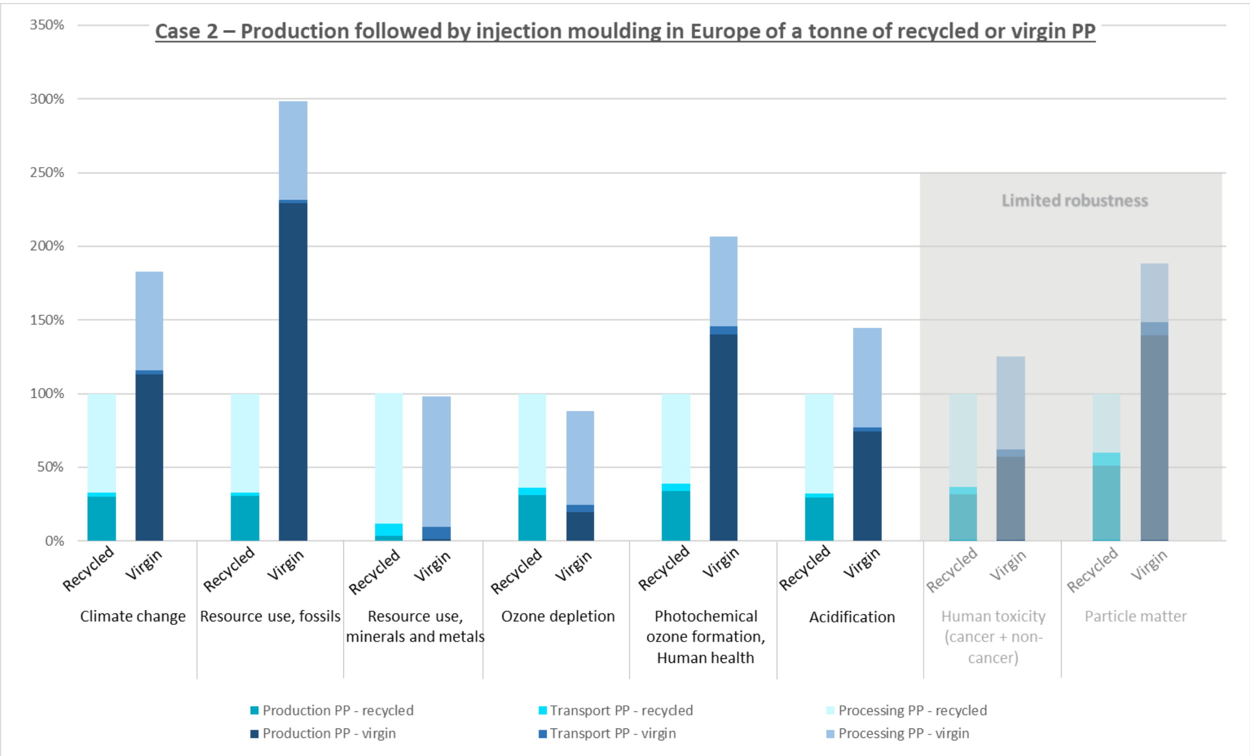


Figure 4 - Details and comparison of the impacts of production in Europe and transport and processing in Europe (Case 2) of recycled or virgin PP, based on 100%

2.2 Results of impacts for PS

The following tables present the detailed results of impacts for PS for the two cases studied (Cases 1 and 2).

		Case 1 – Production in Europe followed by injection moulding in France of a tonne of recycled or virgin PS							
		Impacts with recycled PS				Impacts with virgin PS			
Impact category	FR unit	Production	Transport	Processing	Total	Production	Transport	Processing	Total
Climate change	kg CO_2-eq	621	46	487	**1,150**	2,340	46	487	**2,880**
Resource use, fossils	MJ	12,400	711	25,500	**38,600**	76,500	711	25,500	**103,000**
Resource use, minerals and metals	kg Sb-eq	0.0003	0.0008	0.0074	**0.0085**	0.0004	0.0008	0.0074	**0.0086**
Ozone depletion	kg CFC-11-eq	0.00007	0.00001	0.00016	**0.00024**	0.00001	0.00001	0.00016	**0.00018**
Photochemical ozone formation, Human health	kg NMVOC-eq	1.69	0.21	1.32	**3.21**	4.75	0.21	1.32	**6.27**
Acidification,	mol H+ eq	3.14	0.19	1.78	**5.11**	6.52	0.19	1.78	**8.49**
Human toxicity (cancer + non-cancer)	CTUh	0.000005	0.000001	0.000004	**0.000010**	0.000009	0.000001	0.000004	**0.000014**
Particle matter	Disease incidence	0.000025	0.000004	0.000014	**0.000043**	0.000044	0.000004	0.000014	**0.000062**

Table 5 - Details and comparison of the impacts of production in Europe and transport and processing in France of recycled or virgin PS

		Case 2 – Production followed by injection moulding in Europe of a tonne of recycled or virgin PS							
		Impacts with recycled PS				Impacts with virgin PS			
Impact category	FR unit	Production	Transport	Processing	Total	Production	Transport	Processing	Total
Climate change	kg CO_2-eq	621	46	983	**1,650**	2,340	46	983	**3,370**
Resource use, fossils	MJ	12,400	711	20,700	**33,800**	76,500	711	20,700	**97,900**
Resource use, minerals and metals	kg Sb-eq	0.0003	0.0008	0.0082	**0.0093**	0.0004	0.0008	0.0082	**0.0094**
Ozone depletion	kg CFC-11-eq	0.00007	0.00001	0.00014	**0.00022**	0.00001	0.00001	0.00014	**0.00016**
Photochemical ozone formation, Human health	kg NMVOC-eq	1.69	0.21	2.41	**4.30**	4.75	0.21	2.41	**7.36**
Acidification,	mol H+ eq	3.14	0.19	4.70	**8.03**	6.52	0.19	4.70	**11.40**
Human toxicity (cancer + non-cancer)	CTUh	0.000005	0.000001	0.000009	**0.000015**	0.000009	0.000001	0.000009	**0.000019**
Particle matter	Disease incidence	0.000025	0.000004	0.000019	**0.000047**	0.000044	0.000004	0.000019	**0.000067**

Table 6 - Details and comparison of the impacts of production in Europe and transport and processing in Europe of recycled or virgin PS

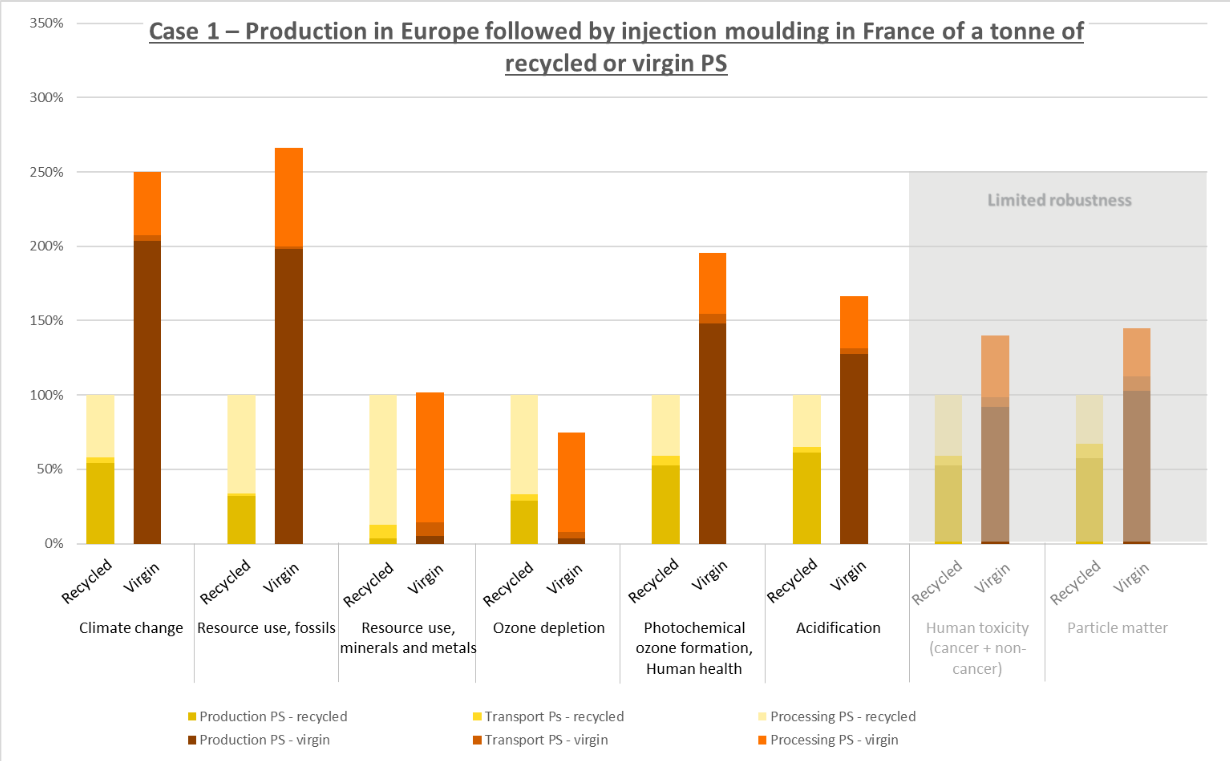


Figure 5 - Details and comparison of the impacts of production in Europe and transport and processing in France (Case 1) of recycled or virgin PS, based on 100%

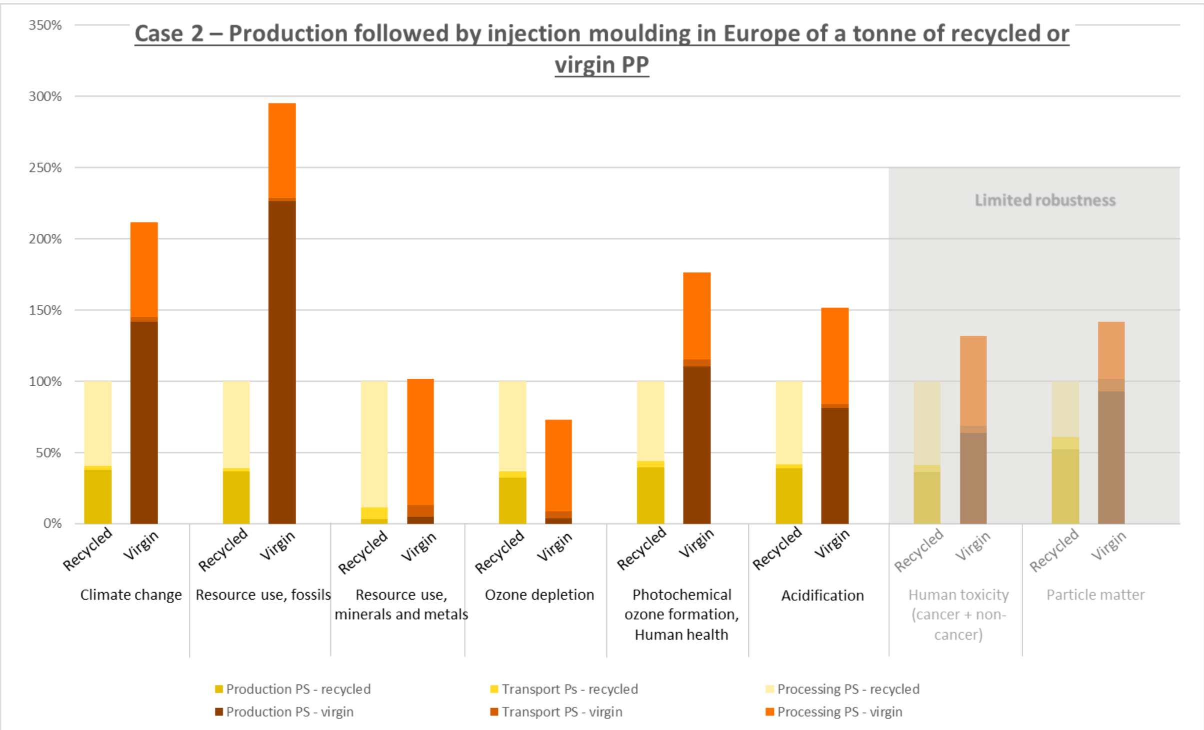


Figure 6 - Details and comparison of the impacts of production in Europe and transport and processing in Europe (Case 2) of recycled or virgin PS, based on 100%

2.3 Results of impacts for ABS

The following tables present the detailed results of impacts for ABS for the two cases studied (Cases 1 and 2).

		Case 1 – Production in Europe followed by injection moulding in France of a tonne of recycled or virgin ABS							
		Impacts with recycled ABS				Impacts with virgin ABS			
Impact category	FR unit	Production	Transport	Processing	Total	Production	Transport	Processing	Total
Climate change	kg CO_2-eq	564	46	487	**1,100**	3,230	46	487	**3,770**
Resource use, fossils	MJ	11,100	711	25,500	**37,300**	84,000	711	25,500	**110,000**
Resource use, minerals and metals	kg Sb-eq	0.0003	0.0008	0.0074	**0.0085**	0.0004	0.0008	0.0074	**0.0086**
Ozone depletion	kg CFC-11-eq	0.00008	0.00001	0.00016	**0.00025**	0.00000	0.00001	0.00016	**0.00017**
Photochemical ozone formation, Human health	kg NMVOC-eq	1.61	0.21	1.32	**3.13**	7.41	0.21	1.32	**8.94**
Acidification,	mol H+ eq	2.82	0.19	1.78	**4.79**	9.36	0.19	1.78	**11.30**
Human toxicity (cancer + non-cancer)	CTUh	0.000005	0.000001	0.000004	**0.000010**	0.000022	0.000001	0.000004	**0.000026**
Particle matter	Disease incidence	0.000027	0.000004	0.000014	**0.000045**	0.000058	0.000004	0.000014	**0.000077**

Table 7 - Details and comparison of the impacts of production in Europe and transport and processing in France of recycled or virgin ABS

		Case 2 – Production followed by injection moulding in Europe of a tonne of recycled or virgin ABS							
		Impacts with recycled ABS				Impacts with virgin ABS			
Impact category	FR unit	Production	Transport	Processing	Total	Production	Transport	Processing	Total
Climate change	kg CO_2-eq	564	46	983	**1,590**	3,230	46	983	**4,260**
Resource use, fossils	MJ	11,100	711	20,700	**32,500**	84,000	711	20,700	**105,000**
Resource use, minerals and metals	kg Sb-eq	0.0003	0.0008	0.0082	**0.0093**	0.0004	0.0008	0.0082	**0.0094**
Ozone depletion	kg CFC-11-eq	0.00008	0.00001	0.00014	**0.00022**	0.00000	0.00001	0.00014	**0.00015**
Photochemical ozone formation, Human health	kg NMVOC-eq	1.61	0.21	2.41	**4.23**	7.41	0.21	2.41	**10.00**
Acidification,	mol H+ eq	2.82	0.19	4.70	**7.71**	9.36	0.19	4.70	**14.30**
Human toxicity (cancer + non-cancer)	CTUh	0.000005	0.000001	0.000009	**0.000015**	0.000022	0.000001	0.000009	**0.000031**
Particle matter	Disease incidence	0.000027	0.000004	0.000019	**0.000050**	0.000058	0.000004	0.000019	**0.000081**

Table 8 - Details and comparison of the impacts of production in Europe and transport and processing in Europe of recycled or virgin ABS

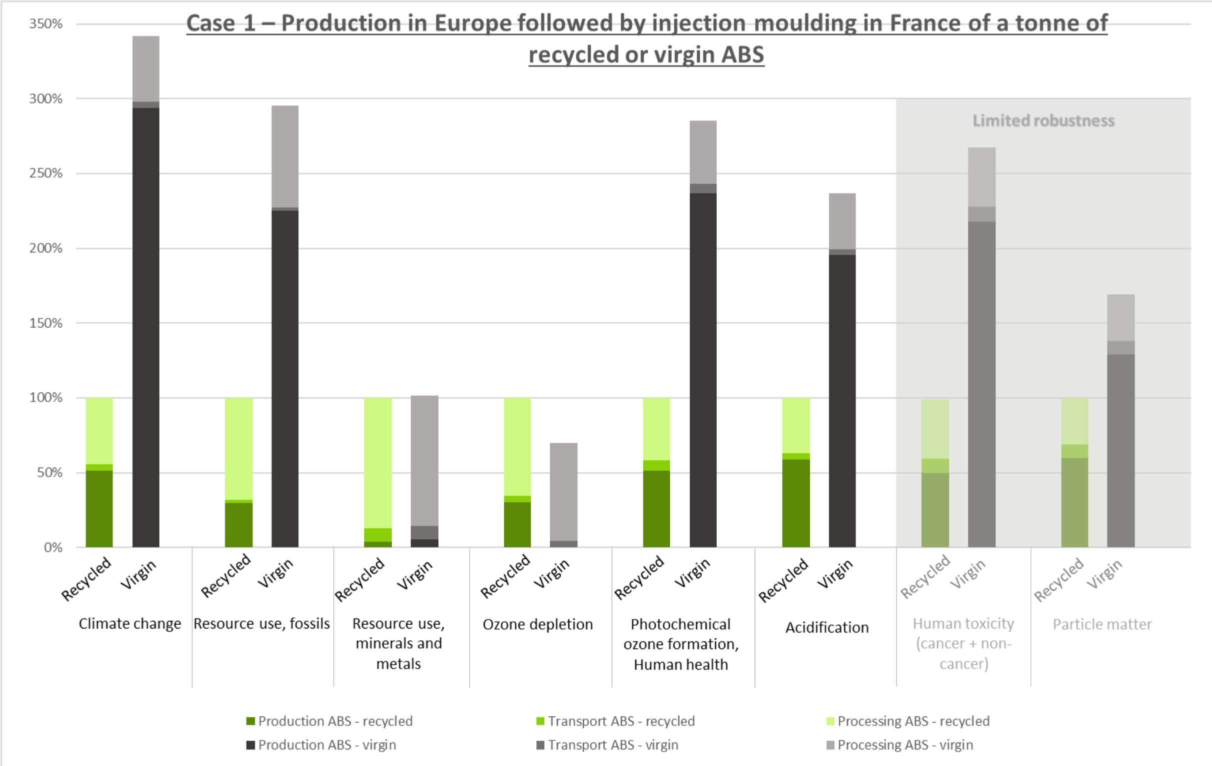


Figure 7 - Details and comparison of the impacts of production in Europe and transport and processing in France (Case 1) of recycled or virgin ABS, based on 100%

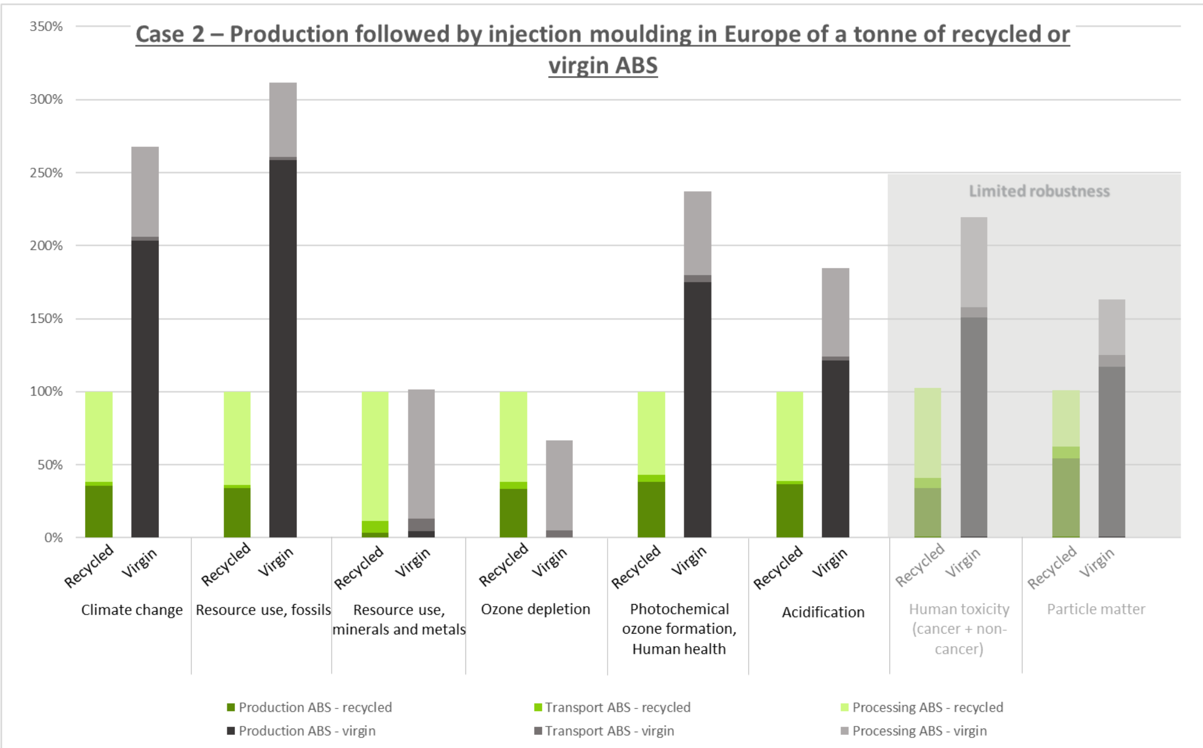


Figure 8 - Details and comparison of the impacts of production in Europe and transport and processing in Europe (Case 2) of recycled or virgin ABS, based on 100%

2.4 Comparison of the plastics studied – example of climate change

The following chart provides a simpler comparison of the results for the different plastics, for the climate change indicator.

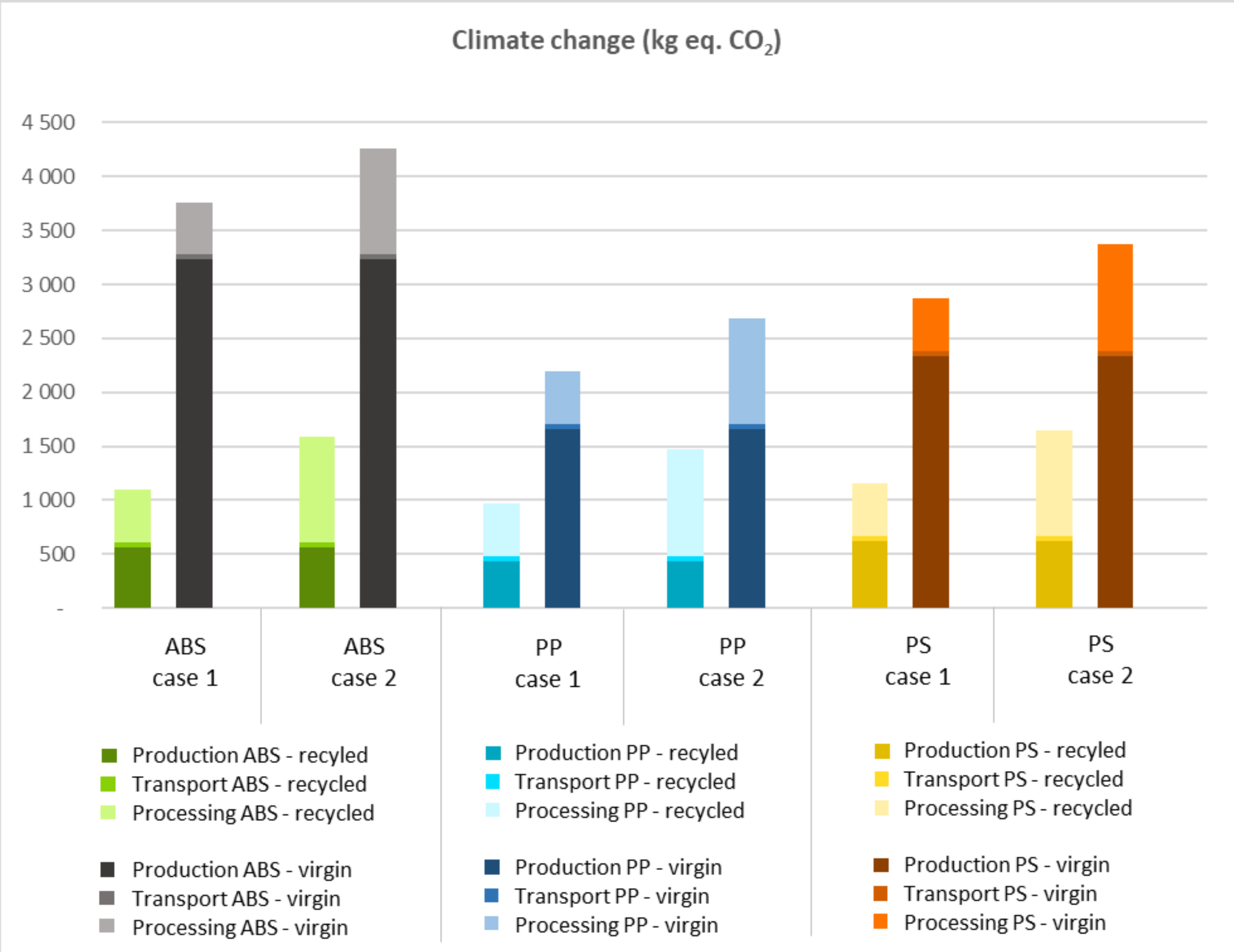


Figure 9 - Impacts on climate change based on the scenarios and plastics studied.

With ABS, it is noticeable that the difference between the impacts of recycled and virgin is greater than for PP and PS. This difference is primarily associated with the greater impact of the production of virgin ABS in comparison to other virgin plastics. On the other hand, the impacts of recycled plastics are of the same order of magnitude.

Furthermore, the comparison between cases 1 and 2 for the same plastic reveals consistently greater impacts for case 2 (production in Europe and transport followed by injection moulding in Europe) than for case 1 (production in Europe and transport followed by injection moulding in France). This is associated with the specific characteristics of the French electricity mix, which is relatively decarbonised in terms of the European electricity mix.

2.5 Impact sources

There are relatively similar profiles between cases 1 and 2 and based on the different plastics studied. For the 6 most robust indicators, the following table summarises the main impact sources identified.

Impact category	Impact sources – recycled	Impact sources – virgin *
Climate change	• Electricity and heat for injection moulding • Electricity for regeneration • Upstream steps of recycling	• Electricity and heat for injection moulding • Production of precursors (styrene, alpha-Methyl styrene, acrylonitrile, butadiene, etc.)
Resource use, fossils	• Electricity and heat for injection moulding • Electricity for regeneration • Upstream steps of recycling	• Electricity and heat for injection moulding • Raw materials (hydrocarbons) used to produce plastics
Resource use, minerals and metals	• Additives (Calcium carbonate and sodium chloride for flotation, masterbatch, etc.) • Indirect effects associated with the use, in our modelling, of some primary data (e.g.: the infrastructure of certain buildings)	• Production of precursors and energy consumption for processing steps • Additives • Indirect effects associated with the use, in our modelling, of some primary data (e.g.: the infrastructure of certain buildings)
Ozone depletion	• Upstream steps of recycling (specifically as the result of the direct impact of oil extraction for power generation) • Uranium production for electricity for the injection moulding phase	• Uranium production for electricity for the injection moulding phase NB: As virgin plastics originate from fossil hydrocarbons, it is surprising not to see the inventories used include a greater contribution of halogenated derivatives emitted during oil extraction.
Photochemical ozone formation, Human health	• Upstream steps of recycling (specifically nitrogen oxides) • Solvent and electricity used for injection moulding	• **
Acidification	• Electricity consumption for regeneration • Electricity used for injection moulding	• Production of precursors (styrene, alpha-Methyl styrene, acrylonitrile and butadiene) • Energy consumption for processing steps

**On the basis of information appearing in the Plastics Europe eco-profiles and ecoinvent data*
***Not specified in Plastics Europe eco-profiles*

Table 9 - Main impact sources identified in cases 1 and 2 and for all the plastics studied.

2.6 Sensitivity analyses

Two parameters were examined within the framework of sensitivity analyses conducted for previous modelling.

Source of uncertainty	Issue	Approach
Quantity of recycled material consumed in comparison to virgin material	• A recycled material is never an exact copy of a virgin material. It may be equivalent for certain technical and aesthetic properties and have slight differences for others. In particular, the question arises of whether it is sometimes necessary to consider an excess of material for recycled in comparison to virgin (e.g.: excess thickness, introduction of ribs for stiffening).	Two sensitivity analyses were conducted: ○ 5% additional material for recycled plastics for case 2 (production of pellets and injection moulding in Europe). ○ For each plastic, determining the additional quantity of recycled material above which the greenhouse gas emissions are equivalent to those for virgin, applied to case 2.
Overconsumption of energy for the injection moulding of recycled plastic	• The processing of a recycled material is not always strictly identical to that for a virgin material, which it may replace. It is sometimes necessary to play with the cycle times and injection moulding temperatures, to dry the material to counteract the absorption of moisture, etc. These actions may result in an overconsumption of energy.	Therefore, two sensitivity analyses were conducted: ○ 5% electricity and 5% additional heat for the injection moulding of recycled plastics for case 2. ○ For each plastic, determining the additional quantity of energy for injection moulding above which the greenhouse gas emissions are equivalent to those for virgin, applied to case 2.

Conclusions of sensitivity analyses:

- **As regards overconsumption of recycled material in comparison to virgin materials:**

Overconsumption of material of the order of 5 % does not change the trends and the main conclusions of the environmental assessment (e.g.: a reduction of just a few percent in the difference between the impacts of recycled and virgin plastics for the climate change and depletion of fossil resources indicators).

For the climate change indicator, the following table presents the factors for the overconsumption of recycled material, which need to be reached in order for the impacts in the case of recycled to exceed those of virgin:

Limiting factor for the overconsumption of recycled PP	1.7
Limiting factor for the overconsumption of recycled PS	2.1
Limiting factor for the overconsumption of recycled ABS	2.2

Table 10 - Factors for the overconsumption of recycled material in order to reach the impacts for scenarios with virgin material.

These factors are very significant and confirm the trends observed as regards the improved environmental efficiency of recycled material, even though its use would require an overconsumption of material.

- **As regards overconsumption of energy for the injection moulding of recycled plastic in comparison to virgin plastic:**

Overconsumption of energy of the order of 5% does not change the trends and the main conclusions of the environmental assessment (this overconsumption adds less than 3% of impacts to recycled plastics, whatever the impact category studied). Such an overconsumption of energy has even less effect on environmental impacts than an overconsumption of material of 5%.

For the climate change indicator, the following table presents the factors for the overconsumption of energy ascribed to the use of recycled material, which need to be reached in order for the impacts in the case of recycled to exceed those of virgin:

Limiting factor for the overconsumption of energy for an injection moulded part in recycled PP	2.3
Limiting factor for the overconsumption of energy for an injection moulded part in recycled PS	3.1
Limiting factor for the overconsumption of energy for an injection moulded part in recycled ABS	4.1

Table 11 - Factors for the overconsumption of energy associated with recycled material in order to reach the impacts for scenarios with virgin material.

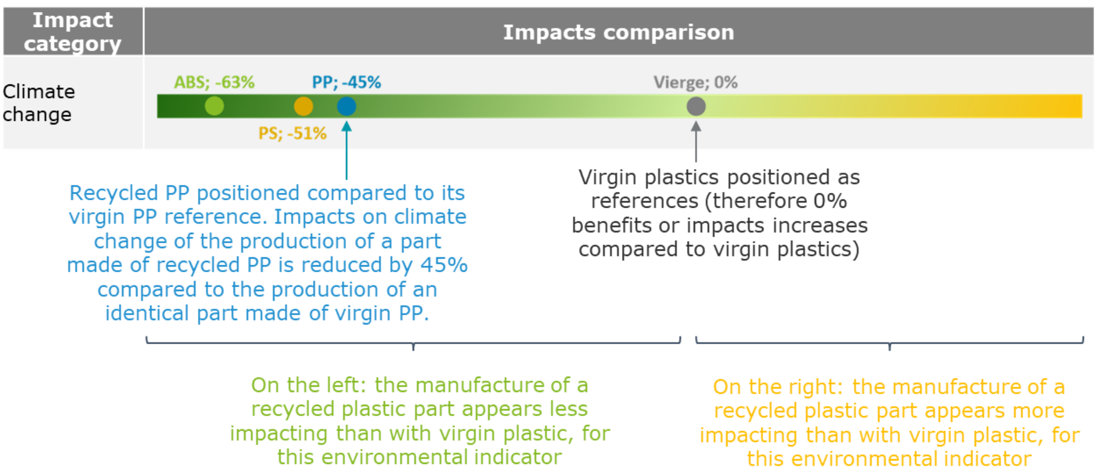
As for the overconsumption of materials, these very significant factors confirm the improved environmental efficiency of recycled material, even though its processing (in this case, injection moulding) would require an overconsumption of energy.

3 Conclusion

This study provides an overview of the environmental footprint associated with recycled plastics from WEEE, compared to equivalent virgin plastics. **On average, there are reduced environmental impacts thanks to the use of recycled plastics**.

The following chart summarises the environmental gains or increasing impacts associated with the use of recycled plastic from WEEE as a replacement for equivalent virgin plastic.

<u>*Guide to reading the chart:*</u>



Summary of the comparison of environmental impacts between the use of plastics from WEEE and the use of virgin plastics:

Impact category	Impacts comparison	Impact sources
Climate change	ABS; -63% · PP; -45% · PS; -51% · Virgin; 0%	• Recycled: Energy for injection moulding and regeneration, upstream steps of recycling • Virgin: Energy for injection moulding, production of precursors
Resource use, fossils	ABS; -69% · PS; -65% · PP; -67% · Virgin; 0%	• Recycled: Energy for injection moulding and regeneration, upstream steps of recycling • Virgin : Energy for injection moulding, Raw materials used to produce plastics
Resource use, minerals and metals	PS; -2% · ABS; 1% · PP; 2% · Virgin; 0% · *Impossible to conclude given the uncertainties (characterization methods, additives modeling...)*	• Recycled: Additives (calcium carbonate and sodium chloride for flotation, masterbatch, etc.) • Virgin : Production of precursors and additives
Ozone depletion	PS; 39% · ABS; 51% · PP; 13% · Virgin; 0%	• Recycled: Energy for upstream steps of recycling, Uranium production for electricity for the injection moulding phase • Virgin : Uranium production for electricity for the injection moulding phase. Questions about the small contribution of halogenated derivatives emitted during oil extraction (see § 2.5)
Photochemical ozone formation, Human health	ABS; -58% · PS; -42% · PP; -52% · Virgin; 0%	• Recycled: Upstream steps of recycling (nitrogen oxides), solvent and electricity used for injection moulding • Virgin : *Not specified*
Acidification	ABS; -46% · PS; -30% · PP; -31% · Virgin; 0%	• Recycled: Electricity used for injection moulding and regeneration • Virgin : Production of precursors, energy for injection moulding

Figure 10 - Environmental impacts of recycled plastics from WEEE compared to their equivalent virgin plastic, applied to case 2 – production, transport and processing in Europe.

This study also represents an example of using LCI data developed by **ecosystem** to model the production of recycled plastics from WEEE collected in France and regenerated in Europe. This data is made available with free access and can be used by everyone for their own modelling (see §1.3.1).

To find out more about recycled plastics from WEEE and their incorporation into electrical and electronic equipment:

- Incorporating recycled materials into new products: **ecosystem support**
- **Practical guide** for the incorporation of recycled plastics into electrical and electronic equipment
- **ecosystem eco-design webinars**

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recycler c'est protéger